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IPM CRSP

INTEGRATED PEST MANAGEMENT

COLLABORATIVE RESEARCH SUPPORT PROGRAM

SIXTH ANNUAL REPORT

1998-1999

Virginia Tech

VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

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IPM CRSP

Integrated Pest Management Collaborative Research Support Program

Sixth Annual Report

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Mali - IER
Philippines - NCPC/UPLB, PhilRice
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Table of Contents

iii

Foreword xiii

IPM CRSP EXECUTIVE SUMMARY FOR YEAR 6 (1998 -1999) 1

AFRICAN REGION 2

MALI 2
Description of the Collaborative Program 2
Selected Research Accomplishments 2
Training and Institution Building 4
Networking Activities 4
Initiation of Regionalization 4
UGANDA 5
Description of the Collaborative Program 5
IPM Constraints Addressed 6
Selected Research Accomplishments 6
Institution Building 9
Networking 9
ERITREA 10
Selected Accomplishments 10
IPM ELECTRONIC COMMUNICATION IN AFRICA: AFRICA IPM LINK 11
Selected Accomplishments 11

LATIN AMERICAN REGION 12

GUATEMALA / HONDURAS 12
Description of the Collaborative Program 12
IPM Constraints Addressed 13
Selected Research Accomplishments 14
Institution Building 16
Student Training 17
Networking 18
ECUADOR 19
Description of the Collaborative Program 19
IPM Constraints Addressed 19
Selected Research Accomplishments 20
Mutuality of Benefits of the Research 20
Institution Building 21
Networking 21

CARIBBEAN REGION 21

JAMAICA 21
Description of the Collaborative Program 21
Selected Research Accomplishments 22
Networking Activities 24
Training and Capacity Building 24

ASIAN REGION 25

PHILIPPINES 25
Description of the Collaborative Program 25
IPM Constraints Addressed 25
Selected Research Accomplishments 25
Mutuality of Benefits of the Research 27
Institution Building 27
Student Training 28
Networking Activities 28

BANGLADESH 28
Description of the Collaborative Program *28*
IPM Constraints Addressed *28*
Selected Research Accomplishments *29*
Mutuality of Benefits of the Research *29*
Institution Building *29*
Research Training *29*
Networking Activities *29*

EASTERN EUROPEAN REGION 30

ALBANIA 30
Description of the Collaborative Program *30*
IPM Constraints Researched *30*
Mutuality of Benefits of the Research *30*
Selected Research Accomplishments *30*
Networking Activities *31*

IPM CRSP - WIDE ACTIVITIES 32

GENDER EQUITY PROGRAMMING IN THE IPM CRSP FOR SECTORAL GROWTH 32
BOARD OF DIRECTORS 33
TECHNICAL COMMITTEE 34
EXTERNAL EVALUATION PANEL (EEP) REVIEWS 37
ADDITION OF 1890 INSTITUTIONS 38
TRIP REPORTS FOR YEAR 6 38
TECHNICAL ASSISTANCE 38
A. Environmental Quality Laboratory in Mali *38*
B. Gall Midge Project in Jamaica *39*

SELECTED IMPACTS FROM THE REGIONS 40

Africa-Wide *40*
Mali *40*
Uganda *41*
Guatemala *41*
Ecuador *43*
Jamaica *44*
Philippines *46*
Bangladesh *47*

AFRICA **49**

MALI AFRICA SITE YEAR 6 RESEARCH PROGRAM OVERVIEW 51

Targeted Insecticide Application, Yellow and Blue Traps, Soap, and Neemfor Control of the Insect Complex on Green Beans 53

Identification of Potential Biological Control, Targeted Insecticide Application, and Use of Neem for Control of the Insect Complex on Hibiscus 55

Solarization, Compost and Biocontrol Measures for Seedling Diseases of Green Bean 56

Innovative Technologies for *Striga* Management 59

Assessment of Pests, Pesticide Usage, and Pesticide Residues on Green Beans, Hibiscus, and Tomato 62

Economic Analysis of Insect Control Trials on Green Beans 72

Gender Issues of IPM Technologies Use and Adoption 73

Regionalization of IPM Technologies 74

IPM CRSP AFRICA SITE IN UGANDA 81

An Assessment of the Occurrence and Management of Cowpea Diseases and Pests in Eastern Uganda 85

Effect of Plant Spacing and Host Genotype on Disease and Pest Occurrence on Groundnut in Uganda 89

Cercospora Xeae-Maydis Resistance and Stalk Strength of Selected Tropical Maize Lines Testcrossed to Corn Belt Testers 92

Disease Development and Progression in Commercial and Local Maize Varieties Under Monocropping and Intercropping System with Beans 97

Stem Borer Infestations on Maize and Establishment of *Cotesia Flavipes* (Hymenoptera: Braconidae) in Eastern Uganda 101

Management of Bean Fly (*Ophiomyia* SP) and Root Rots on Beans by Seed Dressing and Earthing-up During Weeding 107

On-Farm Post-harvest Management of Bruchids in Bean and Cowpea 111

Development of an Integrated Striga Management Strategy for Small-scale Sorghum Farmers in Uganda 113

Developing IPM Systems for Tomato in Central and Eastern Uganda 117

Germplasm Evaluation for Tolerance to Bacterial Wilt in Highlands and Mid-elevations of Uganda 122

Economic Assessment of IPM CRSP Activities in Uganda 124

Economic Impact Assessment of IPM CRSP Activities in Uganda: A GIS Application 126

Baseline II Follow-up Survey of Farmer Pest Management Practices and IPM Technology Adoption and Diffusion 127

The Role of a Farmer Implemented Pest Monitoring Programin the Implementation of On-Farm Maize Pest Management Research 130

ERITREA 135

Monitoring, Survey, and Assessment of Insect and Disease Incidenceand Severity on Farmers' Fields 135

Evaluation of Introduced Sorghum Varieties for *Striga* Resistance 136

Assessment of Advanced Sorghum Varieties for Disease and Insect Resistance 138

LATIN AMERICA 141

ANNUAL REPORT OVERVIEW FOR IPM CRSP CENTRAL AMERICA SITE, YEAR SIX 143

Economic and Socioeconomic Impact Assessment of Non-traditional Crop Production Strategies in Small Farm Households in Guatemala 149

An Assessment of the Value and Importance of Quality Assurance Policies and Procedures to the Guatemalan Snow Pea Trade 156

Institutionalization of an IPM CRSP Quality Control Process in the Production and Export of Snow Peas (*Pisum Sativum* L.) in Guatemala 160

Detection of Papaya Ringspot Potyvirus in Guatemalan Papaya Orchards 162

Development of IPM Techniques for the Control of Leaf Miners on Snow Peas 167

Evaluation of Entomopathogenic Fungi and Entomophagous Nematodes for the Control of White Grub (Coleoptera: Scarabaeidae) in Broccoli Fields in Guatemala 172

Evaluation of Leaf Miner Hosts (*Liriomyza huidobrensis*) for Massive Breeding of the Ectoparasitoid *Diglyphus* sp. 175

Preference of *Plutella xylostella* for Ovipostion and Development of Immature Stages in the Wild Crucifer (*Brassica napus*) and Broccoli (*Brassica oleracea*) var. Italica 178

Integrated Pest Management of White Fly in Tomato at El Progreso, Guatemala 180

Use of Plastic Mesh (antivirus clothing) for the Integrated Management of White Fly (*Bemisia tabaci*) in Tomato, El Progreso, Guatemala, 1997-1998 184

Evaluation of Fruit Scent Traps for Leaf Miner (*Liriomyza huidobrensis*)Management in Snow Pea (*Pisum sativum*) 188

Effect of Strip-Cropping on Yield and Leaf Miner (*Liriomyza huidobrensis* B.) Infestation in Snow Peas 191

Yield and Leaf Miner (*Liriomyza huidobrensis* B.) Infestation Levels in Eight Sugar Snap Pea Cultivars in Guatemala 194

Evaluation of Snow Pea (*Pisum sativum*) Cultivars as related to Yield and Leaf Miner (*Liriomyza huidobrensis*) Infestation 196

Yield and Leaf Miner (*Liriomyza huidobrensis*) Infestation in Four Long-cycle Snow Pea (*Pisum sativum*) Cultivars 200

Compilation of Ancestral Knowledge among the Quiche´ and Cackchiquel Ethnic Groups Quiche´ and Cackchiquel, on the Ecological Management of Agricultural Pests in the Departments of Chimaltenango, Quiche´ and Totonicapan in Guatemala 202

IPM CRSP Activities at the Department of Crop Protection, Zamorano, Honduras 203

OVERVIEW OF SOUTH AMERICAN SITE IN ECUADOR 212

Development of IPM Programs for Plantain Systems in Ecuador 214

Survey of the Incidence and Importance of Potato Diseases in Ecuador 225

Development of IPM Alternatives for Major Potato Pests in Ecuador 228

Development of Potato Varieties with Long Lasting Horizontal or Multigenic Resistance to Late Blight (*Phytophthora infestans*) 238

Verification and Evaluation of Efficiency and Profitability of Chemical Control Strategies of Late Blight (*Phytophthora infestans*) in Susceptible Potato Varieties at Two Areas of the Ecuadorian Highland 243

Biorational Control of the Andean Potato Weevil, *Premnotrypes vorax*, (Hustache) 249

Biological Control of the Central American Tuber Moth, *Tecia solanivora* Povolny with *Baculovirus* and *Bacillus thuringiensis* in Storage for Seed 254

Diagnosis and Etiology of Babaco Diseases in Ecuador 259

Babaco Vascular Wilt: Diagnosis, Etiology and its Association with *Meloidogyne incognita* in Ecuador 263

Chemical Control of *Fusarium oxysporum* in Babaco in Ecuador 267

Control Strategies for the Two Spotted Spider Mite, *Tetranychus urticae* Kork, in babaco, *Carica pentagona* Heilbornni, in Pichincha-Ecuador 271

Plantain/Coffee Agroforestry Systems in Northwestern Ecuador: A Landuse Alternative to Low Quality Pasture 276

Modeling Impacts of Changes in Pest Management Technologies 279

CARIBBEAN **283**

OVERVIEW FOR CARIBBEAN SITE IN JAMAICA 285

Caribbean Site in Jamaica IPM CRSP YEAR 6 ANNUAL REPORT 288

Integrated Pest Management of Pests Affecting Callaloo, *Amaranthus* sp. 289

Integrated Pest Management of Pests Affecting Hot Pepper, *Capiscum chinense* 300

Develop root-knot nematode (*Meloidogyne incognita*) resistant Habanero-type and West Indies Red-type peppers (*Capsicum chinense)* 302

Determine the inheritance of peanut root-knot nematode (*Meloidogyne arenaria*) resistance in *C. chinense* 302

Determine the effectiveness of resistance to root-knot nematodes (*Meloidogyne incognita*) in Scotch Bonnet peppers *(Capsicum chinense*) at high temperatures 304

Evaluation of the performance of *Capsicum chinense* (Scotch Bonnet-type pepper) cultigens in St. Kitts 307

Characterize the resistance to *Meloidogyne arenaria* races 1 and 2 in *Capsicum chinense* Jacq. cultigens 308

Determine the potential of using legume cover-crop mulches to control root-knot nematodes in pepper plantings 310

Monitoring the seasonal abundance of aphids on farms in Bushy Park and Bodles, St. Catherine, Jamaica where Scotch Bonnet pepper, *Capsicum chinense*, is grown 312

Comparing the incidence of virus infection, the quality and quantity of *C. chinense* fruit in fields in which seedlings were a) protected with aphid proof screen before transplanting and then treated with multiple applications of stylet oil after transplanting; b) protected with aphid proof screen prior to transplanting only; and c) not protected or sprayed. 312

Investigating the effect of stylet oil in delaying or reducing the spread of tobacco etch virus in a hot pepper plot 312

Comparing the overall incidence of virus infection, and, quantity and quality of *C. chinense* fruit in fields in which early virus infected *C. chinense* plants are rogued versus those that remain in the field 313

Enhanced Hot Pepper Production Systems 313

Determination of the potential of colored sticky traps to assess populations of the gall midge complex; *Prodiplosis longifila* and *Contarinia lycopersci* (Diptera: Cecidomyiidae) 315

Effect of cultural practices and chemical insecticides on infestations of the gall midge complex, *Prodiplosis longifila* and *Contarinia lycopersci* (Diptera: Cecidomyiidae) affecting hot pepper exports to the USA 315

Effect of aluminum phosphide on larval stages of the gall midge complex 316

IPM of Pests Affecting Sweetpotato, *Ipomoea batatas* 321

Taxonomic Determination of Soil Grubs infesting sweetpotatoes in Jamaica 321

Develop high yielding, red-skinned, cream-fleshed sweetpotato cultivars with resistances to root-knot nematodes, diseases, and insects 322

Evaluation of yield, storage potential and insect resistance traits of select USDA cream-flesh sweetpotato clones to standard Jamaican sweetpotato clones 322

Evaluation of the potential of resistant varieties in combination with fipronyl (Regent®) for the management of the sweetpotato leaf beetle 325

Working with participatory groups to disseminate sweetpotato weevil IPM technology 327

PESTICIDE USE, RESIDUES, and RESISTANCE 330

Monitoring Pesticide Residue Levels on Callaloo 330

SOCIAL AND GENDER-RELATED ISSUES THAT AFFECT IPM ADOPTION 331

Policies Affecting Production Practices for Domestic Markets and Export Opportunities of Jamaican Vegetables 335

ASIA **339**

IMP CRSP ASIA SITE IN THE PHILIPPINES 341

Integrated Weed Management Strategies in Rice-Onion Systems 341

Potential of Nuclear Polyhedrosis Virus (NPV) and *Bacillus thuringiensis* (Bt) for *Spodoptera* Control in Yellow Granex Onion 350

Effects of Rice Hull Burning and Deep Plowing on Soil-borne Diseases and the Rice Root Knot Nematode in Rice-Onion Cropping Systems, with Supplemental Nematode Control Using Soil Amendments 355

Effects of Crop Rotation on Incidence of Pink Root Disease and *Meloidogyne graminicola* in Rice-Onion Cropping Systems 362

The Effectiveness of Trap Plants and Sex Pheromone Traps for *Spodoptera litura* Management 364

Field Evaluation of Damaged Fruit Removal as an Alternative to Insecticide Sprays for Control of Eggplant Shoot and Fruit Borer (*Leucinodes orbonalis*) 366

Preliminary Study on Net Barrier for Eggplant Fruit and Shoot Borer *Leucinodes orbonalis* Management 369

Host Plant Resistance of Eggplant, *Solanum melongena* L. to the Leafhopper, *Amrasca biguttula* (Ishida), and the Eggplant Borer, *Leucinodes orbonalis* Guenee 371

Movement of Arthropod Predators 375

Biological Control of Soil-Borne Pathogens in Rice-Vegetable Systems 378

Characterization of Purple Nutsedge (*Cyperus rotundus* L.) in Rainfed Rice-Onion Systems 382

Evaluation of the Feasibility of Bt Transgenic Eggplant Production for South Asia 387

Interaction Effects of *Phoma terrestris*, *Fusarium* spp. And *Meloidogyne graminicola* on Pink Root Bulb Rot Severity of Onion (Special Project) 388

Management of Bacterial Wilt Disease in Eggplant Using Genetic Resistance and Cultural Management 390

Economic Impacts of IPM Practices in the Rice-Vegetable System 394

Economic and Environmental Impacts of IPM Practices in the Rice-Vegetable System 398

Follow Up Baseline Survey 399

IPM CRSP OVERVIEW OF BANGLADESH SITE IN ASIAN REGION 401

Baseline Survey of Existing Patterns of Vegetable Production and Pest Management Practices in Farmers' Fields 403

Monitoring of Crop Pests and Their Natural Enemies in Rice and Vegetables in Rice-Vegetable Cropping Systems 407

Varietal Screening for Resistance to Bacterial Wilt, Fruit and Shoot Borer, and Root-Knot Nematode in Eggplant 412

Cultural Control of Aphid and Diamondback Moth in Cabbage 415

Comparison of Lures and Effectiveness of Mass Trapping for Cucurbit Fruit Flies *Bactrocera cucurbitae* (Coquillett) 416

Efficacy of Weed Control Methods in Cabbage 420

Efficacy of Weed Management Practices in Okra 422

Integrated Management of Soil-borne Pathogens in Eggplant 425

Production of Healthy Bunching Onion (*Allium fisturosum*) through Integrated Disease Management 428

Disease Management in Cucumber 430

IPM-CRSP Social Science Research Activities in Bangladesh 1-Measure Economic Impacts of Bangladesh IPM-CRSP Research Activities 432

IPM-CRSP Social Science Research Activities in Bangladesh 2-Pest Management Practice Adoption Study and the Price and Marketing Context of Pest Management Decisions in Vegetables 433

EASTERN EUROPEAN SITE IN ALBANIA 435

IPM CRSP SITE OVERVIEW FOR ALBANIA 437

Albania Baseline Survey 438

List of Acronyms 441

FOREWORD

The Integrated Pest Management Collaborative Research Support (IPM CRSP) has successfully completed the first six years phase of its operation. This Annual Report covers activities completed by the CRSP in the sixth year of its existence, 29 September 1997 to 28 September 1999. The Annual Report is organized by the five major geographical regions the CRSP has operated during the year, Latin America, Caribbean, Africa, Asia and Eastern Europe. Under each region, several reports address the major IPM constraints and the associated solutions the CRSP investigators and their collaborators found during the year. The individual reports have been collaboratively prepared by US and host country scientists. Examining all of these reports across the five regions the reader can get a comprehensive understanding of the global IPM issues the CRSP has been handling.

At the beginning of the report, an executive summary presents the highlights of the annual report by region. After the regional coverage, a section of the executive summary covers additional IPM CRSP - Wide Activities such as management and administrative issues. The summary concludes with selected impacts from the well established regions. The regional contents of the executive summary were developed from site overviews prepared by each prime site chair and site coordinator(s) who served during the sixth year. The regional highlights report on IPM constraints addressed, selected research accomplishments, institution building efforts, networking, and information exchange activities. Detailed information on each of these aspects for each region can be found in the individual reports of the CRSP investigators.

Readers of our past annual reports will notice again the increased depth and breadth of IPM issues and solutions the CRSP partners have addressed in this report. We trust that this Annual Report will be an additional useful source of information on the multiple facets of the global IPM issues and solutions.

The authors of the individual papers are the major contributors to this annual report. The site chairs and coordinators carried the major responsibility of coordinating the timely submission of the reports. At the Management Entity, Greg Luther, Stefan Hall, and Jason Jennings contributed significantly to the formatting, editing, and final preparation of the report for printing. Their contributions are gratefully acknowledged and appreciated.

Brhane Gebrekidan
Program Director, IPM CRSP

EXECUTIVE SUMMARY

The purpose of the Integrated Pest Management Collaborative Research Support Program (IPM CRSP) is to develop and implement a replicable approach to IPM that will help reduce: 1) agricultural losses due to pests; 2) damage to national ecosystems; and 3) pollution and contamination of food and water supplies. As stated in the IPM CRSP Phase II renewal document, the goals of the CRSP are to develop improved IPM technologies and institutional changes that will reduce crop losses, increase farmer income, reduce pesticide use, reduce pesticide residues on export products, improve IPM research and education program capabilities, improve ability to monitor pests, and increase the involvement of women in IPM decision making and program design.

Working towards this goal the IPM CRSP follows the following specific objectives:

- Identify and describe the technical factors affecting pest management.
- Identify and describe the social, economic, political, and institutional factors affecting pest management.
- Work with participating groups to design, test, and evaluate appropriate participatory IPM strategies.
- Work with participating groups to promote training and information exchange on Participatory IPM.
- Work with participating groups to foster policy and institutional changes.

Year 6 (September 29, 1998 - September 28, 1999) of the IPM CRSP marks the beginning of the second five year phase. The research activities of the IPM CRSP are based on close collaboration between scientists of the participating host countries and US institutions. The participating host country sites of the CRSP during the year included Albania, Bangladesh, Ecuador, Eritrea, Guatemala, Honduras, Jamaica, Mali, The Philippines, and Uganda. Among the partner US institutions are: University of Georgia, Lincoln University, Montana State University, Ohio State University, Penn State University, Purdue University, U.C.-Davis, University of Maryland - Eastern Shore, North Carolina A&T University, Fort Valley State University, USDA, and Virginia Tech (VT) with VT as the lead and the Management Entity (ME) institution.

This report highlights the activities of the CRSP during Year 6 of its operation. The main part of the report is a presentation of the CRSP's activities by its main regions: Africa, Latin America, the Caribbean, Asia, and Eastern Europe. This document gives for each active site in a region, description of the collaborative program, IPM constraints addressed, selected research accomplishments, progress made in training and institution building, and networking activities. The other sections of the report cover several major activities of the CRSP such as Gender Equity, the Board of Directors Meeting, Technical Committee Meetings, External Evaluation Panel Reviews, 1890 Institutions, Trip Reports, Technical Assistance, and Impacts across Regions. Details on each of these topics and other related items can be found in the institutional reports of the Year 6 Annual Report of the IPM CRSP.

The Site Chairs, host country Site Coordinators, collaborating scientists, and the Management Entity contributed to this report. The Site Chairs and host country Site Coordinators during Year 6 were:

Africa Site in Mali: John Caldwell, Virginia Tech (Site Chair), Kadiatou Touré Gamby, IER (Site Research Coordinator), Bouréma Dembélé, IER (Site Administrative Coordinator)

Africa Site in Uganda: Mark Erbaugh, Ohio State University (Site Chair), Sam Kyamanywa, Makerere University (Site Coordinator),

George Bigirwa, NARO (Deputy Site Coordinator)

Africa Site in Eritrea: Asmelash Wolday, Dept. of Agricultural Research and Human Resource Development (DARHRD) of the Ministry of Agriculture (Site Coordinator)

Latin America Site in Ecuador: Roger Williams, Ohio State University (Site Chair), Patricio Gallegos, INIAP (Sierra Site Coordinator), Carmen Suárez, INIAP (Littoral Site Coordinator)

Latin America Site in Guatemala: Glenn Sullivan, Purdue University (Site Chair), Guillermo Sanchez, Universidad de Valle de Guatemala (Site Coordinator)

Caribbean Site in Jamaica: Sue Tolin, Virginia Tech (Site Chair), Janet Lawrence, CARDI (Site Coordinator)

Asia Site in Phillippines: Sally Miller, Ohio State University (Site Chair), Victor Gapud, PhilRice (Site Coordinator) E. Tiongco and L. Sebastian, PhilRice (Site Coordinators-elect)

Asia Site in Bangladesh: George Norton, Virginia Tech (Site Chair), Rezaul Karim, IRRI Dhaka (Site Coordinator)

Eastern Europe Site in Albania: Charlie Pitts, Penn State University (Site Chair), Doug Pfeiffer, Virginia Tech (Alternate Site Chair)

In the Management Entity the following contributed to the report:

S.K. DeDatta, Principal Investigator, IPM CRSP and Director of the Office of International Research and Development (OIRD), Virginia Tech.

Brhane Gebrekidan, Program Director, IPM CRSP, Virginia Tech.

Greg Luther, Assistant Program Director, IPM CRSP, Virginia Tech.

Jean-Pierre Amirault, Assistant Coordinator, Africa IPM Link, Virginia Tech.

Sally Hamilton, Program Director, Women in International Development, Virginia Tech.

AFRICAN REGION

Mali

Description of the Collaborative Program

The primary focus of the Mali Africa site in Year 6 was participatory on-farm research on IPM technologies for management of diseases and insect pests of the two most important horticultural export crops, green beans and hibiscus. Both economic and gender implications of these technologies were examined in assessing results and research directions. This research was complemented by on-station research on biological control of the key insect pests of hibiscus, and innovative approaches to management of *Striga* parasitic weed on millet and sorghum, the principal cereal crops of Mali. A major new effort was begun to provide support to pesticide residue analysis and develop a Quality Assurance System for Malian horticultural products. Regionalization of phase I technologies developed for pest management in cereals was also carried out.

The on-farm research was conducted in two villages near the capital city of Bamako and within an hour of the airport from which green beans are exported to France. Two sets of trials were conducted, each with five farmers per village: trials comparing IPM practices and farmer insecticides for control of the insect complex on green beans, and trials comparing IPM and farmer practices for control of green bean seedbed diseases. In this first year of research on horticultural export crop pest management, IPM components are being developed independently, to provide the basis for subsequent combination into packages that address different pest problems simultaneously.

Selected Research Accomplishments

IPM Alternatives for Green Bean Insect Pest Management

Results of on-farm testing for control of the insect complex on green beans showed that IPM management practices combining yellow traps and

targeted application of locally-prepared neem extract reduced populations of thrips (*Megatothrips* sp.) and resulted in yields equivalent to the use of insecticides common in the region. These results confirmed hypotheses established prior to the research. Economic analysis showed the use of yellow traps alone was the most profitable technology for each village and also for the average of the two. The use of yellow traps in controlling insects on green beans was more cost-effective one or two applications of Decis, commonly used by farmers.

Yellow traps had an average net benefit of $4,718 / ha. At average yields of 15 metric tons / hectare, the 600 metric tons of green beans exported to France last year would translate to an estimated 40 hectares of production. The total potential net benefit of this technology is nearly $190,000. The reorientation of the Mali site in phase II of the IPM CRSP is already showing strong potential economic impact.

New IPM Solutions for Green Bean Seedbed Disease Management

The level of disease incidence in on-farm trials for control of green bean seedbed diseases was low in 1998, and IPM treatments did not have effects on seedling emergence, the number of plants per hill, or disease incidence at any location. However, well-decomposed compost resulted in a 26% increase in yield compared to the farmer's compost. Overall, farmers' compost reduced yield 18% relative to the mean yield of other treatments. At the Baguineda research station, yield with farmers' compost was less than half yield of plots which were solarized or treated with a botanical product prepared from the local plant *Longocarpus* spp.

Laboratory research laid groundwork in 1998 for future on-farm testing of additional IPM disease control measures. Soil was collected from several fields in the trial villages, the biocontrol agent *Trichoderma* spp. successfully isolated from these samples, and propagation for inoculation into compost begun. Analysis of farmers' and well decomposed compost were negative for *E. coli*, a potential contaminant of the green beans.

Gender Implications of Green Bean Pest Management

A preliminary survey revealed that men are responsible for the application of insecticide, while mainly women and children do watering. Overall, owners of the farm irrespective of gender carry out production and marketing activities. These findings, if confirmed with a larger sample, suggest that disease management trials need to involve women in assessing the practicality and benefits of changes in water management, while insect management trials may involve men more than women.

Potential Biological Control for Hibiscus Insect Pest Management

Research on potential candidates for biological control on hibiscus insect pests was carried out by IPM CRSP-supported graduate student Moussa Noussourou, as part of an MS thesis at the University of Mali. Prospections of farmers' fields around the Baguineda horticultural station and an observational plot at the Baguineda horticultural station identified 16 above ground entomophagous of insect pests of *dah*. Non-choice feeding studies with 9 predators of *Nisotra* spp. identified three predator species (all Reduviidae) with promising rates of consumption (> 3 *Nisotra* spp. / day).

A New, Innovative Approach to *Striga* Parasitic Weed Management

The innovative approach to *Striga* management at the Mali site involves the use of herbicide as the near-equivalent of a vaccine against the parasitic weed. Provided that the crop have sufficient tolerance to the herbicide to germinate and grow normally while retaining a small amount of herbicide in its system, the parasite attaching itself to this crop will accumulate quantities of the herbicide that result in inhibited parasite growth. Screening of Malian sorghum and millet varieties determine their relative tolerance to the selected herbicides identified 'CSM 388,' a very susceptible to *Striga* parasitization, as most tolerant to herbicide coatings. The herbicide prosulfuron was identified as a promising candidate for effective use for seed treatment.

Enhancement of Pesticide Residue Analysis Capabilities for Quality Assurance

The capabilities of the Environmental Quality Laboratory (EQL) of the Central Veterinary Laboratory were increased, and a comprehensive five year plan to make it functional for a wide range of pesticides was prepared. The plan will create a Quality Assurance Program linking research and education, agriculture and consumers, and economic growth and environmental safety.

Initial collaboration with the EQL begin to build information needed for the Quality Assurance System, and to develop sampling and analysis capabilities for the most critical pesticide residue needs. A list of pesticides used in Mali was prepared. Standard Operating Procedures were developed for sampling soil and water, and for handling and storage of these samples. A workable bioremediation plan was developed for managing laboratory chemical wastes. Initial extractions were performed to analyze DDT in water and to test for deltamethrin in green beans.

In a four-week training program, the director and principal resident scientist of the EQL developed skills in preparation of gas chromotography standards from 6 formulated pesticides; injection of organochlorine and organophosphorus pesticides on a gas chromatograph; calculation of standard dilutions; extraction of green beans fortified with deltamethrin using matrix solid phase dispersion; and extraction of soil samples and calculations of percent recovery from fortified soil samples.

Training and Institution Building

Moussa Noussourou was supported by IPM CRSP for his MS graduate study at the University of Mali. The student successfully defended his thesis, "Identification of Potential Candidates for Biological Control of *Nisotra* spp. on Hibiscus (*Dah*) In Mali," in August 1999. Foster and Caldwell served as outside members of his committee, providing input into the research design and interpretation of results in September 1998 and January 1999. In between and after these trips, Caldwell assisted in literature searches, and Foster assisted with identification of certain predators.

Networking Activities

Two major networking activities occurred this year. First, the IPM CRSP field research team was able to link up with the EQL pesticide residue analysis personnel to merge common goals for decreasing risks from pesticide misuse, pesticide application where other IPM techniques can provide equivalent or better protection, and loss of revenue from not meeting organic standards for exported agricultural products. Second, Drs. Dunkel and Yeboah established linkages with growers, exporters and NGOs in Mali to discuss exchange information on needs related to pesticide residues and agricultural products in Mali.

Bouréma Dembélé visited Virginia Tech from April 2-17, 1999 and James Westwood visited Mali, July 2-12, 1999.

Six graduate and undergraduate students and mentorees with an international focus presented a 3 hour workshop for students and faculty in Montana State University. The workshop was entitled "Adventures in Ethnopharmacology: From Village Elders to Toxicology Laboratory to Commercialization." Results presented included research using neem in integrated pest management systems.

Dr. Gamby and Dr. Georges Ntoukam, entomologist at IRAD (Maroua Research Center), Cameroon presented sessions for farmers and World Vision trainers in San, Mali (March 1999). These sessions included workshops on participatory on-farm research and integrated pest management.

Initiation of Regionalization

Several regionalization activities were carried out for phase I results. A training-of- trainers activity and farmer workshop was held with World Vision in San, in eastern Mali. Participants included farmers, World Vision technicians, agricultural field technicians, and IER scientists. This effort had an inter-CRSP aspect. Results of IPM CRSP research in Mali was presented, while a

demonstration of the construction of solar heaters and triple bagging storage was given by the Bean Cowpea CRSP-Cameroon. Another regionalization effort involved identifying other economic uses of the presses used to prepare neem extract with the manufacturer of the presses, an NGO, and Appropriate Technologies, Inc. (ATI). A poster series was developed to visually convey information about the breadth of use of the products of the neem tree for use in a future interCRSP series on seed protection.

Uganda

Description of the Collaborative Program

The Uganda Site operates under a Memorandum of Understanding with Makerere University Faculty of Agriculture. Dr. S. Kyamanywa, Chairman of the Crop Science Department, continues to serve as the Site Coordinator. He is functionally linked to the Ugandan National Agricultural Research Organization (NARO) through the Deputy Site Coordinator, Dr. G. Bigirwa. The Director General of NARO, Dr. J. Mukiibi, appointed Dr. Bigirwa as the IPM Coordinator for NARO in October 1998. In the recent reorganization of the Ministry of Agriculture and Animal Industries, all technology transfer (extension) activities now fall under the purview of NARO. The IPM CRSP team in Uganda consists of 4 co-PIs and 5 graduate students from the Faculty of Agriculture, 8 co-PIs from NARO and 4 extension agents, representing 8 separate disciplines. In addition, there are 7 USA based co-PIs who work collaboratively with Ugandan counterparts to plan and implement research activities. This multi-institutional and disciplinary program is coordinated by the Site Chair, Dr. Mark Erbaugh at Ohio State University and administered locally by Drs. Kyamanywa and Bigirwa. In addition to the contact between the Site Chair and Coordinators each of the co-PIs are encouraged to maintain communication with their respective collaborators on individual research activities.

The IPM CRSP in Uganda is also working closely with 5 farmer associations, two each at research sites in Iganga and Kumi Districts, and an informal organization of tomato growers located in Mpigi District. Linkages with farmers, a cornerstone of this project, are maintained through on-farm trials, assessment and training activities and through contact with extension agents. This mode of operation has provided Ugandan research scientists with valuable on-farm experience and successfully raised their visibility in the rural areas.

IPM CRSP research efforts in Uganda are planned through a series of steps that seek to maximize institutional and farmer collaboration. An initial workshop was held on December 7-8, 1998, in Jinja, Uganda, with Ugandan co-PIs from Faculty of Agriculture, Makerere University, the National Agricultural Research Organization (NARO) and the Ministry of Agriculture and Animal Industries' Extension Service to discuss progress and problems with the previous seasons' research activity implementation. This meeting also provided an opportunity to reassess and build upon the priorities originally established through the farmer participatory appraisal process, baseline survey, and farmer field pest monitoring activities. This on-going process of prioritization, evaluation and team building was aided by a visit to Uganda in December 1998 from Dr. S. Ramaswamy, a member of the IPM CRSP External Evaluation Panel (EEP). Co-PIs were then charged with discussing research plans for the upcoming season with collaborating farmer NGO groups and with USA based co- PIs. In early March another meeting of the IPM CRSP Uganda Site co-PIs and 3 USA based co-PIs was held in Mbale, Uganda to present brief progress reports, discuss priorities, and to develop draft work plans for Year 7. This draft work plan was then presented and discussed with Drs. Mukiibi, Director General NARO, and Sabiiti, Dean, Faculty of Agriculture, and Mr. R. Stryker, USAID/Kampala, before being presented by the Site Chair, Site Coordinator and Deputy Site Coordinator at the IPM CRSP Annual Meeting held at Purdue University in May, 1999. Another management component added this year was a Research Reporting Workshop held in

Mbale, Uganda, in late August 1999. At this meeting 15 research papers prepared by co-PIs and graduate students were presented and critiqued. It is hoped that this workshop will fulfill the request and promise contained in the External Evaluator's report: "Everyone of the players involved in the (Uganda Site) IPM CRSP appears to be in synch, supporting each other's research activities to the extent that significant returns are expected".

The planning and implementation of IPM CRSP activities in Uganda also involves co-PI communication and collaboration with the local USAID Mission, the International Center for Insect Physiology and Ecology (ICIPE), the Rockefeller Foundation through the Makerere University Legume Improvement Program, germplasm exchanges with 3 IARCs including IITA, CIAT and CIP and the founding of a Grey leaf spot collaborative network that includes several IPM CRSP USA and Ugandan co- PIs, CIMMYT/Harare, Rockefeller Foundation and several Universities in South Africa. Collaborative activities with ICIPE and the Rockefeller Foundation have provided opportunities to cost-share several graduate student training programs at Makerere University.

IPM Constraints Addressed

The primary constraint to IPM adoption in Uganda is the lack of proven alternatives to multiple applications of chemical pesticides, particularly for important legume crops in Eastern Uganda, but also for newly added horticultural crops. The capacity of the Ugandan research system to develop IPM alternatives has been historically impeded by research fragmentation among the various institutions and by weak links between research scientists and farmers. During the initial participatory assessment and the later baseline survey farmers indicated a strong dependence on and use of multiple sprays to control pests and diseases on cowpea and groundnuts. Research efforts by the IPM CRSP have developed agronomic, and reduced spray alternatives for these crops, and, in the case of groundnuts have popularized a disease resistant variety. The presentation of research results by 15 co-PIs and graduate students in August demonstrated progress towards the development of IPM technologies for most priority crops. Another constraint is the lack of data on incidence and severity of pests and diseases. Farmer field pest monitoring results provided important documentation of the unrecognized importance of bean fly as a critical pest on beans. A survey of maize diseases demonstrated the importance of gray leaf spot. Remaining constraints are to sustain research momentum, to broaden impacts, and, to convince key policy makers that IPM is economically and socially viable. These constraints are intertwined, and require a redoubling of effort to document, disseminate and publish results. The recently completed follow-up assessment will help provide some of this information but greater attention needs to be applied to economic evaluations of IPM technologies. Several of these efforts have potential for impact in the United States. Perhaps the best example from the Uganda Site is the work being done on identifying genetic resistance to gray leaf spot, the number one foliar disease of maize in Uganda and in the US Corn Belt.

Selected Research Accomplishments

- Field trials with cowpea in Eastern Uganda established that the major diseases were viral (Cowpea mosaic virus), scab (*Sphaceloma* sp.), yellow blister (*Synchytrium dolichi* (Cooke), cercospora leaf spot (*Cercospora cruenta* and *C. canescens*) and powdery mildew (*Erysiphe polygoni* DC). The major insect pests were pod sucking bugs (*Riptortus* spp., *Nezara viridula*, *Acanthomia* spp. and *Anoplocnemis* sp.) and *Maruca* sp. and Blister beetle (*Mylabris* spp.). Trial treatments included effect of plant density, planting date and minimal pesticide application on disease severity and pest infestation. Trials indicated that a spacing of 60 x 20 cm. and planting at the on-set of rains significantly reduced disease severity and insect pest infestation. In addition, the minimum spray schedule consisting of two insecticide spray applications (as compared to the farmers'

practice of using six applications) resulted in the highest yield and income.

- *Striga* parasitism of sorghum can be minimized by using an integrated striga management strategy consisting of a striga tolerant sorghum variety, Seredo, modest fertilizer application, two hand weedings and interplanting with *Celosia argentia*, locally known as *Striga* chaser. Results indicate that use of a resistant/tolerant sorghum variety coupled with moderate dose of nitrogen (80kgN/ha) and weeding twice is the best approach to reduce the level of *Striga* attack and increase sorghum yield. Interplanting sorghum with *C. argentia* is an affordable alternative when farmers cannot employ use of improved varieties and fertilizer. The impact of interplanting sorghum with cowpea compared with interplanting with *C. argentia* on *Striga* emergence was not significantly different. However, the cowpea intercrop reduced sorghum yield while *C. argentia* increased yield. This is explained by the cowpea growth habit of climbing the sorghum thus reducing sorghum height.

- Development of an integrated disease and pest management package for groundnuts indicated that the improved variety *Igola-1* was more resistant to rosette disease and Cercospora leaf spot compared to the two unimproved local cultivars despite the recording of high aphid populations. Thus, the resistance of *Igola-1* is directed to the virus and not the aphid vector. Close plant spacings recorded higher incidences and severities of leaf spot but lower rosette incidences and severities. Therefore the medium plant spacing of 45 x 15 cm along with the *Igola-1* variety is recommended to control both diseases. Plant spacing had a significant effect on reducing aphid infestation but no significant effect on root rot and thrips infestation.

- *Chilo partellus* was found to be the predominant stem borer species in Eastern Uganda on maize and sorghum, and in importance is has surpassed *Busseola fusca* in Iganga District. Yield losses caused by stem borers on maize in Iganga were found to range between 212 and 440 Kg/ha. Intercropping maize with beans offers moderate levels of control on stem borer infestations. *Cotesia sesamiae* was the most common local parasitoid found. The introduced parasitoid, *Cotesia flavipes*, multiplied and released in a collaborative activity between the IPM CRSP and ICIPE, has been established and causes parasitism of up to 23% in Iganga and 18% in Kumi on *C. partellus*.

- Seed dressing to control bean fly (*Ophiomyia* sp.) and root rots (*Fusarium solani* and *Fusarium phaseoli*) increased bean grain yields by 75%-156%. Diazinon was as effective in reducing bean fly damage as Endosulfan. Use of the fungicide Benlate as a seed dressing was not as effective in controlling root rots as use of Endosulfan supporting other observations that root rot infection is related to bean fly incidence. The impact of seed dressing is more pronounced under drought stress conditions. Earthing-up at first weeding reduced bean fly damage and increased grain yield between 32%-35%. The practice of earthing-up is recommended for small-scale bean production. Over 100 farmers near research sites in Iganga have been exposed to the practice of seed dressing and earthing-up through a combination of on-farm trials, farmer open-days, and the development and distribution of fact sheets.

- Treatments testing the efficacy of selected biorationals, solarization and a synthetic insecticide to control damage by bruchids (*Acanthoscelides obtectus* and *Callosobruchus* spp.) found that beans admixed with Mexican marigold (*Tagetes* spp.) and *L. camara* dust had the highest bean damage level whereas beans mixed with tobacco dust had the lowest damage level. The performance of tobacco, Actellic, ash and solarization in reducing bean bruchid damage did not differ significantly. The most effective treatments for cowpea

included solarization, and admixing with tephrosia and tobacco. Unlike in beans, solarization method did not affect cowpea seed germination/viability. Farmers in seven districts (Iganga, Kumi, Soroti, Katakwi, Lira, Apac, and Mpigi) have adopted solarization and admixing beans with tobacco leaf powder; and solarization and admixing of cowpeas with tephrosia or tobacco leaf powders.

- Tomato growers ranked late blight *(Phytophthora infestans)* and bacterial wilt (*Ralstonia solanacearum*) as their most important disease problems during a participatory assessment held with growers in Mpigi District, March 1999. The PA also established that most farmers sprayed their tomatoes twice a week throughout the growing season. First season on-farm disease surveillance and pest-monitoring trials indicated that late blight was the most prevalent disease and thrips (*Megolurothrips sjostedti* (Trybom)) the most prevalent insect pest. Three tomato clones tolerant to bacterial wilt were identified and introduced into on-farm trials. Farmers have already taken seed from these trials for use in their own fields. First season on-station trials on alternative methods to control late blight provides preliminary evidence that transplanting seedlings into a cover crop (Sirato) may provide protection by spores spread by rain splash on soil.

- Longe-1, a commercial open pollinated variety demonstrated more resistance to maize streak virus than local varieties and out yielded local varieties. Intercropping did not significantly reduce maize streak disease incidence.

- The profitability of growing maize as a monocrop versus intercropping with beans was evaluated using partial budgeting. The most profitable practice was to grow the improved and streak resistant maize variety Longe-1 in a monoculture providing the highest net cash benefit with an added return of USD 257/ha compared to the local maize monocrop with an added net return of USD 107/ha compared to intercropping with beans. The local maize monocrop yielded the lowest net benefit of about USD 10/ha compared to its intercrop. Intercropped Longe-1 added USD 159 in net returns per ha compared to the local maize intercrop.

- Yield loss assessments derived from on-farm trials demonstrated that the prevailing yield loss due to stalk borers on a total stand basis was only 3%. If the same criterion is applied to the level of foliar stand injury observed by farmers, the prevailing yield loss on a total stand basis would be 2%. In general, farmer observations of pest activity on maize demonstrated that termites are a more significant problem than stalk borer. As a result, IPM CRSP activities on maize have shifted to a greater programmatic emphasis on termites than on stalk borer.

- An important result of the farmer field pest monitoring program has been farmer training for their subsequent participation with on-farm trial experiments. Farmers participating in the process of collecting crop monitoring data become familiar with the importance of sampling procedures, record keeping, and develop an awareness of the systematic process required to participate in agricultural research. Since an important goal of participatory agricultural research is to empower farmers to learn, adapt, and to become active investigators, the contribution of this model program should be recognized.

- Gray leaf spot (*Cercospora zeae-maydis*) resistant germplasm was identified with acceptable agronomic performance in both Ohio and Uganda. Breeding efforts to utilise disease resistance of tropical germplasm were successful and cooperative evaluations revealed suitable agronomic performance across temperate and tropical environments when breeding lines were testcrossed with temperate maize inbred testers.

- A follow-up baseline questionnaire to obtain information on pests, pest management practices and socio-economic factors associated with knowledge, awareness and practice of IPM was administered to 200 farmers in Iganga and Kumi Districts in Uganda. Preliminary data analyses indicate that 63% of the respondents are using pesticides on field crops. Pesticide usage is more common in Kumi than in Iganga district. Among the IPM CRSP focal crops that include maize, beans, groundnuts, sorghum, and cowpea, the most commonly sprayed crops are cowpea and groundnuts. In both districts, men are more likely than women to purchase and apply pesticides. However, within the household, women are commonly involved with pest management decisions.

- Fifteen advanced potato clones with diverse backgrounds were screened for resistance/tolerance to bacterial wilt, one of the most serious diseases of potatoes worldwide and in Uganda. Five of the 15 genotypes, evaluated on the principle performance indicators of yield, plant survival, minimum rotting tendency and number of plants that survive till maturity, appear to be promising. The clones in order of performance are: 388575.9, 390854.11, 388575.5, 390018.3 and 388574.6. Future selection will involve tuber and culinary characteristics along with the initiation of intercropping trials.

Institution Building

The IPM CRSP's emphasis on process, including research planning and farmer participation, and the locally recognized need to advance multi-institutional and disciplinary research have been recognized by several administrators as a key contribution of the IPM CRSP to agricultural research in Uganda. Another indicator of IPM's institutionalization is the creation of a new department of Crop Protection at Makerere University. Dean Sabiiti gives partial attribution to the IPM CRSP for stimulating the demand for this department.

Four Ugandan graduate students have made substantial contributions to on-farm data collection and to IPM CRSP activities as a whole. In a recent conference at Makerere where 38 graduate students from the Faculty of Agriculture presented their research findings, two IPM CRSP graduate students placed first and third in a competition for best presentation. The graduate student training being done by Makerere University was another aspect of Uganda Site activities commended in the external evaluation report. Dr. George Bigirwa spent several weeks with Dr. R. Pratt, at the Ohio Research and Development Center entering and analyzing data from their survey of maize diseases. This collaboration has resulted in three papers being presented at the All African Crop Science Society meetings.

There were 8 trips made to the Uganda Site this year by USA based co-PIs. In addition Mr. Tom Debass, graduate student from Virginia Tech joined Drs. Erbaugh, Warren and Bhagsari to participate in the work plan development meeting, training of baseline enumerators program; and to collect data for his Masters thesis. Drs. Erbaugh, Gebrekidan and Luther also participated in the research results conference held in August. Drs. Pratt and Willson made individual trips to pursue their collaborative research activities.

Networking

In-country networking between the two primary agricultural research institutions in Uganda is promoted by the functional links between the Site and Deputy Site Coordinators, who remain in close contact through their respective heads, the Director General of NARO, and the Dean of the Faculty of Agriculture at Makerere. The Site Coordinator always ensures that USA based scientists make a courtesy visit with both the DG and the Dean and the Site Chair always meets with these two gentlemen to update them on progress and to seek their support on various issues that arise. Additionally, the composition of the Uganda team includes scientists from all the major research institutes in the country including Kwanda, Naumulonge, Serere and Kabanyolo research institutes. Also, meetings are regularly

held and updates are provided to USAID/Kampala and the technical assistance personnel attached to the primary agricultural project in Uganda, the IDEA Project. As a result of his IPM CRSP involvement, Dr. Kyamanywa was invited to participate in a USAID consultancy which examined the USAID/Uganda Agricultural Sector Pesticide Procedures Guidelines and, Dr. Willson was asked to make contributions to the Quick Reference Guide for Crop Chemicals being produced by the IDEA Project.

Regional networking takes the form of communication, participation and occasional collaboration with other organizations and professional societies. Drs. Pratt and Erbaugh presented IPM CRSP acknowledged papers at the recent meetings of the All African Crop Science Society meetings held in Casablanca, Morocco, as did 2 Uganda co-PIs and 4 Makerere graduate students. The IPM CRSP was the only CRSP represented at this meeting. Drs. Erbaugh and Caldwell, Site Chair for Mali, presented papers at the 15th International Symposium of the Association for Farming Systems Research-Extension held in Pretoria, South Africa. Again, the IPM CRSP was the only CRSP represented at this meeting. ICIPE has cost shared the training of a graduate student with IPM CRSP, and Dr. Charles Omwega from ICIPE, participated in Mbale Workshop where research results were presented. The Site Chair and Coordinator also held discussions with Dr. K. Gallagher, Assistant Director, of the Global IPM Facility, an entity initiating farmer field schools in Uganda and other countries in East Africa. Networking also continues with the Rockefeller Foundation. Joint activities with the Rockefeller Foundation occur via the Makerere University Grain Legume Program. Most recently, at the meeting in Morocco, the Grey Leaf Spot Network for East and Southern Africa was established with important inputs from Dr. Pratt and leadership provided by IPM CRSP co-PI Dr. Adipala. At the organizational meeting the IPM CRSP's pioneering work in this area was acknowledge. Finally, the Africa IPM-Link continues to provide a network for dialogue across the continent on issues pertaining to IPM.

Eritrea

The IPM CRSP activities involve the participation of the Eritrean Department of Agricultural Research and Human Resource Development (DARHRD) of the Ministry of Agriculture, Virginia Tech, and Ohio State University. The program was initiated through the financial support of the USAID Mission in Eritrea through the USAID Global Bureau. The initial funds were allocated for an intensive training program for researchers, extension and development agents, and lead farmers. The training program was successfully completed as planned and yet the allocated funds were not exhausted. These balance of training funds were used to initiate the collaborative research program presented here.

Research was carried out on the following topics: monitoring, survey, and assessment of insect and disease incidence and severity on farmers' fields; integrated *Striga* management trial; evaluation of introduced sorghum varieties for *Striga* resistance; assessment of advanced sorghum varieties for diseases and insects; study and identification of races of fungi; monitoring seasonal activity of adult stem borer populations utilizing pheromone traps.

Selected Accomplishments

Striga infestation was considerably reduced when sorghum received integrated management (inter-cropped with soybean, applied nitrogen fertilizer, and hand weeded twice) as compared to the check plot. The application of appropriate *Striga* management practice reduced the *Striga* weed population by 95 % and increased grain yield of sorghum by 46 % and additional legume yield of 117kg/ha was obtained. Integrated management practice improved sorghum production both by depressing *Striga* and increased sorghum grain yield through the appropriate growing media being provided.

- In the trial of screening highland sorghum cultivars for their resistance against *Striga* all the varieties were infested with the parasitic weed. Although the yield of all the treatments

could not be obtained, the relative resistance of the treatments could be observed by the number of *Striga* plants emerged in each cultivar. IS-29415 sustained relatively fewer *Striga* than others.

- In the trial of screening lowland sorghum cultivars for their resistance against *Striga*, the *Striga* count during the early growth stage of sorghum was very few in number, but the number of *Striga* increased greatly during late season when the crop was already well established to cause reduction of sorghum grain yield. Varieties with entry numbers as P8579 and P8568 were with no *Striga*.

- In the stalk borer trials, variety IS-25557 had one of the highest stalk borer infestations, however, but Amal the local variety had less stalk borer infestation.

IPM Electronic Communication in Africa: Africa IPM Link

The main goal of Africa IPM Link (AIL) is the promotion and use of Information & Communication Technologies (ICTs) in Africa for IPM and related topics. The AIL activities were partially supported by funds originating from USAID AFR/SD office but received through the Global Bureau of USAID. Hence the activities have been implemented as an integral part of the IPM CRSP.

The principal objectives of AIL are to provide electronic networking opportunities for African IPM practitioners, to initiate and promote electronic discussions among professionals with interest on IPM related issues in and on Africa, to update content and improve the IPM CRSP and Africa IPM Link web sites, and to provide training opportunities for African IPM practitioners in the effective use of e-mail and the WWW for IPM information sharing.

Selected Accomplishments

- **Email-based Discussion List, Afrik-IPM:** The main purpose of the Afrik-IPM discussion list is to provide IPM practitioners in sub-Saharan Africa with a networking tool for quick, inexpensive, and effective IPM information exchange. The discussion list has been well established and is operating actively and effectively. In the past year, list "membership" has increased from 61 to 104, representing a wide range of organizations and individuals from 29 countries, including 18 African countries.

- **Africa IPM Link Web Site** (http://www.cals.vt.edu/ail/index.html): The bilingual Africa IPM Link web site was redesigned for easier navigation and a local search engine was added. English and French content was regularly updated; the site currently contains links to over 200 English IPM sites, 100 French IPM sites, and some useful Information & Communication Technology (ICT) sites. Information from the site is routinely accessed from several African countries by IPM practitioners.

- **IPM CRSP Web Site** (http://www.cals.vt.edu/ipmcrsp/index.html): The IPM CRSP web site was redesigned in November 1998. Trip reports, working papers, newsletters, annual report/workshop abstracts, and other IPM CRSP products were posted as they were submitted to or produced by the IPM CRSP Management Entity. Next addition to the IPM CRSP web site will be a discussion forum to allow for easy exchange of information and ideas between all IPM CRSP Co-PIs .

- **IPM Communications Strengthening:** Regional institutions have been identified as partners but funds were not secured for the organization of a bilingual IPM Communications Workshop for West/Central Africa based on the model of the Nairobi workshop of March 1998. Efforts are now being focussed on linking with existing

IPM/sustainable agriculture organizations, commodity/research networks, and other planned initiatives in Africa to provide capacity building sessions for small groups of people on the use of Email and the Internet. The first of such sessions is anticipated to take place during PAN-Africa's regional workshop on IPM and Sustainable Agriculture to be held in Thiès, Senegal, in May, 2000.

- **Assist in Providing Internet/Email Connectivity**: Start-up funds for the purchase of a modem and six months worth of Email connectivity were provided to the headquarters of the Desert Locust Control Organization / Eastern Africa (DLCO/EA) in Ethiopia. In Guinea, the Assistant Coordinator of AIL facilitated a meeting between the director of Entraide Universitaire pour le Développement (EUPD-Guinée), a national NGO umbrella organization, and the coordinator of PAN-Africa with the purpose to secure funding for one-year Email connections for two or three Guinean NGOs through a PAN-Africa/AfricaLink regional NGO connectivity activity.

- **Linkages**: Active electronic linkages have been maintained with international, regional, and national organizations, as well as NGOs. During the year, new strong linkages were formed with NGOs and the National Directorate of Agriculture in Guinea. Linkages were also made with RADHORT, a horticulture network in Francophone West Africa.

LATIN AMERICAN REGION

Guatemala / Honduras

Description of the Collaborative Program

The Central American Site operates through a site committee structure, with Guatemala as the prime site. Dr. Guillermo Sánchez, Head of the Department of Agricultural Sciences and Forestry at the Universidad del Valle, serves as the regional site coordinator for Central America. The Regional Site Committee is comprised of Dr. Sánchez, Ing. Luis Calderón (ICTA), Juan Enrique Leal (AGRILAB), Luis Alvarez (ARF/AGEXPRONT), Rafael Solorzano (ALTERTEC), Eddy Diaz/Victor Salguero (MAGA), Luis Caniz (APHIS-IS), Dr. Linda Asturias (ESTUDIO 1360), and Maria Mercedes Doyle (ZAMORANO). The U.S. researchers that collaborate with the regional site committee and provide research support, technical support, and program coordination include: Drs. Glenn H. Sullivan, Stephen C. Weller, C. Richard Edwards, and Ray Martyn (Purdue University) and Dr. Sarah Hamilton (Virginia Tech). The overall Central American site activities in Year Six were funded through IPM CRSP core funds from the USAID Global Bureau under subcontract with Virginia Tech, and grant funds generated from the Government of Guatemala (GOG), FONAPAZ, and ARF/AGEXPRONT.

ZAMORANO (Honduras) was the principal regional collaborating institution outside Guatemala. In Year Six, however, substantive discussions were carried forward with Nicaragua and El Salvador with the purpose of establishing MOU's in these countries during Year Seven.

APHIS and ARF/AGEXPRONT continued to provide strong collaborations in the development of IPM / ICM strategies for reducing pesticide use and improving the performances for achieving safer food supplies in the NTAE sector. APHIS-IS continued to provide collaborative leadership in the development of pre-inspection programs in Guatemala. ICTA has collaborated in testing and revising IPM CRSP production strategies for

improved pest management in snow peas (leaf miner), tomatoes (white fly), and broccoli (*Plutella xylostella*). ESTUDIO 1360, in collaboration with Dr. Sarah Hamilton (Virginia Tech) contributed substantively to research activities that evaluated the socioeconomic impacts of NTAE production at the community and household levels.

Research collaborations with FONAPAZ were strengthened in Year Six. FONAPAZ proceeded to revise their domestic development programs in Guatemala commensurate with IPM CRSP program priorities, including community level transfers of IPM CRSP developed production strategies and protocols. FONAPAZ grants to the IPM CRSP researchers at Univ. del Valle provided funds for community level technology transfer activities, including field demonstrations.

Preliminary research agendas and budgets for the Central America Site are established during the annual Technical Committee Meetings. These broad research agendas are then presented to the Site Committee for review, discussion, and prioritization of specific research activities for the year. The Site Committee meets monthly to discuss research progress and make consensus decisions on any revisions. Each collaborator and/or collaborating institution has the opportunity throughout the year to request revisions in previously approved research agendas and budgets. Such revisions require Site Committee consensus.

IPM Constraints Addressed

Public and private sector policies significantly influence NTAE development in Central America, including the implementation of performance-proven IPM / ICM practices and certified pre-inspection programs. In Guatemala, the private sector has led the initiative for policy revision. AGEXPRONT has reorganized their overall committee structure in a serious effort to develop more proactive policies that will enhance performances in the NTAE sector. Science-based production and pre-inspection policies that lead to reduced pesticide usage and decreased product rejections at U.S. ports-of-entry are now a major focus of AGEXPRONT's policy revision initiatives. Similarly, private sector firms like Tierra Fria and Frutesa have established aggressive proactive policy revisions in their operating performances in a serious effort to enhance their competitive position in the NTAE sector.

On the other hand, government initiatives to revise policies commensurate with the needs of a more competitive marketplace in the NTAE sector have been slow to develop, and currently represent a serious impediment to Guatemala's future performance capacity in international and/or regional markets for NTAE crops. The research and technology transfers of performance-proven IPM / ICM production and post-harvest practices advanced by the IPM CRSP have been frustrated by the lack of timely and response-effective policy initiatives at the central government level.

The timely implementation of performance-proven IPM CRSP production and post-harvest handling strategies continue to be a constraint. Again, the lack of timely and response-effective support from government is an important factor delaying these transfers. ICTA has not yet been given an administrative mandate and/or funding to provide the GOG leadership effectuating such technology transfers, and no other GOG entity, other than FONAPAZ, is positioned to assume such a leadership role. As a result, too many small independent NTAE producers still rely heavily on agrochemical sales agents and unregistered pesticides for their disease and insect pest control information. This constraint will gradually be overcome as more IPM CRSP approved pest management information is transferred through regional workshops, seminars, and field demonstrations, and as the private sector struggles to overcome the gaps left by the government's slow response. However, the private sector alone cannot provide the resources needed to reverse Guatemala's gradual decline in competitiveness in the international marketplace. Recent IPM CRSP market competitiveness assessments indicate that Guatemala is now the 15th most competitive external supplier of vegetables for export to the

USA, a decline from the 5th most competitive position in 1992.

A primary constraint to IPM program adoption in Central America in past years has centered on the research capacity within the collaborating institutions and among the individual collaborators. Many of the collaborating institutions / collaborators simply have lacked the scientific capacity to bring science-based solutions to current pest management problems. While we have made significant progress in resolving this constraint over the last two years, much remains to be done in Guatemala and Honduras. Research is now more focused relative to our overall IPM CRSP objectives and missions, and is presented in a more scientific manner. Dr. G. Sánchez, the IPM CRSP Site Coordinator and plant pathologist trained in the United States, is well founded in science-based research and has been extremely successful in helping raise the level of scientific approach to current research activities among collaborators. Sánchez's leadership in this important area, combined with Universidad del Valle, Purdue University, and Virginia Tech collaborations, and with AGEXPRONT's restructuring and science-based focus, have combined to help enhance the scientific rigor of IPM CRSP research in Guatemala.

Selected Research Accomplishments

- The premier accomplishment in Year Six centers on further development and formalization of the pre-inspection program for snow peas in Guatemala. Guatemala's competitive position in the NTAE sector has suffered since 1995 due to sanitary and phytosanitary violations detected at U.S. ports-of-entry. In Guatemala and throughout the region, the need for a program that controls the product's quality at the point-of-origin is accepted by a progressive group of snow pea growers and exporters. AGEXPRONT has been instrumental in helping focus the private sector attention on pre-inspection. It is through this group that a <u>voluntary pre-inspection pilot program</u> was established in the 1998-1999 growing seasons and further finalized for the 1999-2000 seasons. After two years of field trials the IPM CRSP and its collaborators clearly demonstrated that high quality snow peas meeting all sanitary and phytosanitary regulations could be produced with the technology currently available when properly implemented and precisely managed. These results have been the basis for the field and post-harvest handling protocols to be followed in the pre-inspection program. Under the leadership of the IPM CRSP, the pre-inspection program was tested in the 1998-99 growing seasons with the participation of several key collaborators. Seven major NTAE packers/exporters agreed to participate in this effort, their combined output accounting for approximately 30%-40% of the country's total snow pea exports.

- Future economically sustainable expansion in the Central American NTAE sector will substantially depend upon the industry's capacity to address increasingly important aforementioned non-economic constraints to interregional trade. An assessment of U.S. trade data suggests that there is a correlation between the lack of compliance with these non-economic constrains and a decline in Guatemala's competitive position in the U.S. vegetable market. In 1992, Guatemala was ranked 5th among all countries supplying fresh vegetables to the United States and 8th among countries supplying fresh fruit, other than bananas, to the United States. But in 1997, Guatemala was ranked only 12th among fresh vegetable suppliers. The NTAE sector is very competitive, and the more successful competitors seem to have adopted a more "market-driven" focus. Our research suggests that given its relative economic competitiveness, Guatemala could be the 5th or 6th largest supplier of fresh vegetables to the United States with full implementation of a certified pre-inspection program. The IPM CRSP is playing a pivotal role in helping reestablish regional competitiveness in the NTAE sector.

- The technology transfers associated with these activities (pre-inspection) significantly impacted NTAE crop producers by helping reduce pesticide use to acceptable and sustainable levels. Snow pea producers participating in the IPM CRSP integrated pest management / integrated crop management programs reduced pesticide applications from 13 to 4 in each snow pea cropping cycle, while increasing product quality and marketable yields to 12,600 lbs. per menzana (approximately 18,000 lbs. per hectare). This level of performance translates to about $2916 per acre in gross revenue, or about $895 per acre net return to management and family labor. This level of performance is approximately 35% above the average, helping assure economic and socioeconomic sustainability at the small farm household level.

- Overall, IPM CRSP sponsored research documentation and training at twelve regionally dispersed community sites, comparing performance-proven IPM / ICM practices to traditional snow pea production practices, resulted in 25 to 50 percent higher average marketable yields with 75 percent fewer pesticide applications for IPM CRSP developed management strategies.

- More importantly, performance-proven IPM / ICM strategies for tomatoes have allowed the reintroduction of tomato production into regions that were no longer being cultivated because of severe white fly – geminivirus problems. The implementation of IPM CRSP developed strategies for control of white flies in tomatoes has enabled several regions in Eastern Guatemala (Sanarate, San Agustin Acasaguastlán and Retana Valley) to reestablish high value fresh market tomato production. Research in tomato has shown that use of the IPM CRSP developed 22 point program for control of white fly and its associated gemni-virus can reduce the number of needed insecticide sprays from 30 to 12, and greatly improve grower profits.

- The significance of the aforementioned IPM CRSP research accomplishments in Central America were highlighted in the inaugural issue of *Sustainable Development International: Strategies and Technologies for Local and Global Agenda 21 Implementation* (an entity created by 174 heads of state at the United Nation's Rio Summit in 1992). The paper titled "Sustainable Development in Central America's Non-Traditional Export Crops Sector Through Adoption of Integrated Pest Management Practices: Guatemala Case Study" was published and is summarized as follows: Non-traditional crops for export (NTAE's) have played an increasingly important role in Central America's economic development since 1983. This relatively new market-driven development opportunity has represented the fastest expanding sector of the agricultural industries in Central America, with an average annual growth rate of 16 percent between 1983 and 1997. However, future development of economically sustainable expansion in NTAE crops in Central America will be substantially influenced by the region's capacity to meet more demanding food safety standards in the United States and Europe. Market access in these countries is increasingly being determined by sanitary and phytosanitary standards, and not solely by economic competitiveness at the production level. Case studies in Guatemala found that chemical overuse was the primary factor contributing to high detentions and rejection rates for NTAE shipments at ports-of-entry in the United States. It was found that producers who adopted performance-proven integrated pest management practices had significantly fewer sanitary and phytosanitary compliance problems. Further, these producers achieved higher marketable yields at lower production costs, resulting in greater economic and socioeconomic sustainability.

- The Central American IPM CRSP was recognized in Year Six by the Association for International Agriculture and Rural

Development (AIARD), Washington, D.C. as one of three exemplary case studies of international development that benefits both the United States and foreign host countries.

- ICM research was elevated in Year Six IPM CRSP activities. ICM (integrated crop management) focuses on the combining of integrated pest management, intercropping, and strip-cropping techniques to achieve a holistic production management strategy that significantly reduces pesticide use, increases marketable product yields and quality, and achieves greater economic, environmental, and socioeconomic sustainability at the small producer and community levels. The integration of these techniques were found to increase marketable yields in snow peas by an average of 25 percent, while reducing pesticide use to only 3 to 4 applications per cropping cycle. The full significance of this research will be determined in Year Seven, but preliminary results are extremely encouraging.

- The institutionalization of IPM CRSP performance-proven production strategies in snow pea, broccoli, tomatoes, and sugar snaps realized a quantum leap forward in Year Six. The "foundation" research in the development of pre-inspection protocols, combined with the aforementioned ICM research, captured the attention of private sector entities, resulting in widespread adoption of IPM CRSP pest management strategies in Guatemala. Led by AGEXPRONT and FONAPAZ, it is estimated that over 50 percent of Guatemala's current commercial snow pea production in 1999/2000 will be managed under IPM CRSP developed pest management strategies. This conversion to more sustainable production strategies will help assure the transfer to other NTAE crops, and provide the basis for the revision and institutionalization of GOG policies that are sorely needed to support this new production paradigm throughout the region.

- Research focusing on the use of entomopathogenic fungi and entomophagous nematodes for control of white grub in broccoli was advanced in Year Six through collaborations with ICTA. Research also continued on parasitoids for the control of leaf miner in snow pea. The parasitoid research on white grub control was inconclusive, but the potential for ectoparasitoid *Diglyphus* in the control of leaf miner was found to be quite promising. Parasitoids have a potentially promising role to play in a fully integrated pest management strategy. Concurrent research has found that once sustainable pest management strategies are implemented for at least three cropping cycles in snow peas, the natural parasitoid populations begin to reestablish. Therefore, the role of a massive parasitoid breeding program may prove not to be economically justifiable. But, this research clearly has helped IPM CRSP researchers understand the role natural enemies play in a balanced and sustainable production regime.

- Socioeconomic research findings completed in Year Six enabled collaborators to establish baseline models for measuring NTAE/IPM adoption impacts at the small farmer household and community levels. These research findings will be used to develop and initiate a comprehensive quantitative assessment of socioeconomic and economic impacts from NTAE cropping regimes in Year Seven.

Institution Building

The Government of Guatemala has strongly supported the IPM CRSP's overall objectives for strengthening scientific capacity and market-focused planning in the NTAE sector. Institutional linkages with the Ministry's of Finance and Agriculture, FONAPAZ, and ICTA have been important factors in moving the IMP CRSP research and development agenda forward in Central America. In addition, institutional collaborations with APHIS-IS, FAS, and AGEXPRONT have been critically important in helping bring additional program funding and focus to the IPM CRSP. APHIS-IS has been instrumental in helping move the pre-inspection

program forward in the NTAE sector. FAS has teamed with the GOG (Ministries of Finance and Agriculture) to provide additional funding for the IPM CRSP Guatemala workplan activities. AGEXPRONT has been instrumental in providing additional research funds and in the transfers of performance-proven IPM CRSP pest management strategies.

The leadership role that was established between Purdue University and Universidad del Valle and Dr. G. Sánchez has helped strengthen the scientific research capacity of collaborating institutions in Guatemala, as well as, that of collaborating researchers and student training programs. The Universidad del Valle has an excellent reputation in the science areas, and has the human resources to play an ever increasing role in the institutional strengthening objectives of IPM CRSP. In recognition of the role that Dr. Sánchez and Universidad del Valle have played in the IPM CRSP, Purdue University awarded Dr. Sánchez an Adjunct Professorship in Year Six. In this appointment, Dr. Sánchez has full rights given to Full Professors at Purdue University with respect to serving on graduate student and research committees, electronic access to the Purdue University system, publication rights, etc.

Efforts continued in Year Six to strengthen institutional collaborations with Zamorano and Fundacion Hondureña de Investigacion Agricola (FHIA) of Honduras. However, progress has been slow with the departure of Drs. Zeiss and Hruska, and the impact of Hurricane Mitch. These efforts will continue in Year Seven through collaborations with Dr. Maria Mercedes Doyle at Zamorano and Dr. Dale Krigsvold at FHIA.

IPM CRSP in Central America continues to place high priority on strengthening the institutional capacity of collaborators and collaborating institutions. IPM CRSP scientists in the United States have collaborated with individuals to strengthen their capacity in research and technology transfer.

Student Training

The human resource development initiatives in Central America focus on five areas: (1) greater student training at U.S. institutions and/or in collaboration with U.S. scientists, (2) NGO training and technology transfer through national and regional workshops, (3) capstone research (thesis) training in collaboration with ZAMORANO and the Universidad del Valle, (4) continued strengthening of the research capacity of host country collaborators, and (5) research training that emphasizes less reliance on pesticides and improved food safety/quality to achieve expanded market opportunities in the NTAE sector. The following students were trained during the year through the IPM CRSP.

Phillip Lamport, a native Guatemalan, completed his Master of Science Degree under the direction of Dr. Stephen Weller and C. Richard Edwards at Purdue University. His thesis title was "Development of IPM Techniques for the Control of Pea Leaf Miner *Liriomyza huidobrensis* (Blanchard) on Snow Peas, *Pisum sativum* L.." His research led to a new and extremely effective trap crop system, using faba beans as a border planting to reduce leaf miner damage in snow pea. The result was a significant reduction in the use of pesticide applications and higher marketable yields.

Jim Julian, a U.S. citizen, finished his Master's Degree in marketing under the direction of Dr. Glenn H. Sullivan at Purdue University. His thesis titled "An Assessment of the Value and Importance of Quality Assurance Policies and Procedures to the Guatemalan Snow Pea Trade" has been instrumental in helping move the public and private sectors towards finalization of a formal pre-inspection program, as the findings clearly quantified the benefits of quality assurance to enhancement of market performance in NTAE crops.

Carlos Mayen, a native Guatemalan and undergraduate student in his senior year at Universidad del Valle, spent the 1999 summer term at Purdue University working on IPM field research with Drs. Stephen Weller and C. Richard

Edwards. Carlos will return to Purdue in July 2000 to pursue a Master of Science Degree under the direction of Dr. Weller.

Victor Hernandez, a native Guatemalan, completed his Ing. Agronomy thesis at Universidad Rafael Landívar titled "Intercropping Impacts on Control of Leaf Miner in Snow Peas". This research was conducted under the direction of Dr. Sánchez.

Sergio Torres, native Guatemalan, achieved partial fulfillment of his research for his Ing. Agronomy degree at San Carlos University testing the resistance of various snow pea cultivars to leaf miner infestation. This research was conducted in collaboration with ICTA under the direction of Ing. Luis Calderón.

Margarita Palmieri and Laura Vergara, both of Guatemala, completed an eight week training session at the University of Georgia under the direction of Dr. Wayne Parrot and assistance from Dr. Sánchez at Universidad del Valle in molecular biology techniques. This research will be instrumental in furthering the IPM CRSP work for the detection and evaluation of papaya ringspot potyvirus. This research training is being used in the tissue culture labs at Universidad del Valle in an effort to help solve the devastating effects of ringspot damage in papaya orchards throughout Central America. This research was partially funded by the Guatemalan National Science and Technology Council.

Brenda Tevalán, a native Guatemala, and a member of the Estudio 1360 staff directed by Dr. Linda Asturias received her licenciatura degree in Anthropology from the Universidad del Valle with a thesis titled "La división del trabajo por género en la producción agrícola de Santa María Cauqué durante la segunda mitad del siglo XX." This research focused on the socioeconomic dynamics of NTAE crop production at the small family farm level.

Networking

Workshops have been developed at the regional, district, and community levels. This activity has been expanded in Year Six with funding from FONAPAZ. The regional workshops have focused on technology transfers to NGO's and independent private sector technicians, while district and community workshops and IPM demonstration research have focused on small NTAE producers in collaboration with ICTA. All workshops and demonstration research have been supplemented with published research materials and user manuals that present performance proven IPM pest management strategies.

Collaborations with APHIS-IS in the development and testing of pilot pre-inspection programs have helped further expand the IPM CRSP networking activities in Year Six. Private sector grower-shippers and shippers of NTAE crops that are participating in the IPM CRSP led initiative became important "conduits" for technology transfers, potentially reaching nearly 9,500 small farm producers, field technicians, and community leaders throughout Guatemala in our Year's Five and Six workplan activities.

Initial programs collaborations were explored with UTZ SAMAJ in Tecpán, Chimaltenango, Guatemala to develop an IPM / ICM technology transfer program for small NTAE producers throughout the central highlands. UTZ SAMAJ recently received a grant to achieve the transfer of IPM / ICM technology through community level program collaborations, and IPM CRSP was contacted to help achieve the overall program objectives, as the IPM CRSP already has established collaborations in over 56 communities throughout the region.

The IPM CRSP strengthened regional collaborations with AGRITRADE and AGEXPRONT through assistance in the development of the 1999 Regional AGRITRADE Conference. This important conference includes public and private sector participants from throughout the region (Guatemala, El Salvador, Nicaragua, Honduras, and Costa Rica). The IPM CRSP portion of AGRITRADE program focuses on "Food Safety and Implications for Market Development in the NTAE Sector". Drs. Sullivan, Sánchez, and Weller are the lead IPM

CRSP participants in the 1999 AGRITRADE Conference. Participation in this program has led to further discussion on IPM CRSP regionalization with Nicaragua and El Salvador.

Finally, the IPM CRSP held a series of discussion with the Ministry of Agriculture in Guatemala (MAGA) seeking to strengthen program collaborations through greater participation in the development of research priorities and workplan activities. These discussions were still in process at the end of Year Six. It is likely that these discussions will generate a positive result early in Year Seven of the IPM CRSP, after the new GOG administration assumes office.

Ecuador

Description of the Collaborative Program

This is the second year of activity at the South American Site/Ecuador. A total of 8 regular activities and two special projects were conducted. This site operates under a Memorandum of Understanding with INIAP, the research arm of the Ministry of Agriculture in Ecuador. Two site coordinators manage activities under the CRSP because the crops we work with are primarily located in two locations. Patricio Gallegos currently serves as the Site Coordinator of the Sierra (higher elevations). He is located at the INIAP Experimental Station at Santa Catalina near Quito and coordinates activities with potato and Andean fruits. Carmen Suárez currently serves as Site Coordinator for the Littoral (lower elevations). She is a researcher at the INIAP Tropical Experimental Station at Pichilingue near Quevedo and coordinates activities with plátano (plantain or cooking banana). Cooperation between the two Site Coordinators facilitates institutional communications and collaborations. Each Activity (research project) has a leader that is responsible for interactions with their respective coordinators and cooperators.

Activities in Year 6, second year for the South American Site, were funded primarily through USAID IPM CRSP and collaborating institutions: INIAP, PROEXANT, CIP, FORTIPAPA and the U.S. Universities that are involved. Even though research activities at the South American site are relatively recent, we are developing collaborative ties with several local organizations which are well established in Ecuador: CIP (Centro Internacional de la Papa), FORTIPAPA, PROEXANT, and an Inter-CRSP with the SOILS CRSP. Through student employees and especially graduate students we are also developing collaborative ties with the local Universities. Jointly developed collaborative research plans have allowed us to buy into ongoing research programs and initiate new projects with joint funding. This approach has been used with the three primary crop areas on which research was initiated (plantain, potato and Andean fruits), and has been particularly effective in Year 6. Since trained personnel were already on board, we were able to take advantage of their skills to conduct collaborative investigations. This system will allow us to provide deliverables at a much faster pace.

IPM Constraints Addressed

The South American Site/Ecuador is addressing some of the known production constraints of some key horticultural staples in the area. Late blight of potato is a worldwide limiting factor in potato production. In Ecuador we have been selecting resistant potato clones with horizontal (durable) resistance. Activities in clonal selection are currently underway, and several lines have been selected for use in future research activities. Andean fruits are a source of healthful food for the entire nation, and have potential for export. However, mites, nematodes, fruit and stem borers, and especially diseases such as *Fusarium* vascular wilt have made it difficult to produce these fruits economically. We feel that great strides are being made in this area. Plantain is a staple food for people living in the littoral (lowland Tropics). In fact, plantain is a substitute for potatoes at the lower elevations. Disease and pest problems of plantains are thought to be similar to those of bananas. A survey of pests and diseases is helping define the critical research needs of this crop as

are research activities and evaluation of various IPM practices for use in plantain.

Substantial progress in the use of safer compounds for the control of insects has been made. Research on the use of biorationals to control the Andean potato weevil has given rise to two potential candidates. Laboratory and field studies have confirmed the efficacy of Spinosad and Naturalis-L. They both are biorational insecticides, which may have important roles in the future control of the Andean potato weevil. Research during year 6 has led us to do more detailed investigations with Spinosad. It has been found to be a useful IPM tool to potato farmers. These are both new compounds which represent a major step in pesticide safety to humans and the environment.

One objective of the research in the plantain pest-survey is the identification and quantification of nematodes associated with this crop. This is the first such investigation of its kind that we are aware of. Unfortunately the pesticide safety manuals being developed by the Ministry in cooperation with IPM CRSP have not been developed.

Selected Research Accomplishments

Even though this is a new site, at which funding actually begun in March 1998, we have been able to make some significant accomplishments.

- Through working with researchers that were involved in related work and by collaborating with established agencies, great strides have been made in the control of the Andean potato weevil by finding effective biorational insecticide that replace some of the traditional, more toxic materials.

- Several studies on Andean fruits have been centered around the major mite and disease problems of babaco (Mountain Papaya) and surveys have been conducted to determine the organisms involved. *Fusarium* vascular wilt is the most important disease. It can kill up to 100% of the plants in a commercial orchard. Control of *Fusarium* has been under investigation and the most effective treatments have been identified.

- Mite control strategies for babaco in the greenhouse have shown that their are several effective materials available. One of the most effective compounds was a botanical soap.

- We have defined the dosage and application timing for the control of the Andean potato weevil.

- We have demonstrated that the Central American Tuber Moth can be controlled with a virus (biological agent) originally found in the region. In addition, *Bacillus thuringiensis* is effective in controlling the moth.

- Several potato cultivars have been identified that are acceptable to consumers, and have strong (horizontal) resistance to late blight. A survey of the incidence and importance of the major potato diseases has also been conducted.

- Farmer field schools are being conducted, and will enhance our abilities to introduce integrated crop management practices emphasizing control of the Andean potato weevil.

- The survey conducted on plantain has provided information that will aid in the biological control of important insect pests through natural enemies.

Mutuality of Benefits of the Research

The results of plantain research will have benefits in Ecuador and to the region. The U.S. and Europe are becoming major importers of plantain and as production increases relative prices will encourage and expand global acceptance.

Potato research to find clones which are long term resistant to late blight and that are highly acceptable to consumers will benefit Ecuador, the region and the world. This is a top priority for North America as well as for our neighbors in South America and steady progress is being made.

Institution Building
We have been able to supply INIAP researchers with some of the new biorationals that are being approved by EPA for food crops use in the U.S. Two of these have been tested and appear to have promise in the control of the Andean potato weevil. This is a case where only a small amount of foliage is treated and put under a cardboard and this acts as a trap, which is capable of controlling the weevil.

Several Ecuadorian undergraduate and graduate students are presently being funded through various activities of the IPM CRSP for their Independent Study theses and their MS theses from Ecuadorian Universities. This system is helping the CRSP and the Universities to get research accomplished and to train individuals in applied agricultural research.

One of our researchers on the Andean fruit project has taken a short course on diseases at Turrialba Research Center in Costa Rica.

Our student-training plan is to use as many Ecuadorian students as possible in country in conducting the various activities. In addition, plans have been made to allow two junior researchers have research internships in the US beginning in the summer/fall of 2000. They are presently studying English. We are hopeful a third candidate, a senior researcher, will start on his Ph.D. at Ohio State in 2000.

Networking
We conducted our first one-day Mini Workshop on October 23, 1998. This workshop reviewed results for the first year activities and also reviewed plans for the second year activities (Yr. 6) which began September 29, 1999. Over 30 people including most of the investigators of the IPM CRSP from Ecuador and US universities attended this Workshop. We were fortunate to have Bob Hedlund, USAID Project Manager, and two representatives from the INIAP administration and several visitors from other agencies in attendance. We plan to make this an annual meeting which will gradually grow into a larger forum to include students, researchers, extension workers, agricultural buyers and suppliers.

CARIBBEAN REGION

Jamaica

Description of the Collaborative Program
The activities of the Caribbean site are conducted under four main research components: IPM Systems Development, Pesticide Use Residues and Resistance, Social-economic, Policy and Production Systems, Research Enhancement through Participatory Activities. For the 1998-1999 project year, the activities of the site were conducted mainly under the first three research components. Research activities presented herein are the collective efforts of scientists from Caribbean and US Institutions including the Caribbean Agricultural Research and Development Institute (CARDI), Ministry of Agriculture (MINAG), Rural Agricultural Development Authority (RADA), Pennsylvania State University (PSU), Virginia Polytechnic Institute and State University (VPI), Ohio State University (OSU), United States Department of Agriculture - Vegetable Laboratory (USDA-VL) and Lincoln University (LU).

Key components have been identified to form the framework of an IPM model for the management of major pests on callaloo. Validation studies of the field chart designed in year five to guide pest management decisions have been completed and have shown the potential to reduce the frequency of pesticide application by up to 60% without significant increase in pest damage and economic loss due to lepidoptera species. The use of the sampling plan has been demonstrated to over 60 farmers within the major callaloo-growing parish of St Catherine. Some farmers had the opportunity to compare callaloo which had received 11 applications based on the calendar

sprayed system with those sprayed six times using the sampling plan. Unanimously the farmers thought the sampling plan plot was either less damaged or had the same level of damage as the weekly sprayed plants.

Selected Research Accomplishments

Pests Affecting Hot Pepper, *Capsicum chinense*
A breeding program to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into Habanero pepper was continued; the third backcross was completed and resistant plants from this backcross are being used to complete the fourth backcross. A breeding program was initiated to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into West Indies Red; the initial F1 cross was completed and F1 plants are currently being backcrossed to the West Indies Red parent. The resistance to the peanut root-knot nematode (*Meloidogyne arenaria* Race 1) in *C. chinense* was found to be conditioned by a single dominant gene; this finding confirms the results of the inheritance study conducted in 1998. The results of growth chamber tests confirmed earlier findings that resistance to southern root-knot nematodes (*M. incognita*) in *C. chinense* is partially compromised at high temperatures. However, the root galling response and nematode reproduction in the resistant Scotch Bonnet germplasm at high temperatures was significantly lower than in susceptible Habanero-type peppers. Root-knot resistant *C. chinense* cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates. The results of a second year of field tests conducted cooperatively with a CARDI investigator in St. Kitts confirmed that the recently released *C. chinense* germplasm lines PA-353, PA-398, and PA-426 are resistant to indigenous field populations of *Meloidogyne* spp.

Seven legumes (velvetbean, Iron-Clay cowpea, sunnhemp, soybean, Cahaba vetch, crimson clover, and hairy vetch) selected for their potential usefulness as cover-crop mulches for weed control in pepper plantings were evaluated for host suitability to southern root-knot nematodes; the velvetbean, Iron-clay cowpea, sunnhemp, and soybean entries were highly resistant and are potentially useful for managing *M. incognita* if used as a cover-crop mulch for weed control.

Viruses are a major constraint to hot pepper production in Jamaica. During the past year, studies were conducted to determine the dynamics of the aphid vectors, the epidemiology and evaluate the potential of stylet oil and cultural practices to reduce virus incidence. Over twenty species of aphids were identified throughout the time of sampling, with the period of greatest species diversity occurring during December 1998 to April 1999. The spread of TEV was slower in plants sprayed with stylet oil than unsprayed plants. As a stop gap to the virus problem which is crippling the hot pepper industry, West Indian Red hot pepper variety was introduced into four project areas inclusive of IPM CRSP target sites. Using IPM technologies, the West Indian red variety proved to be an economically viable crop for small farmers.

In 1998, high gall midge interceptions crippled the hot pepper industry in Jamaica, resulting in the enforcement of mandatory fumigation as a condition of entry of the product into US markets. This prompted several responses, many of which were lead by the IPM CRSP team. The development of an IPM strategy to reduce infestations was the focus of the activities and included both pre and post harvest investigations. During the past 12 months, a monitoring system that includes the assessment of larval infestation in fruits was developed. This methodology was used to assess populations in IPM studies that evaluated the potential of cultural practices and chemical insecticides to reduce gall midge infestations. The use of cultural practices in combination with selective chemicals fipronyl (Regent ®) and imidacloprid (Admire®) suppressed populations of the gall midge for over 3 weeks below a 5% threshold. These results are being used in technology transfer programs being conducted by the task force.

IPM of Pests Affecting Sweetpotato, *Ipomoea batatas*

A new insect pest attacking sweetpotatoes in Jamaica was identified as the sweetpotato leaf beetle (*Typophorus viridicyaneus* Crotch), and a scoring system for assessing the damage to sweetpotato roots caused by this insect was refined. Sweetpotato IPM component research focused on developing high yielding, red-skinned, cream-fleshed sweetpotato cultivars with resistances to root-knot nematodes, diseases, and insects. In addition, the integration of these varieties with a selective low toxic compound, fipronyl was initiated. Several USDA-developed sweetpotato clones and Caribbean varieties demonstrated good resistance to the sweetpotato leaf beetles, sweetpotato weevils, and/or the WDS soil insect complex in a replicated field test in Jamaica. The regionalization of the sweetpotato IPM was one of the highlights of the component. Researcher exchanges and visits to Jamaica, St Kitts and Nevis, St Vincent, Montserrat and St Lucia provided the medium to initiate sweetpotato research and has set the stage for future expansion of the IPM CRSP research activities.

Pesticide Use, Residues, and Resistance

The goal of this topic is to assess the extent to which pesticides are used on pepper, callaloo, and sweetpotato. We hypothesize that many of these pesticides remain on crops long after application even to the extent to which residues can be detected in local and export marketplaces. Thus, the activities described below attempt to quantify pesticide use and residues that can either cause human health problems or rejection in the marketplace. Resistance to pesticides may also be a result of excessive pesticide use or of those chemicals that degrade very slowly under field conditions.

Over the past three years, results of market basket surveys have demonstrated that pesticide residues are present on marketable produce. In an effort to address the problem. IPM technologies geared at reducing spay applications were developed. To further demonstrate the benefits of these technologies, samples of callaloo from a field experiment which compared routine farmer spraying with a limited pesticide spraying regime were analyzed for pesticide residues.

Policy, Social and Gender-related Issues that Affect IPM Adoption

The primary activity of Year 6 was the analysis of data collected during Year 5's baseline socioeconomic survey in three communities, each affiliated with the IPM CRSP for one target crop and each located in a distinct ecological zone and geo-political region. The goals of this activity were to identify (1) socioeconomic constraints to IPM adoption and (2) beliefs and practices that contribute to health and environmental problems associated with pesticide use.

Among the gender equity issues addressed is whether the adoption of IPM is likely to alter the gendered division of labor and resources within households in ways that would disadvantage women. Findings indicate that IPM adoption would not disadvantage women. However, the potential benefits of IPM adoption may not be as available to women as to men, as women are less likely to receive relevant technical assistance or to be involved in technology development. Gender bias in technology design and delivery may also constrain adoption by households.

Results of a probability-sample household survey in three IPM CRSP research communities showed that women produce and market targeted crops, choose among pest management alternatives, and select and purchase pesticides; as women appear to have less access than men to IPM-related extension, it is recommended that the CRSP intensify efforts to incorporate women farmers in field research activities and to disseminate gender-disaggregated information to extension officers.

At the beginning of Year 6, information had been collected on government policies potentially affecting IPM adoption in Jamaica. Information had been collected on the effects of IPM on costs and returns for callaloo, sweet potato, and sweet pepper. General information had been collected for vegetable production costs and returns for farmers in Ebony Park, Clarendon, Jamaica. A modeling framework was developed for

evaluating returns from IPM adoption for producers of callaloo, hot pepper, and sweet potato in Jamaica. Research findings indicated that the IPM systems developed for callaloo, hot pepper, and sweet potato are potentially profitable. The systems remain more profitable than conventional systems when 1) assumed chemical savings from IPM are eliminated; and 2) labor requirements for IPM are increased by 50%. When the assumed yield increase with IPM was reduced from 30% to 5% for the crops, IPM continued to be more profitable at Ebony Park but not at Bushy Park.

The policies evaluated included pre-clearance of vegetables for export, elimination of water subsidies, elimination of credit subsidies, a reduction in the real interest rate, elimination of the duty concession, a lowering of the Common External Tariff, and an appreciation of the real exchange rate. None of the policies had large effects on the returns to IPM adoption. Policies designed to liberalize the domestic economy are not likely to affect the potential for IPM adoption in sweet potato, callaloo, and hot pepper in Jamaica.

Networking Activities

US and host country scientists active in the Caribbean participated in the IPM CRSP Annual Planning Workshop, West Lafayette, in May 7 - 8, 1999.

D. Clarke-Harris coordinated and presented a farmer training series - Integrated Pest Management- Monitoring Populations of Major Pests on Callaloo, Management of Pests in Callaloo and also attended a CARINET workshop on Identification of whiteflies and mealybugs, Trinidad, W I.

Janet Lawrence, Phillip Chung and Don McGlashan along with other members served as the national the task force on gall midge. A national strategy was developed by the task force and CARDI was given the responsibility to coordinate the compilation of the proposal. This proposal was submitted to the IPM CRSP for funding.

F. McDonald, J. Lawrence, and D. Clarke-Harris helped to coordinate a workshop "Integrated Commodity Approach to the Development of the Hot Pepper Industry". St Mary, Jamaica (November 1998).

D. Clarke-Harris, F. D. McDonald, and J. L. Lawrence planned and coordinated hot pepper stake holders meeting "Development of marketing strategies for the hot pepper industry in Jamaica and the wider Caribbean". Kingston, Jamaica (October 23, 1999).

A number of the IPM CRSP researchers both from the US and Jamaica attended the Caribbean Planning Workshop – Year 6 and beyond at USDA vegetable lab, Charleston, June 28 - 29, 1999; presented summary of research results and recommendations.

Training and Capacity Building

Gary Schlosser and Tina Schlosser, graduate students in the Department of Geography at Virginia Tech, have published results in their Masters theses, which can be downloaded at http://www.vt.edu.

S. McDonald; Ph.D. student at VPI conducted research on hot pepper in Jamaica during the past year. She visited the Division of Plant Industry, Florida Department of Agricultural and Consumer Services in Gainesville to be trained in aphid identification by Dr. Susan Halbert, a Homopterist. (March 21st – 28th, 1999).

Joe Ogrodowczyk, project graduate student, visited the Jamaica site from November 14 to November 28, 1998 to collect data at Bushy Park, St. Catherine, and also to exchange information with CARDI scientists collaborating on the project, and to interview government officials and policy analysts.

D. Clarke-Harris disseminated callaloo pest management guides to farmers, extension agents and researchers in Jamaica. Copies of the publication were also distributed to collaborators in the Caribbean Region.

ASIAN REGION

Philippines

Description of the Collaborative Program
IPM activities in the Philippines site were concentrated in four program areas during Year 6:

(1) multi-disciplinary on-farm pest management experiments,
(2) multi-disciplinary laboratory, greenhouse and microplot experiments,
(3) socioeconomic analysis and training, and
(4) IPM technology transfer and feedback

Work on two special projects was continued in Year 6: (1) Eggplant resistance to leafhoppers and eggplant borer, and (2) Interaction effects of fungal pathogens and nematodes on pink root and bulb rot severity in onion.

The work was done as a collaborative effort among scientists at the Philippine Rice Research Institute (PhilRice), the University of the Philippines-Los Banos, the International Rice Research Institute (IRRI), the Asian Vegetable Research and Development Center (AVRDC), Ohio State University, Penn State University and Virginia Tech.

The Year 6 workplan was focused on crops, pests and constraints identified in the participatory appraisal process, a structured baseline survey and crop monitoring in years two through four. Planning and collaborative research efforts for the year took place through:

(a) discussions among U.S., Philippine and other cooperating scientists at planning meetings in the Philippines,
(b) joint host-country/U.S. scientist two-page proposals,
(c) a workshop among cooperating scientists to integrate the two page proposals into the overall plan and budget, and
(d) revisions to the plan followed by review by the scientists, ME and USAID.

Field research is conducted in six villages in San Jose, Nueva Ecija, in Bongabon, Nueva Ecija, and at the PhilRice experimental farm, also in Nueva Ecija. The host country site coordinator oversees the field research activities. U.S., UPLB, VISCA, IRRI and AVRDC scientists visit the sites periodically to address specific projects. Laboratory and field research is also conducted at AVRDC in Taiwan, and training activities take place at Virginia Tech, Ohio State, Penn State, UPLB and AVRDC.

IPM Constraints Addressed
Key constraints to IPM in the Philippines that were addresses during Year 6 were:

(1) absence of economical IPM solutions for specific pest problems,
(2) lack of basic understanding of the biology of specific pests,
(3) lack of knowledge of sources of germplasm for resistance to insects, pathogens and nematodes, and
(4) absence of knowledge about policies, sociocultural beliefs and perceptions, regulations and other factors influencing pest management practices.

Specific major pests being addressed in the IPM program are the root knot nematode (*Meloidogyne graminicola*), bulb rot (*Fusarium* spp.), pink root (*Phoma terrestris*), cutworms, (*Spodoptera* spp.) and various weeds, particularly *Cyperus rotundus*, in onions. Fruit and shoot borers (*Leucinodes orbinalis*), leafhoppers (*Amrasca biguttula*) and bacterial wilt (*Ralstonia solanacearum*) of eggplant were also addressed.

Selected Research Accomplishments
Descriptions of research progress and results are provided in the individual institution/activity reports. The following are examples of progress and key results obtained in the Philippines site.

- In rice-onion cropping systems the cost of farmer's weed control practices can be reduced by 50% from one herbicide application followed by three hand weedings to one herbicide application and one hand weeding

without reducing weed control efficacy and onion yields. This results in a net added benefit of P22,386 ($1 US = P38) per hectare compared to the traditional farmer's practice.

- Scale-up of the microbial biocontrol agent NPV-CRSP was completed resulting in production of 9 Kg of a wettable powder formulation for use in field experiments to control onion cutworm.

- *Helicoverpa armigera* emerged as a new pest of onion in both Bongabon and Palestina sites for the 1999 dry season. The combined larval densities of *S. litura* and *H. armigera* did not differ among the treatments but were significantly different from the untreated control plots in both Bongabon and San Jose sites.

- Results of a Year 5 study indicating that rice hull burning could significantly reduce the soil population of pathogenic fungi were confirmed in Year 6. The incidence and severity of pink root infection in onion was lower and onion yields were higher in plots in which rice hulls were burned, compared to unburned plots. Partial budget analysis showed that rice hull burning can provide a net benefit of P188,958 per hectare (1$ US = P 38).

- Several plant species had strong nematicidal activity against the root knot nematode. Highly active extracts were prepared from neem tree, papaya, Euphorbia and kuyot. Use of *Tagetes* sp. and two *Crotalaria* spp. reduced the number of galls and nematodes in roots and soil.

- Planting non-host crops of *Phoma terrestris* in rotation with onion significantly reduced disease pressure, resulting in low incidence and severity of pink root infection. However, crop rotation was not effective in controlling the root-knot nematode.

- Sex pheromone traps detected *Spodoptera litura* and *S. exigua* even before seeding of onion crops. Peaks in sex pheromone trap catches were followed in a few days by peaks in egg density of *S. litura* as monitored in castor plants. Trap catches could be used as a monitoring tool for efficient timing of interventions in the field, thus resulting in reduced costs and insecticide usage in onion.

- Removal of damaged shoots and fruits of eggplant is a viable alternative to insecticide application for the management of *Leucinodes orbonalis*. If implemented at the same time as harvest, labor costs can be cut down drastically. With the drastic reduction or non-use of insecticides, great savings will be realized, leading to high economic returns to farmers. Partial budgets analysis indicated net added benefits of P128,157 per hectare for weekly removal of damaged fruits compared to tri-weekly application of insecticides.

- Several farmers' and commercial varieties of eggplant evaluated were resistant or tolerant to the cotton leafhopper. The farmer's variety SRO2 has dense trichomes that prevented leafhoppers from feeding and oviposition. IPB GS 1, an improved line, has few trichomes but is resistant to leafhopper and yields high. The use of these varieties significantly cut production costs as no pesticide inputs were added. This was coupled with the abundance of natural enemies, which helped reduce and manage leafhopper and borer populations below damaging levels.

- Rice pest predators including spiders, ants, Dermaptera and carabids provide early season control of rice pests. The age of the crop as well as farm operations affect predator movement across bunds, the closest refugia for these predators. In the young crop *Pardosa* (spider) females with eggs or young move from or across the bund and into the field. This trend is later reversed so that the older crop may serve as a source of spiders to neighboring crops. During farm operations, such as harrowing, predators escape into the bunds. Later other groups of predators arrive

and become more numerous than the walking predators. One of the first is balooning spiders, later followed by, among others, a high number of aquatic hemipteran predators. During fallow collembolans and dipterans provide important alternative prey for the predators, thus allowing many predators to survive in and around the field. After the crop is planted, numbers of alternative prey fall dramatically, producing a perfect timing with many hungry spiders at the time of early pest attack.

- The bacterial antagonist *Bacillus* sp. strain LEP 118 has the potential to control pink root and other soil-borne pathogens in rice-onion systems and is most effective if applied as a protective coating on the root surface. *Trichoderma viride* and *Trichoderma* sp. strain T5 were suppressive to the soilborne pathogens *Rhizoctonia solani* and *Sclerotium rolfsii* in laboratory and greenhouse assays.

- Morphologic and genetic variation was observed between the lowland and upland types of the purple nutsedge, *Cyperus rotundus*. The results of this study will serve as a basis in formulating short-term and long term integrated weed management strategies in rice-onion rotation systems.

- Development of transgenic Asian eggplant varieties was determined to be feasible but currently limited by funding constraints. However, availability of varieties resistant to the fruit and shoot borer could result in highly significant reductions in pesticide use.

- Bacterial wilt incidence was lower in the eggplant cultivars Jackpot and Dumaguete Long Purple than in the cultivar Abar. Mulching with straw increased the incidence of bacterial wilt compared to unmulched controls. Soils that has been cultivated and not mulched contained markedly reduced numbers of the bacterium. However, yield of eggplant cultivars was higher in mulched than in unmulched plots.

- The environmental benefits of the IPM CRSP were estimated at more than 6 million pesos for the roughly 4600 inhabitants in the villages where the IPM CRSP is immediately centered, or about $150,000 per cropping season.

- Two IPM CRSP papers presented at the Pest Management Council of the Philippines Conference in May 1999 won Best Paper and Best Poster awards. These were: Best Paper (Weed Science) – Agroecological Approaches to Managing Weeds in Rainfed Rice-Onion Systems, by A. Baltazar, E. Martin, M. Casimero, F. Bariuan, S. Obien and S. K. DeDatta; Best Poster (Plant Pathology) – Root Knot Disease Caused by *Meloidogyne graminicola* and its Management in Rice-Onion Systems, by E. Gergon, V. Judal, C. Ravina, R. Gapasin, and J. Halbrendt.

Mutuality of Benefits of the Research

Most of the pest problems addressed in the Philippines site activities are widespread throughout Asia and also occur in other parts of the world. Strategies developed to manage these pests economically and sustainably can thus be applied to other countries. IPM methods developed for managing pests of onion and eggplant are particular examples. Economic analyses have shown that strategies such as appropriate timing of application of herbicides combined with hand weeding in onions, use of microbial biocontrol agents in onions, and removal of eggplant fruits damaged by the fruit and shoot borer, are economically beneficial to farmers in Central Luzon. These strategies are likely to benefit farmers in other Asian countries as well in the near term, and have the potential to be adopted in other regions.

Institution Building

Funds were provided for long-term rental of a vehicle for travel to and from research sites. U.S. scientists also provided research supplies during visits to the Philippines site. Research articles were sent from U.S. cooperators, and bibliographies were prepared at Penn State and provided to IPM CRSP scientists. Approximately

50% of the total Philippines site budget were provided to PhilRice and cooperating institutions in the Philippines.

Student Training

Several students are currently being supported by the project in graduate programs in a collaborating host country university (UPLB) or U.S. institutions. M. Casimero and E. Gergon are pursuing Ph.D. degrees in weed science and nematology, respectively, at UPLB. J. Recta is pursuing a Ph.D. in statistics at Penn State. L. Cuyno completed a Ph.D. in agricultural economics at Virginia Tech.

Networking Activities

Networking is accomplished through institutional collaboration between PhilRice, UPLB, VISCA and other agricultural colleges in the Philippines. PhilRice is part of the Department of Agriculture (DA) and its national IPM program coordinates with IPM CRSP. Workshops during Year 6 include

- "Cultural Management Practices and IPM for Vegetables", July 14-15, 1999, PhilRice.
- "Training for Agricultural Technicians and Farmer-Leaders on Rice-Vegetables with Emphasis on IPM", August 2-6, 1999, PhilRice.
- NOGROCOMA (onion growers cooperative) meeting at PhilRice July 30, 1999, involving IPM CRSP scientists, NOGROCOMA members and barangay captains of Bongabon, Nueva Ecija.
- IPM CRSP scientists also developed a training module for IPM in rice-vegetable systems, farmer-appropriate training materials and facts sheets on pest problems.

Bangladesh

Description of the Collaborative Program

IPM activities in the Bangladesh site were concentrated in three program areas during year 6, which was year 1 for Bangladesh. The first of these areas was a baseline survey and crop monitoring. The second was multidisciplinary on-farm pest management experiments. The third was socioeconomic analyses. The work was conducted as a collaborative effort among scientists at the Bangladesh Agricultural Research Institute (BARI), the Bangladesh Rice Research Institute (BRRI), the Asian Vegetable Research and Development Center (AVRDC), the International Rice Research Institute (IRRI), the University of the Philippines-Los Banos, Penn State University, Purdue University, and Virginia Tech. Rezaul Karim served as Site Coordinator and George Norton served as Site Chair.

The Year 6 workplan focused on crops, pests, and constraints identified in the participatory appraisal process. Planning and collaborative research took place through: a) discussions among host country and US/international scientists at planning meetings in Bangladesh, and b) preparation of joint host-country/US/international scientist two-page proposals. Planning for Year 7 also involved discussion of the plans jointly with scientists working in the Philippine site during the planning workshop at Purdue in May.

Field research is conducted in farmers' fields in Kashimpur, with BARI/BRRI scientists visiting experiments on a regular basis. Some research is also conducted on station, especially varietal screening for insect, disease, and nematode resistance. Training takes place primarily at U.S. universities and AVRDC. CARE-Bangladesh has participated in the planning but not the research.

IPM Constraints Addressed

The key constraints addressed in Bangladesh in year 6 were the need for IPM solutions to specific pest problems in vegetables and the need for information on socioeconomic factors influencing adoption of IPM. Specific major pests being addressed in the IPM program are fruit and shoot borer (*Leucinodes orbinalis*) and bacterial wilt (*Pseudomones solanacearum*) and other pathogens in eggplant, various weeds in cabbage and eggplant, soil borne pathogens such as root knot nematodes (*Meloidogyne* sp.) and *Fusarium* in gourds, and aphids and diamond back moth in cabbage.

Selected Research Accomplishments

Descriptions of research progress and results are provided in the individual institution activity reports, but the following are examples and key results obtained in the Bangladesh site:

- Baseline surveys conducted in Kashimpur and Konobari districts provided information on existing patterns of vegetable production and pest management practices. Very little IPM was found currently being practiced on vegetables.
- Monitoring of crop pests and their natural enemies in rice and vegetables identified the most serious insects, diseases, and weeds in the Gazipur district.
- Of the 23 accessions of eggplant tested for resistance to bacterial wilt, root knot nematode, and fruit and shoot borer, none were found resistant, but a few exhibited tolerance to one or more of the pests and will be tested further.
- A trap with the synthetic pheromone lure, Cuelure proved effective in trapping fruit flies in cucurbit crops.
- Results of on-farm experiments in both okra and cabbage found that, instead of the current practice of three or four weedings, farmers can effectively control weeds through deploying two weedings, one early and one mid-growth stage in the crop and generate the highest net returns.
- The first season's experiments found that incorporation of mustard oil-cake in eggplant fields effectively reduces nematode infestations and increases yield.
- Plots with poultry manure incorporated produced taller, heavier bunching onions and has less disease and nematode infestation.
- Sawdust burning and soil incorporation of poultry refuse were effective in reducing deaths of cucumber seedlings, promoted growth of cucumber plants and produced 1.5 times more yield.

Mutuality of Benefits of the Research

The pest problems assessed in these studies are widespread throughout Asia and also occur in other parts of the world. IPM approaches to manage these problems have broad applicability, especially in Asia. The consumption of vegetables is growing in Bangladesh and the region The primary feedback in terms of benefits to the United States will be through (a) the effects of economic growth in the region on trade and demand for U.S. products in international markets and (b) improved relations with a major country in a politically sensitive area of the world.

Institution Building

Funds were provided for vehicle repair and rental to facilitate transport to and from research sites. Computers, copier, supplies, etc. were provided.

Research Training

One U.S. student, T. Debass, worked on his masters thesis at Virginia Tech (agricultural economics) assessing the economic benefits of the IPM program. One Indian student at Penn State, Joseph Kodamanchaly, began his dissertation research in sociology with a focus on factors influencing IPM adoption in Bangladesh. One Bangladeshi student, Chowdhury Mahmoud, began his MS program in agricultural economics at Purdue.

Networking Activities

Networking is accomplished through institutional collaboration among BARI, BRRI, UPLB, the Institute of Post Graduate Studies in Bangladesh (IPSA), CARE-Bangladesh, and IRRI-Bangladesh. Both IRRI and AVRDC play key role in networking with other countries in the region. Scientists involved in the project work throughout the region and can spread research results though visits to other countries and participation in workshops, meetings, and other networking activities. U.S. universities also help with networking in the region. The Bangladeshi student at Purdue was formerly a research assistant at the office of the International Food Policy Research Institute (IFPRI) in Dhaka, and avenues for future collaborative work with IFPRI scientists are being explored. Some of the scientists on the project also work with the Philippines site, including the weed scientist from UPLB working in the Bangladesh site. One US scientist on the project also works with the SANREM CRSP in SE Asia, providing

another opportunity for networking within the region and the CRSP system.

EASTERN EUROPEAN REGION

Albania

On October 29, 1998, a meeting was held at OIRD with Dr. Phil Warren (USAID/ENI), Dr. Joe Pastic (USAID/Albania), Virginia Tech, and Penn State University participants, to discuss the Participatory Appraisal and workplan for the period in which Albania was closed to US co-Pis (Aug. 1998 - Apr. 1999). A PowerPoint presentation was made on the interaction between olive IPM and Albanian history and politics. The Baseline Survey was executed in Albania in January 1999. This survey is an integrated activity that describes the socioeconomic context of pest management in olive production in Albania. It provides background and context for the experimental studies to be carried out by IPM CRSP/Albania. The main purpose of the Baseline Survey is to identify the farmers' stock of knowledge and their perceptions regarding olive pests, natural enemies, and pest management practices, as well as to specify their knowledge gaps with respect to olive pest control.

Description of the Collaborative Program
Albanian scientists are distributed across disciplines (Entomology, Plant Pathology, Crop Protection, Agricultural Economics, and in three institutions: Agricultural University of Tirana, Plant Protection Research Institute (Durress and Fruit Tree Research Institute (Vlore).

The entire budget for the Albanian CRSP project originates from the USAID Mission in Tirana through the Global Bureau of USAID. This will support all objectives in the plan of work. We will investigate potential collaboration with VOCA.

Albanian and American scientists met in Tirana after the farm visits during the PA to develop proposal, and to sign up individual faculty with projects of interest.

IPM Constraints Researched
Overview of IPM constraints in the country/region. By 1990 the cumulative effects of Albania's central planning system had led to an economic crisis. The transition from a centralized system to a market economy brought about radical changes concerning the nature of basic elements of Albanian agriculture (the production process, farmers, the farm and farm business) as well as the functioning of essential support services. Currently pesticides are seldom available to growers. The result has been uncontrolled populations of some key pests, but establishment of natural enemies for other pests. A challenge is to develop control for the key pests that are nondisruptive to existing beneficial populations.

Examples of research progress. The research in only now getting underway. The Baseline Survey was completed, providing a detailed evaluation of the nature of the Albanian olive industry and pest management problems.

Mutuality of Benefits of the Research
Benefits to Albania relate to development of IPM practices that are not disruptive to ecological systems or human welfare, and will allow Albanian olive products to be competitive in an international market. Benefits to U.S. relates to observation of IPM systems in perennial cropping systems under a regime of low pesticide availability. American commodities are facing loss of key pesticide groups, and specialists will benefit from working in the Albanian system.

Selected Research Accomplishments
The most important findings relate to the level of grower education, and the inadequacy of a viable extension system.

- A valuable descriptive cross section of the Albanian olive industry was created. This included size of crop, marketing outlets, main pest problems, etc.

- Significant gaps in grower educated were revealed. Farmers gave diverse responses regarding the nature of damage caused by olive pests. They generally could give a description of the damages caused by pests on olives, but in some cases they failed distinguish between certain pests. In many cases their description of pest damages did not match those of respective pests. Farmers' knowledge about the natural enemies of olive pests was very limited. Even those farmers, who responded, seemed a little bit surprised about this question because they had never thought about it. Farmers revealed little awareness with respect to the potential harmful effects of pesticides on human health and the environment. The majority of farmers either did not agree or expressed no opinion that pesticides can harm water quality.

- There are significant obstacles to farmers obtaining agricultural credit. Only 38% of respondents consider it possible to borrow. The rest stated they have not tried to get credit because there are so many constraints and the interest rates are too high.

- Farmers mentioned various reasons for the credibility of sources of pest advice in olives. Most of respondents indicated that extension specialists are more credible as a source of advice because they are more knowledgeable, have more experience, have university education, tell what and how to do things. However, no farmer interviewed quoted extension specialists as being accessible. A small number of respondents also considered research specialists as a credible source of information for being knowledgeable and experienced, but not accessible in most of the cases. Only two percent of farmers reported to have participated in a training course related to pest control in olives. However, the overwhelming majority (82.5%) said they are willing to participate in such courses in the future.

Networking Activities

On October 29, 1998, a meeting was held at OIRD with Dr. Phil Warren (USAID/ENI), Dr. Joe Pastic (USAID/Albania), Virginia Tech, and Penn State University participants, to discuss the Participatory Appraisal and workplan for the period in which Albania was closed to US co-Pis (Aug. 1998 - Apr. 1999). An e-mail network was set up recently to support such sharing of information.

IPM CRSP - WIDE ACTIVITIES

Gender Equity Programming in the IPM CRSP for Sectoral Growth

The IPM CRSP was designed, and has been implemented, with a strong gender-equity component. The CRSP is committed to the equitable involvement of women as both program scientists and beneficiaries. The Management Entity of the IPM CRSP, Virginia Tech's Office of International Research and Development (OIRD), designed and is implementing a program that ensures that these program benefits will be equitably distributed among women and men. As a research program, the focus of gender-equity programming has been on research into the likely outcomes of IPM research activities for women and men, and on involving women farmers in these activities, in order to ensure that women's livelihood strategies receive equal attention with those of men. With a view to sectoral growth as well as to equity issues, programming is designed to ensure that women who produce targeted crops are included in research and dissemination activities.

The IPM CRSP has investigated linkages among measures of gendered resource ownership and control, women's access to and use of IPM and other agricultural technologies, productivity, agricultural incomes, and women's control of income in Africa, Asia, Latin America, and the Caribbean. Research methodologies include participation by women stakeholders at all levels in participatory appraisals used to guide program planning; probability sampling of households in areas where the CRSP is engaged in research, with participation by both women and men; and ethnographic studies of women's roles in household production, resource ownership and control, income, and access to development programs. Findings have been disseminated to interdisciplinary research teams of U.S. and host-country scientists. Recommendations for the inclusion of women farmers in technology development, as well as in related extension efforts, have been made for several sites, including those in Uganda, Mali, the Philippines, Guatemala, and Jamaica. Intrahousehold research is under way in Ecuador.

In Mali and Uganda, these recommendations have resulted in attention to women's crops and production constraints, and to technologies that improve women's food processing enterprises. Half of producer groups involved in IPM research in Uganda are female-oriented. Research findings from Uganda demonstrated that women are more likely to use pesticides than men, owing partly to their crop choices and corresponding market niches. These findings contribute to recently emerging studies in all regions showing that women are more likely to be high-technology commercial producers than influential earlier WID studies had shown. In Jamaica, where there is much less gendered division in crops and tasks, women farm and/or market all CRSP crops. Community-level outreach is attempting to ensure that women farmers are made aware of field days and other activities associated with CRSP research.

In Guatemala, women specialize to some degree in non-CRSP commercial crops, but work in CRSP-focused household production, as well, in 94% of households surveyed by the CRSP. According to their husbands, women make relevant land use decisions in three-fourths of these households, and pest management decisions in one-third of households. The CRSP is now focusing on targeting research to women, to determine their perceptions of their roles in pest management and their evaluation of access to and control of resources and their primary production constraints. Women attend field days and other extension activities, but have participated less than their husbands. Extension-related host-country

colleagues are considering mechanisms to provide women with female-oriented activities. These activities will focus on agricultural productivity rather than traditional "women's activities," but will be presented in a female-oriented environment.

In the Philippines, household surveys and ethnographic research have demonstrated that even women who do not work in the fields often control funds used to purchase IPM technologies, and thus should be included in all information campaigns. Filipinas are somewhat more likely than their husbands to prioritize spending for pesticides, as they are less inclined to risk crop loss, but are also more likely to be receptive to cost-effective IPM practices. The CRSP involves Filipina farmers in several contexts. One of these is a large export-oriented production cooperative headed by a woman and whose financial resources are controlled and channeled primarily through women officers and employees despite the fact that the membership is primarily male. Wives of male members are encouraged to attend meetings, either together with husbands or in their stead, and they do so. Earnings from household agricultural production are pooled and managed by wives. Gender-egalitarian control of household financial resources is not unique to this cooperative, but has been reinforced by gender-egalitarian control of cooperative resources.

The Management Entity is fully committed to gender equity issues among both scientists and project beneficiaries. Under the leadership of the Management Entity, the IPM CRSP has worked to ensure that both US and host-country women scientists are involved as investigators. Although these efforts have been somewhat more successful within host countries, the number and disciplinary diversity of scientists from the U.S. is increasing. The gendered division of graduate training awards has been equitable.

Two of eight US Site Chairs are women. Three of 11 host-country Site Coordinators are women. The Management Entity encourages the participation of the OIRD gender specialist as an investigator; she has been involved in research in most of the regions of the CRSP

It is important that gender issues receive increased attention from the Technical Committee, as the progress of gender equity issues on the IPM CRSP has depended largely upon the good will of collaborating institutions and the quality and impact upon them of gender-related social-science field research. In spite of direction from both USAID and the Management Entity, several institutions continually fail to meet their resource commitments for gender-related research. In some of these institutions, dedicated researchers have contributed to progress on gender equity issues despite the failure of these institutions to honor commitments they have made to allow their scientists time to participate in gender-related research.

In summary, the IPM CRSP features an approach that is genuinely committed to gender equity issues. This commitment can be seen most clearly in the record of graduate training, host-country scientist participation, global gender-focused research, and increasing incorporation of women farmers in collaborative research and extension efforts. These positive results would be multiplied if all partner institutions were held strictly accountable for meeting their commitments to gender-focused research, and, where relevant, to related extension efforts.

Board of Directors

The Board of Directors of the IPM CRSP annual meeting was held at Virginia Tech on 30 - 31 March 1999. Attendees were:

Appointed members: Ed Kanemasu (Board Chair; University of Georgia), Ikbal Chowdhury (Lincoln University), David Sammons (Purdue University), Santiago Obien (PhilRice), S.K. De Datta (Virginia Tech), Tom Mew (IRRI), David Denlinger (for Bobby Moser; Ohio State University), Ed Rajotte (for Paul Backman; Penn State University), (Rick Bennett, USDA unable to attend)

Ex-Officio Members: Brhane Gebrekidan (Program Director, IPM CRSP, Virginia Tech), Greg Luther (Assistant Program Director, IPM CRSP, Virginia Tech), Robert Hedlund (Project Manager, IPM CRSP, USAID)

Others: George Norton (Chair of Technical Committee, IPM CRSP, Virginia Tech)

Minutes of the Board Meeting are available on request. Major decisions made by the Board included:

- The Board should express in a letter to Emmy Simmons, John Lewis, Sally Shelton, and USAID Administrator concern for the apparent lack of congruence between review results and allocation of resources.
- The Board recommended that the TC and EEP use the "Criteria for resource allocation across country sites in Phase II" write-up by George Norton when determining resource allocation this year.
- The ME and the host country representative on the Board (currently Santiago Obien) will make set of criteria for choosing the Site Coordinator.
- The Board recommend that the Executive Committee (EC) of the Technical Committee (TC) consider inclusion of an external member. Also, the EC could rotate out one member per year to have continuity.
- The IPM CRSP, in order to fulfill its duty to consider cutting edge research, should consider transgenic plants at its various sites, to the limits of its resources with special consideration of projects with potential high impact.
- Collaborating scientists can be brought into the IPM CRSP to fill a particular niche, modality of arrangement can be decided on a case by case basis, and that scientist's activity with the IPM CRSP will terminate with that project.
- The Board agreed to send a plaque to Tom Payne to express the Board's appreciation for serving well for 5 years as Chair of the IPM CRSP Board.
- The Board concurred with the following changes: in Year 6 the EEP had a new member, Laurian Unnevehr (U. of Illinois), who replaced Mel Blasé, on the Board of Directors, Bob Moser replaced Tom Payne, Rick Bennett replaced Jennifer Sharp, and Tom Mew replaced Paul Teng. On the Technical Committee, N.S. Talekar replaced K.L. Heong.

Technical Committee

The IPM CRSP Technical Committee (TC) held several conference calls during the year and held its main annual meeting at Purdue University in West Lafayette, Indiana, on May 6-9, 1999. Technical Committee (TC) members who attended the Purdue meeting were:

Sally Miller, Site Chair, Asian Site in the Philippines

George Norton, TC Chair, and Site Chair, Asian Site in Bangladesh

Sam Kyamanywa, Site Coordinator Representative

Mark Erbaugh, Site Chair, African Site in Uganda

Brhane Gebrekidan, IPM CRSP Program Director

Greg Luther, IPM CRSP Assistant Program Director

N.S. Talekar, International Agricultural Research Center Representative

Charlie Pitts, Site Chair, European/Eurasian Site in Albania

Roger Williams, Site Chair, South American Site in Ecuador

Glenn Sullivan, Site Chair, Central American Site in Guatemala

S.K. De Datta, Principal Investigator, IPM CRSP

John Caldwell, Site Chair, African Site in Mali

Sue Tolin, Site Chair, Caribbean Site in Jamaica

Bob Hedlund, IPM CRSP Project Manager, USAID

Seymour van Gundy, Temporary External TC Member (Michael Irwin unable to attend).

The minutes for this meeting are available on request. In addition to the Technical Committee

members, many other IPM CRSP scientists gathered at Purdue to plan for the upcoming project year (IPM CRSP Year 7).

Major decisions made and motions passed during the meeting included:

- A transgenics issues committee was formed to prepare a document as a guide for the Site Chairs and other IPM CRSP scientists on this topic. Sue Tolin, N.S. Talekar and George Norton will make up this committee.
- A global training plan to further IPM institutionalization is being drawn up. This training document will cover the next 4 years.
- The list of the IPM CRSP Publications, Presentations, and Other Products of the IPM CRSP (available on request), and a summary of the totals for a variety of categories (Table 1).
- The IPM CRSP will decide what the probable funding base will be for the next 3 years, and then have a portion of the budget that is flexible for rewarding sites.
- It was agreed that the IPM CRSP must produce more scientific publications out of each site.
- The Executive Committee (EC) of the TC met before the TC Meeting and came up with a recommended budget to be a starting point for discussion amongst the entire TC as follows:

Starting Point Budget from Executive Committee	
Guatemala	$ 180,000
Ecuador	$ 155,000
Jamaica	$ 120,000
Philippines	$ 190,000
Bangladesh	$ 180,000
Mali	$ 130,000
Uganda	$ 195,000
Global Themes	$ 50,000

After much discussion, the TC adopted the EC-recommended budget as the budget for Year 7.

Table 1. Publications, Presentations and Other Products of the IPM CRSP
Cumulative Compilation through May 1, 1999

Category	General / Other	Albania	Bangladesh	Ecuador	Guatemala	Jamaica	Mali	Philippines	Uganda	Total
Papers Published in Refereed or Reviewed Publication	0	0	0	0	3	14	2	4	3	26
Proceedings	14	0	0	0	64	10	9	42	7	146
Theses And Dissertations	0	0	0	1	3	0	2	2	0	8
Papers/Seminars Presented	0	1	0	0	55	18	11	4	8	97
Abstracts	0	0	0	0	2	7	1	2	2	14
Electronic Presentations	0	0	0	0	0	4	0	0	1	5
Fact Sheets	0	0	0	0	0	1	0	0	3	4
Workshops	0	0	0	0	0	3	0	0	0	3
Newsletters	10	0	0	0	0	1	1	0	1	13
Extension Publications	0	0	0	0	4	6	1	0	0	11
Reports	27	4	4	11	123	105	63	91	40	468
IPM CRSP Annual Reports	5	0	0	0	0	0	0	0	0	5
IPM CRSP Working Papers	2	0	0	0	3	0	3	6	1	15
Germplasm Releases	0	0	0	0	0	4	0	0	0	4
Videotapes	0	0	0	0	0	1	1	1	0	3
World Wide Web Sites and Documents	2	0	0	0	0	3	0	0	0	5
Books/Book Chapters	0	0	0	0	2	0	0	0	0	2
Bibliographic Databases and Miscellaneous	0	0	0	0	0	0	0	6	0	6
Posters	1	0	0	0	3	11	0	1	0	16
Magazine and Newspaper Articles	0	0	0	0	1	0	0	0	0	1
Total	61	5	4	12	263	188	94	159	66	852

External Evaluation Panel (EEP) Reviews

The External Evaluation Panel (EEP) of the IPM CRSP conducted a review in Year 6 at Purdue University in West Lafayette, Indiana, on May 4-5, 1999. Members of the present EEP are Don Plucknett (Chair), Sonny Ramaswamy, Doug Rouse and Laurian Unnevehr. In addition to the meeting at Purdue, Ramaswamy visited and reviewed the Uganda site on December 12-22, 1998.

The complete report of the full EEP review at Purdue is available on request. However, the main points of this review are shown below:

Summary of the EEP report to the CRSP leadership.

- The Panel was worried about (i) **Too little money for the task**, and (ii) **Too many sites for the money**.
- An overriding concept that underpins the CRSP is that Participatory IPM is the major task of the CRSP, and that the CRSP has a major responsibility (i) to carry out Participatory Appraisals (including baseline surveys and monitoring studies) and (ii) that the PA process needs to be analyzed for lessons learned and publications prepared. In doing this, it must be remembered that getting IPM going in developing countries is the task of the CRSP, and the process involved in making it successful is important.

The Panel reviewed criteria prepared within the CRSP to assess the 'mature' (or 'maturing') sites – Jamaica, Guatemala, Mali and Philippines, plus Uganda which has had 5 years of operations. Criteria were: i) productivity, ii) impact (potential or demonstrated), and iii) overall management effectiveness. Using the criteria, the Guatemala, Philippines and Uganda sites rated high, while Jamaica and Mali did not.

Sonny Ramaswamy's full report on his Uganda review is available on request. However, his summary and recommendations sections are copied below.

1) Overall Observations

I was pleasantly surprised by how welcoming Uganda was and with the potential for excellent economic progress, especially in the agricultural sector. Uganda is a country poised to make dramatic gains in improving its lot, and the activities of IPM CRSP are very much in congruence with those of the National Agricultural Research Organization (NARO). Every one of the players involved in IPM CRSP appears to be *in synch*, supporting each other's research activities to the extent that significant returns are expected. A major contributor to such a state of affairs is the phenomenally congenial atmosphere amongst the various players and, especially, the very close working relationship of the Site Chair, Mark Erbaugh, and Site Coordinator, Sam Kyamanywa - the chemistry is perfect! Mark's and Sam's close working relationship has energized this site and is key to the close coordination of activities and the morale of the American and Ugandan scientists. Additionally, soliciting input from all site participants into experimental design, workplans, research accomplishments, etc., during an annual meeting is to be commended. The Ugandan IPM CRSP collaborators have a well-coordinated organizational structure with the leadership of Makerere University (MU) personnel. I was impressed with the dedication of the team members in this effort, but they have a daunting task in improving the lot of the average Ugandan farmer who farms small plots. The experiments planned or under way may be in jeopardy with the extended drought. The scientists are encouraged to develop contingency plans for greenhouse/laboratory experiments.

Every one of the administrators I met with at MU and NARO were of the opinion that IPM CRSP has been a tremendous synergist for the coordinated agricultural research activities pertaining to pest control within Uganda. The major refrain was that they are excited about the activities of IPM CRSP and wondered why they could not be extended to other commodities such as livestock and horticultural products. I heard similar responses from farmers in the Kumi and Iganga districts, suggesting that both stakeholders and clientele are appreciative and supportive of IPM CRSP activities. The Ugandan IPM CRSP team needs to be careful, lest it gets further over-extended by taking on additional commodities, exacerbating an already stretched-too-thin situation. My recommendation is that they not

undertake work with additional commodities at this time, unless they receive a significant increase in their operating funds.

Component research in several areas are being undertaken and integration of some of these various facets is also being undertaken. Transfer of technology is the next step. The IPM fact sheets, pest identification aids, workshops, etc. being developed will help in this effort. The Ugandans need to undertake these latter aspects at an accelerated pace. Additionally, I saw very little effort at determining the impacts of the IPM CRSP activities i.e., the participatory appraisal activities need to be followed continually. Especially since this site, like the others, is at the end of Phase I and the beginning of Phase 2, this is an opportune time to determine the impacts of the several years of IPM CRSP activities to allow the necessary adjustments for Phase 2. The Ugandans have capitalized only in part on expertise available at ICIPE and CIMMYT, and there is little evidence of inter-Site linkages, even within Africa. Such linkages need to be encouraged so that expertise available from within the IPM CRSP family may be used. The ME is encouraged to provide any help in these efforts.

My assessment of the situation in Uganda is that this site is at the verge of making a major contribution to the IPM effort in Africa. This assessment and optimism is shared by every one of the individuals I had the opportunity to visit with.

2) Recommendations

- All of the IPM CRSP scientists need to rapidly complete data analysis and publication of their research results. In this vein, several of the scientists complained they do not have access to computers for data analysis. IPM CRSP must make the effort to help alleviate this situation.
- Socio-economic analyses and cost-benefit analyses need to be undertaken to allow determination of the efficacy of IPM CRSP activities.
- Training opportunities at MU be considered for Malian and Eritrean students.
- Short term visits by Ugandan scientists and graduate students to US institutions for workshops and specialized training be encouraged.
- The IPM CRSP scientists associated with MU do not have a reliable vehicle to travel to work sites. They have ingeniously refurbished an old vehicle that is used for travel over long distances, but the safety and well being of the driver and riders are not guaranteed. I recommend that this site be allowed to purchase a used vehicle of more recent vintage.
- Graduate students being trained at MU are paid a stipend of $120 by IPM CRSP, compared with their cohorts who are paid $200 for work on similar projects being funded by other international agencies. Probably the most significant and lasting impact of IPM CRSP is developing the infrastructure and making available trained personnel. I recommend that IPM CRSP make the effort to equalize stipends being paid to their students with those of other students.
- African IPM CRSP scientists (from all three sites) have annual IPM workshops and symposia in conjunction with their efforts to develop annual workplans.
- The ME make every effort to increase the line of credit to $25,000 and hasten the reimbursement of bills submitted by the Site Coordinator.

Addition of 1890 Institutions

In Year 6 of the IPM CRSP, a fifth 1890 Institution was added to the program: Florida A&M University. Four other 1890 Institutions remain members of the IPM CRSP consortium. These are:

Lincoln University
University of Maryland, Eastern Shore
North Carolina A & T University
Fort Valley State University

Trip Reports for Year 6

Trip reports from Year 6 of the IPM CRSP totaled as follows:
Albania: 1, Bangladesh: 3, Ecuador: 1, Guatemala: 2, Jamaica: 4, Mali: 6, Philippines: 2, Uganda: 4. These reports are all posted on the IPM CRSP web site,
http://www.cals.vt.edu/ipmcrsp/index.html

Technical Assistance

A. Environmental Quality Laboratory in Mali

In Year 6, the Mali Site of the IPM CRSP began collaboration with the Environmental Quality

Laboratory (EQL) of Mali, to address needs in pesticide residue analysis, environmental monitoring, and development of a quality assurance program for agricultural products in Mali. The EQL, a part of the Central Veterinary Laboratory, has a comprehensive mandate that reflects the needs of Mali and the West African region for the analysis of pesticide residues on crops, food, and medicinal products, and in water, soil, and sediments. Data it will obtain on pesticide residues will assure the safety of agricultural products for home and market consumption in Mali and West Africa and for export to global markets that include the United States as well as Europe. These data will also serve as the base for the standardization of pesticides used throughout West Africa, the development of strategies for the selective use of appropriate pesticides in the subregion, and the development of educational programs to help vendors and farmers use pesticides in a safe and more environmentally sound basis.

The IPM CRSP worked with the EQL during the first half of 1999 to develop a program of collaboration and a corresponding proposal. Funding at a level of $530,000 for the five-year program was subsequently approved by the USAID/Mali Mission.

The new program began on July 17, 1999 with a four-week training and collaborative visit at Virginia Tech by EQL Director Dr. Halimatou Koné Traoré and EQL laboratory specialist Dr. Safiatou Berthé. During these four weeks, in collaboration with IPM CRSP scientist Jean Cobb and the staff of the Pesticide Residue Laboratory (Department of Biochemistry), Dr. Traoré and Dr. Berthé focused on techniques for residue analysis of deltamethrin, the principal pesticide used on green beans, the most important Malian export horticultural crop. Additional training in instrumentation was provided by staff of the Chromatography Laboratory (Department of Chemistry). Parallel to the laboratory work, Dr. Traoré and Dr. Berthé also interacted with Don Mullins and Pat Hipkins (Department of Entomology) and John Caldwell (Department of Horticulture) to learn about pesticide safety, quality assurance, and extension programs relevant to Malian needs.

B. Gall Midge Project in Jamaica

In Year 6 a proposal was written for Jamaica entitled, "National Strategic Plan To Combat The Gall Midge Complex Affecting Hot Pepper." It was subsequently approved for funding, with the USAID/Jamaica Mission supplying $45,000 and the IPM CRSP $45,000 for a two-year project.

The project commenced at the beginning of IPM CRSP Year 7 (September 29, 1999). The goal of this activity is to address fundamental issues surrounding the emergence of new pests, the gall midges *Contarina lycopersci* and *Prodiplosis longifilia*, and their impact on the hot pepper export market. There are six major components to this project: (1) Determine the biology and taxonomy, behaviour and ecology of the gall midge complex. (2) Develop an Integrated Pest Management strategy. (3) Improve post-harvest technology and its application for export fruits. (4) Transfer IPM technologies to farmers and extension officers. (5) Make the public aware of the importance of the gall midge complex. (6) Monitor and analyze the introduced IPM technologies.

Expected outputs of this project are: (1) Improvements in the quality and quantity of exportable and local hot peppers. (2) Development of IPM options for managing gall midge populations. (3) Improvements in the knowledge base of farmers in pest management. (4) Increased number of farmers/extension trained in IPM. (5) Knowledge of the relation of the gall midge with respect to phenology of the crop and agroecology.

Projected impacts are: (1) Reduced fumigation of exported produce, reducing the environ- mental hazard. (2) Increased hot pepper production, resulting in increased income to producers. (3) A tracibility system for hot peppers grown for export. (4) Improved coordination and information flow among persons within the hot pepper industry.

SELECTED IMPACTS FROM THE REGIONS

Africa-Wide

- In electronic based communications, closer collaboration among and between African and American scientists has improved.
- Increased networking opportunities for African scientists has been achieved.
- African IPM information hubs of AIL and IPM CRSP contact points will encourage researchers, NGOs, and the private sector to make their own information available to a greater number of African stakeholders.
- Maintenance and improvement of both the IPM CRSP and the AIL web sites continues to enhance information availability for researchers, extension agents, and NGOs which in turn is expected to enhance IPM knowledge transfer to farmers.
- Improved understanding by our African partners of the power of Email and the WWW for IPM information sharing and establishing contacts continues to improve their IPM knowledge base.

Mali

- In one of our trial sites in Mali, the use of yellow traps alone on thrips was the most profitable technology with net additional benefits of $4,443 per hectare compared to $4,233 per hectare for yellow traps plus neem. At a second location near Bamako, however, the use of yellow traps and neem oil had a higher net additional benefit than the use of yellow traps alone

- The combination of sticky traps and neem in green beans production is comparable to the farmers' standard practice, two applications of Decis, in levels of insect control, amount of pod damage, and yields.

- In the first 4 years of this project, we identified a local (harvestable within each village) natural product with pest management potential in preharvest and postharvest IPM systems in the Sahel and near-Sahelian areas of Mali. We have tested by-products of the plant *Azadirachta indica* and developed several formulations appropriate for use in villages in Mali

- A gender difference with implications for insect and disease IPM was found in a preliminary survey, with men responsible for the application of insecticide, while watering primarily done by women and children..

- Continued experiments on a potentially useful new strategy for the integrated control of *Striga* in sorghum and millet. The herbicide prosulfuron appears to have the characteristics to be effective in the control of *Striga* and initial results are encouraging.

- The development of national capability in the Environmental Quality Laboratory (EQL) to analyze pesticide residues will assure the safety of agricultural products for home and market consumption in Mali and West Africa and for export to global markets that include the United States as well as Europe. Our EQL collaborative work will serve as the base for the standardization of pesticides used throughout West Africa, the development of strategies for the selective use of appropriate pesticides in the subregion, and the development of educational programs to help vendors and farmers use pesticides in a safe and more environmentally sound basis. The program will also develop a pesticide monitoring system for sampling and analysis of pesticides on agricultural products. This will begin with priority crops for export (green beans, hibiscus flowers, and mango) and local

markets (tomato and lettuce). Through this new collaborative program in partnership with USAID and the IPM CRSP core research program, the EQL will not only acquire the technical skills needed to address pesticide residue analysis needs in Mali, but it will also develop the capability to serve as the premier laboratory of its type in West Africa

Uganda

- A survey of maize diseases in Uganda demonstrated the importance of gray leaf spot (GLS). Our gray leaf spot research efforts have potential for impact both in Uganda and the United States. Perhaps the best example from the Uganda site is the work being done on identifying genetic resistance to gray leaf spot, the number one foliar disease of maize in Uganda and in the US corn belt. We identified GLS resistant germplasm with acceptable agronomic performance in both Ohio and Uganda.

- Bean grain yields on seed dressed and earthed-up plots were demonstrably higher compared to the untreated bean plots, resulting in adoption of seed dressing technology by farmers in groups we have been working with. To ensure that the technology is disseminated on a larger scale, this technology has been passed to the IDEA Project (IDEA is a USAID funded project). IDEA is now conducting nation wide demonstration trials for bean growers. IPM CRSP and IDEA have produced a fact sheet and posters for use by extension workers. It is hoped that adoption of this technology will boost bean production in the region, leading to reduction in malnutrition and poverty.

- The study has that shown *C. partellus* is the most important stem borer of maize and that its parasitoid *Cotesia flavipes* has established itself in Iganga and Kumi. Therefore, the parasitoid is likely to reduce the damage by *C. partellus* and increase maize yield.

- An integrated management option consisting of a of tolerant sorghum variety, Seredo, modest fertilizer application, two hand weedings and interplanting with *Celosia argentia* can minimize the impact of *Striga* parasitism on sorghum. Economic analysis indicates the use of fertilizer is economic only on the improved sorghum variety. We have confirmed that *C. argentia* indeed influences *Striga* emergence and subsequent sorghum grain yield. In 1999, IPM CRSP Uganda worked with farmers and confirmed that *C. argentia* can suppress *Striga* in farmers' fields and the farmers of Kumi district have expressed interest to use it.

- The aggregate economic impact of IPM technologies has been assessed using partial budget analysis and economic surplus methods for Uganda. The Maize variety Longe-1 and seed dressing for beans are being evaluated. From preliminary results of the partial budget analysis, all treatments give higher net return than the farmers' practices.

Guatemala

- If open market supply channels implement the same production and post-harvest handling practices as the grower-shipper and contract producer supply channels, practices that are consistent with U.S. Good Agricultural Practice guidelines, the volume of snow peas culled would be reduced and the cost per unit of snow peas exported would decrease. It is also likely that the adoption of these practices would play an important role in maintaining and increasing access to North American markets by preventing future FDA detentions and events such as the snow pea-leaf miner crisis. In turn, this change would increase net operating profit for exporters and increase economic sustainability at all levels. Therefore, this research concludes that snow pea producers and exporters would benefit from an industry-wide implementation of uniform production and post-harvest handling

practices which are consistent with U.S. Good Agricultural Practice guidelines.

- The establishment of an effective quality control program for snow peas that will guarantee 1) the quality of the product to the final consumer, and 2) the sustainability of the snow pea industry in Guatemala are main impacts of the IPM CRSP research. In addition, it is expected that in the next 2-3 years the majority of Guatemalan snow pea exporters will implement the IPM CRSP-generated ICM production guidelines.

- Papaya ringspot potyvirus (PRSV) has not been officially detected in Guatemala, as it does not appear in the listings of the International Regional Organization of Plant Health (OIRSA). As is the case in many developing countries, the presence of important plant diseases has not been detected. Growers, even though they may be familiar with the symptoms, do not know how to deal with such diseases and incur severe losses. The detection and quantification of important plant diseases such as PRSV represents the first step in the development and implementation of appropriate IPM programs for many non-traditional agricultural export crops, including papayas.

- Although still in the initial stage in the development of a massive rearing procedure of the parasitoid *Diglyphus*, a fundamental aspect of this process was achieved, as snow peas, common beans and green beans were determined to be suitable hosts for leaf miner larvae colonization. These larvae are to be utilized as hosts for the parasitoid, during the breeding process being developed at ICTA's experimental station in Chimaltenango. The long-term impact of this study will be to release vast numbers of *Diglyphus*, as a biological control for the snow pea leaf miner, *Liriomyza huidobrensis*.

- The integrated technology of three or more management tactics (seedlings in transplant plugs, sorghum barriers, yellow plastic traps, and rational use of chemicals) were effectively validated as white fly management tools in tomatoes grown in Guatemala in the control of the white fly viral complex. Revenues were increased, mostly derived from increased yields and reduced variable costs associated with insecticide applications.

- The use of plastic screens of a 50-mesh size, incorporated into the previously developed integrated management for white flies in tomato, had the following effects: a) substantially reduced adult white fly populations; b) significantly reduced the incidence of viral diseases; c) reduced the variable costs compared to the farmer' technology; d) increased the yield and profitability; and e) reduced the number of insecticides' applications.

- The IPM CRSP work has demonstrated that there is a higher response to the optic stimulus that yellow traps produce on the populations of leaf miner (*Liriomyza huidobrensis*), compared with the attractive stimulus of the pulp of fruits. The populations of adults were not different in the treatment with insecticides, compared with the use of traps, which confirms that non-chemical alternatives can be incorporated in the integrated pest management of snow pea. The use of yellow plastic traps with a sticky agent should be used in the crops where the leaf miner is considered as an economically important pest, since it is an affordable practice that reduces insecticide use and does not present risks of contamination to the environment.

- Strip cropping becomes an attractive option for farmers in the highlands of Guatemala. The diversification of crops will favor the long-term sustainability of these export crops and locally marketed vegetables, as well. In addition, the higher diversity will promote the build up of the natural control and help maintain pests at manageable levels. The existence of a healthy agroecosystem will also

prevent the emergence of new primary pests, and better natural control of existing pests. Our results suggest that the Integrated Crop Management (ICM) strategy devised by the IPM CRSP in Guatemala is applicable to multi-crop systems, such as strip-cropping. The ICM strategy increases the economic benefits to the farmer, as profit margins are increased due to reduced usage of chemical pesticides.

- The past year's IPM CRSP research results suggest that new cultivars such as SP 18 or SP 517 may effectively replace Oregon Sugar Pod II as the primary seed material for snow peas grown in Guatemala. However, the experimental line SP 6 could also meet productivity criteria if plant density and yields can be increased. An added attractiveness of SP 6 is the lower numbers of leaf miner larvae it supports, in contrast to the other tested cultivars. Results indicate that SP 6 may be an acceptable cultivar for snow pea production in areas heavily infested with *L. huidobrensis* or, during the dry season when high leaf miner populations are common in the Guatemalan Highlands. Cultivar options other than Oregon Sugar Pod II (in terms of productivity and attractiveness to leaf miner infestation) will prove valuable to farmers and the snow pea industry as a more diverse genetic background in the field should decrease the risks for future pest outbreaks.

- In Guatemala, in ancient times, there was a different knowledge base and specific techniques used for management of pests in crops. Interviews with farmers suggest this knowledge and these practices may allow small producers to maintain sustainable agricultural production for rural families. IPM CRSP surveys indicated that farmers using these practices rely on their own farm-based resources, while maintaining the rich soil. These surveys will insure that much of this knowledge will be rescued, documented, and validated in future research as to its potential for use and incorporation into Integrated Pest Management programs for NTAE crops.

Ecuador

- The addition of sugarcane bagasse and bagasse + ash appears to reduce soil nematode populations. Because some lepidopteran pests are attracted to fresh bagasse it may be possible to apply microbial control agents to the bagasse and thereby achieve some measure of control.

- If *Fusarium oxysporum* in babaco is detected early, a single application of propiconazol alternated with carbendazim could eradicate the disease. It is suggested that the fungicide be applied to apparently healthy plants in the vicinity of diseased plants. Where the disease is established, a combination of eradication of infected plants and fungicide application is recommended.

- Research on soil-borne diseases in potato has been neglected in Ecuador. Most of the farmers do not use cropping plans, crop rotation is reduced and the frequency of potato, an important cash crop, is often high. Elucidating the nature of these diseases, and their role in potato production will help formulate a management strategy for increasing productivity through higher production and improved tuber quality. At this time, only one mating type of the late blight pathogen *P. infestans* is known to occur in Ecuador. IPM CRSP research is designed to demonstrate if any changes have occurred in this situation.

- In Chimborazo the IPC 2 clone 95-9-1 with horizontal resistance was selected by local growers as the most promising selection. The IPC 3 clone P-84-1 was selected as the clone with vertical resistance that had the highest probability of acceptance by local growers. In Carchi clones 95-68-3 and 95-8-2 were selected as the best clones with horizontal

resistance and CHP-3 was the best clone selected by growers with vertical resistance.

- The damage level in the check only reached 12.7%. The nucleopolyhedrosis virus provided a greater effect; only 1.37% of tubers were damaged. The infestation procedure of the stored tubers, by means of adults of *Tecia* will have to be reviewed in order to obtain a better development of the insect population. The use of biological control for *Tecia* will allow potato farmers in Ecuador to avoid intoxication problems and to obtain economical insect control during storage of seed pieces.

- A model is being developed for the geographic region where the potato IPM work is underway on the IPM CRSP. It is proposed that reductions in pesticide use be measured or projected due to generation and adoption of IPM technologies on potatoes and that these pesticide use changes be fed into the bio-economic model as a scenario, with modifications made to the model as needed. It is further proposed that the per unit cost reductions measured or projected due to IPM CRSP technologies be combined with measured or projected information on adoption and included in an economic surplus model to generate aggregate benefits. All changes in input use, outputs, and prices are being measured for each of the CRSP experiments. This information will be used to help generate per unit cost changes.

Jamaica

- Callaloo production is currently heavily reliant on pesticides because its marketability is dependent on the aesthetics of leaves, which are attacked by several voracious herbivorous arthropod species. With the growing concern among consumers globally about pesticide residues on food, non-chemical methods of pest control would give a competitive advantage to this commodity. Exclusion of major pests by using a mesh barrier was demonstrated in earlier trials to be very effective. Other horticultural considerations such as optimal light requirements and the selection of cost-effective screens will provide valuable information for the development of this technology in order to produce callaloo economically in a protected agriculture system.

- Callaloo farmers spray their crop once weekly mainly as a prophylactic treatment against lepidopterous pests. This practice is probably the major contributor to the eroded efficacy of most contemporary pesticides. The introduction of any new chemistry without the implementation of a resistance management program would only again result in insecticide resistance and the cycle would continue. The sampling plan used by the IPM CRSP shows the potential to indicate economic pest population levels and thereby guide farmers in timing spray applications. The development and implementation of this sampling plan was a fundamental step to minimizing pesticide use in callaloo production systems and guiding the sustainable use of new biorational chemistries now available to control lepidoptera species on leafy vegetables. Synthetic pesticides currently being used on callaloo in the management of major pests, mainly lepidoptera species, fail to give adequate control despite frequent applications. It is unlikely that any developed IPM strategy would exclude the use of pesticides, therefore, the selection of more effective chemistries is critical to the successful implementation of IPM. Two biorational pesticides used in our trials trials, viz. spinosad and tebufenozide are registered for use on leafy vegetables and are therefore ready candidates for use with the developed sampling plan.

- Previous IPM CRSP-funded research conducted at the U.S. Vegetable Laboratory has shown that none of the *Capsicum chinense* cultivars currently available to U.S. and Jamaican farmers are resistant to the southern root-knot nematode. This nematode is a severe pest of this pepper species and the utilization

of resistant cultivars would be the ideal way of addressing the problem. The previous research resulted in the discovery and release of three southern root-knot nematode resistant Scotch Bonnet-type germplasm lines. The results available so far indicate that the utilization of classical plant breeding methods can be used to quickly incorporate southern root-knot nematode resistance into *C. chinense* cultivars. The Habanero has become a popular pepper in the U.S., and the availability of a root-knot nematode resistant Habanero cultivar would provide U.S. growers an alternative to the use of soil fumigates to control root-knot nematodes in Habanero plantings. West Indies Red is a leading processing cultivar in Jamaica, and a root-knot nematode resistant version of this cultivar should be a valuable tool for use in any IPM program designed to control pepper pests in Jamaica.

- The peanut root-knot nematode is a potentially a major pest of pepper. Parasitism of susceptible cultivars results in severely stunted plants and significantly reduced yields. The ideal method to control this nematode in *C. chinense* plantings would be to use resistant cultivars. The results of this study indicate that a single dominant gene conditions the high level of resistance to the peanut root-knot nematode exhibited by the *C. chinense* germplasm line PA-426. This finding confirms the results of the inheritance study conducted in 1998.

- Hot peppers (*C. chinense*) are very popular in the Caribbean market and have become increasingly important as an export crop to the U.S.A. and other countries. Root-knot nematodes (*Meloidogyne* spp.) cause severe yield losses in pepper worldwide. The loss of many nematicides from the market and increased public awareness of the environment has focused interest on the use of host resistance, if available, for managing root-knot nematodes in vegetable crops. Thus, the root-knot resistant Scotch Bonnet-type pepper lines PA-353, PA-398, and PA-426 should be a useful component of an integrated pest management system for hot pepper.

- Towards developing a viable and sustainable hot pepper industry in Jamaica, current production technologies from Jamaica and the Eastern Caribbean were successfully introduced into selected parishes in Jamaica. Economic returns from producing hot pepper with the recommended technologies demonstrate that pepper is a lucrative crop for small farmers.

- In 1998, high gall midge interceptions crippled the hot pepper industry in Jamaica, resulting in the enforcement of mandatory fumigation as a condition of entry of the product into US markets. This prompted the several responses, many of which were lead by the IPM CRSP team. The development of a IPM strategy to reduce infestations was the focus of the activities and included both pre and post harvest investigations. During the past 12months, it was demonstrated that the use of cultural practices in combination fipronyl or imidacloprid suppressed populations of the gall midge complex below a 5% threshold for at least 3 weeks. These results are being used in technology transfer programs being conducted by RADA. The ultimate release of a cream or dry fleshed sweetpotato cultivar with resistances to root-knot nematodes, Fusarium wilt, and insects will address some of the major constraints facing the sweetpotato industries in the USA and Jamaica.

- Findings offer CRSP researchers and cooperating extension specialists an opportunity to better serve needs of all farmers who produce target crops and make relevant pest management decisions, regardless of gender. Increased adoption of IPM should result, enabling related improvements in farm income, health, and resource-base sustainability. Women appear to be differentially constrained with respect to IPM adoption, as they may have less access to CRSP project activities and related extension

than men may. This is particularly problematic, as women produce targeted crops and make pest management decisions, but may have less knowledge of pests than men. Women are unlikely to face differential labor constraints owing to potential IPM adoption.

Philippines

- Our data confirm results obtained in year 5 in the Philppines, showing that one herbicide application followed by one hand weeding can provide sufficient weed control with no significant reduction in yields. The total cost of weed control can be reduced by 50-60%, which means a lower cost of production and thus increased profits for farmers. As a benefit to the U.S. this study provides comparison of chemical and cultural methods of weed control in the tropics vs. purely chemical methods in the U.S.

- The occurrence of *C. rotundus* in both onion and rice crops poses more problems to farmers. Results of our study show morphologic and genetic variations between the upland and lowland ecotypes of *C. rotundus*. Our observations in this study will be used as a basis in the development of management strategies to control *C. rotundus* in rainfed rice-onion systems. The lowland and upland types of *C. rotundus* may respond differently to herbicide treatments, hence, cultural management strategies have to explored to manage the weed.

- It has been shown that NPV and Bt can be viable alternatives to chemical insecticide use. Thus, it would greatly benefit onion farmers who are dependent on chemical insecticides for control of cutworm. Direct effects are reduced pesticide use, better health of farmers, and sustainable *Spodoptera* management. In addition, farm-produced NPV will cut down on cost of crop protection by farmers. As a result, the market quality of their onion produce will be greatly enhanced by their low insecticide residue levels, thereby meeting the export requirements of foreign markets.

- The impact of our study shows the great possibility of drastically reducing, if not totally eliminating, insecticide use in eggplant fields, by replacing it with properly timed removal of damaged shoots and fruits, together with the already existing sanitation measures (disposal of damaged fruits from the field) which the farmers are assumed to be doing now, along with the harvesting schedule of farmers. Where before, insecticide spraying could be as high as 40 times in a 5-month crop, it is now possible to reduce it to 7 times (every three weeks). In this regard, the effect is tremendous in terms of improved environmental quality and savings attributed to insecticide use. The labor costs of removal are eventually incorporated into the labor cost for harvesting.

- Correlation studies showed that leafhopper counts, leafhopper damage rating, fruit yield and trichome density are good and reliable parameters. Jackpot, a commercial variety, is considered tolerant because it yields high in spite of the higher leafhopper damage at vegetative stage. The use of resistant or tolerant eggplant varieties is a promising alternative to reduce crop loss, increase farmer income and reduce pesticide use as shown by the differential varietal responses of several eggplant varieties against the leafhopper.

- The potential of non-chemical management strategies like plant antagonists, biological control agents, and animal manure against nematode, pink root and bulb rot pathogens were identified. The use of antagonists against damping off pathogens may be feasible with the discovery of *Trichoderma* species that are very effective and suppressive. While we understand their limitations these biological control agents should be tried in the field especially during the seedling stage of onion. Their use should compliment the use of chemicals. Continued efforts must be made in discovering other antagonists especially from

other organic waste materials and in soil rich in organic matter.

- Our study showed that planting non-host crops of *Phoma terrestris* in rotation with onion can significantly reduce the disease pressure resulting in low incidence and severity of pink root infection. However, crop rotation did not seem to be effective against the root-knot nematode.

Bangladesh

- Baseline data are required to understand the suite of socio-economic factors that influence crop production patterns and practices, pest perceptions, pest management practices and potential constraints to IPM adoption. These data can be used to compare practices of different sites, which can be useful for planning and targeting of extension and training efforts. These data can also be used to retrospectively assess the project impacts. The findings of the survey contributed to understanding of the incidence pattern and status of pests attacking rice and winter vegetables in rice based vegetable cropping systems. The results also helped to identify some appropriate researchable issues in order to develop management technologies.

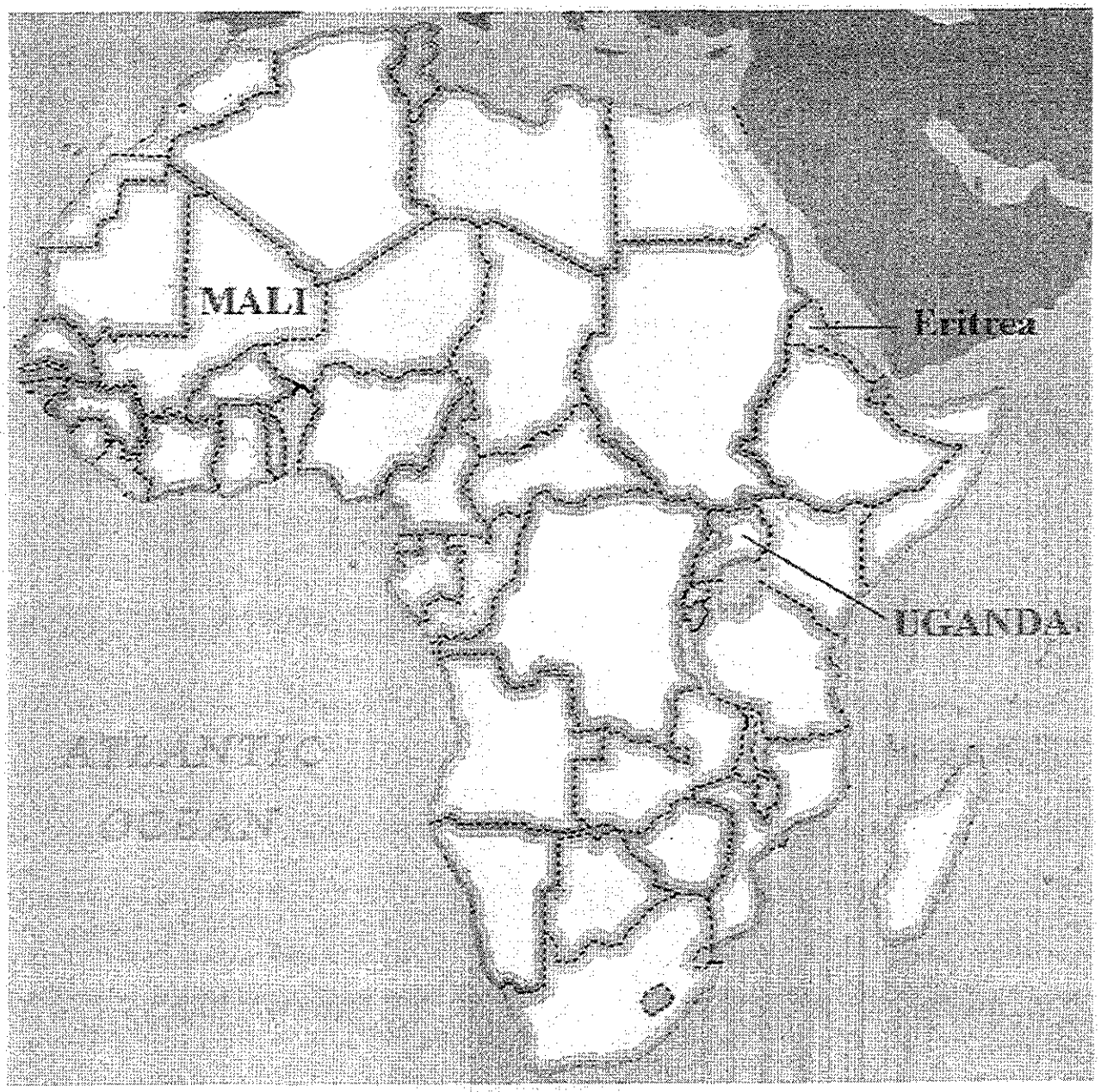
- Our overall results so far indicate that the test eggplant varieties we have tested possess genetic variability for resistance /tolerance to bacterial wilt, root-knot nematode and fruit and shoot borer. Test of traditional and exotic varieties against these pests may lead to the identification of resistant sources, which may be used for developing agronomically acceptable resistant varieties.

- Results so far obtained suggest that the lure traps can capture considerable number of cucurbit fruit flies and thereby reduce the natural populations of fruit flies. Using this technique the use of chemical pesticides can be greatly minimized, which will ultimately contribute to production of healthy, pesticide free cucurbits.

- Our results showed that farmers adopted weed control measures to keep their okra fields free of weeds without considering the crop growth stage when weeding was most critical to minimise yield loss. As a result, frequent weeding operations increased the cost of cultivation. On the other hand, two hand weeding at 15 and 35 days after planting, which coincided with the critical active growth stage of the crop effectively controlled the weeds, minimised weeding cost and produced satisfactory yield that brought about better economic returns.

- Our first season experimental results also showed that, among the various soil amendment treatments and chemical control, soil incorporation of mustard oil-cake in eggplant field can effectively minimize nematode infestation and plant mortalities due to the infection of various soil-borne diseases, and can produce higher yield. This will also help to reduce the residues of chemical fungicides in the food chain.

- Soil incorporation of poultry refuse alone or in combination with fungicide and nematicide applications can effectively minimize leaf blight and nematode infestation and can promote the growth of bunching onion producing significantly higher yield. Since poultry refuse is abundant and much cheaper, farmers can use it to obtain more profits from the cultivation of bunching onion. Sawdust burning and soil incorporation of poultry refuse + sawdust burning in cucumber planting beds were highly effective in reducing pre- and post-emergence deaths of cucumber seedlings, promoted the growth of cucumber plants and produced 1.5 times more yield. This practice can reduce pesticide use minimizing its residues in the food chain.



AFRICA

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Mali Africa Site Year 6 Research Program Overview

Site Chair: J. Caldwell[1]
Site Administrative Coordinator: B. Dembélé[2]
Site Research Coordinator: Gamby K. Touré[2]

Introduction

The primary focus of the Mali Africa site in Year 6 was participatory on-farm research on IPM technologies for management of disease and insect pests of the two most important horticultural export crops, green beans and hibiscus. Both economic and gender implications of these technologies were examined in assessing results and research directions. This research was complemented by on-station research on biological control of the key insect pests of hibiscus, and innovative approaches to management of Striga parasitic weed on millet and sorghum, the principal cereal crops of Mali. A major new effort was begun to provide support to pesticide residue analysis and develop a Quality Assurance System for Malian horticultural products. Regionalization of phase I technologies developed for pest management in cereals was also carried out.

The on-farm research was conducted in two villages near the capital city of Bamako and within an hour of the airport from which green beans are exported to France. Two sets of trials were conducted, each with five farmers per village: trials comparing IPM practices and farmer insecticides for control of the insect complex on green beans, and trials comparing IPM and farmer practices for control of green bean seedbed diseases. In this first year of research on horticultural export crop pest management, IPM components are being developed independently, to provide the basis for subsequent combination into packages that address different pest problems simultaneously.

IPM alternatives for green bean insect pest management.

Results of on-farm testing for control of the insect complex on green beans showed that IPM management practices combining yellow traps and targeted application of locally-prepared neem extract reduced populations of thrips (*Megatothrips* sp.) and resulted in yields equivalent to the use of insecticides common in the region. These results confirmed hypotheses established prior to the research. Economic analysis showed the use of yellow traps alone was the most profitable technology for each village and also for the average of the two. The use of yellow traps in controlling insects on green beans was more cost-effective one or two applications of Decis, commonly used by farmers.

Yellow traps had an average net benefit of $4,718 / ha. At average yields of 15 metric tons / hectare, the 600 metric tons of green beans exported to France last year would translate to an estimated 40 hectares of production. The total potential net benefit of this technology is nearly $190,000. The reorientation of the Mali site in phase II of the IPM CRSP is already showing strong potential economic impact.

New IPM solutions for green bean seedbed disease management.

The level of disease incidence in on-farm trials for control of green bean seedbed diseases was low in 1998, and IPM treatments did not have effects on seedling emergence, the number of plants per hill, or disease incidence at any location. However, well-decomposed compost resulted in a 26% increase in yield compared to the farmer's compost. Overall, farmers' compost reduced yield 18% relative to the mean yield of other treatments. At the Baguineda research station, yield with farmers' compost was less than half yield of plots which were solarized or treated with a botanical product prepared from the local plant *Longocarpus* spp.

Laboratory research laid groundwork in 1998 for future on-farm testing of additional IPM disease control measures. Soil was collected from several fields in the trial villages, the biocontrol agent *Trichoderma* spp. successfully isolated from these samples, and propagation for inoculation into compost begun. Analysis of farmers' and well decomposed compost were negative for *E. coli*, a potential contaminant of the green beans.

Gender implications of green bean pest management.

A preliminary survey revealed that men are responsible for the application of insecticide, while mainly women and children do watering. Overall, owners of the farm irrespective of gender carry out production and marketing activities. These findings, if confirmed with a larger sample,

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suggest that disease management trials need to involve women in assessing the practicality and benefits of changes in water management, while insect management trials may involve men more than women.

Potential biological control for hibiscus insect pest management.

Research on potential candidates for biological control on hibiscus insect pests was was carrried out by IPM CRSP-supported graduate student Moussa Noussourou, as part of an M.S. thesis at the University of Mali. Prospections of farmers' fields around the Baguineda horticultural station and an observational plot at the Baguineda horticultural station identified 16 above ground entomophagous of insect pests of *dah*. Non-choice feeding studies with 9 predators of *Nisotra* spp. identified three predator species (all Reduviidae) with promising rates of consumption (> 3 *Nisotra* spp. / day).

A new, innovative approach to *Striga* parasitic weed management.

The innovative approach to *Striga* management at the Mali site involves the use of herbicide as the near-equivalent of a vaccine against the parasitic weed. Provided that the crop have sufficient tolerance to the herbicide to germinate and grow normally while retaining a small amount of herbicide in its system, the parasite attaching itself to this crop will accumulate quantities of the herbicide that result in inhibited parasite growth. Screening of Malian sorghum and millet varieties determine their relative tolerance to the selected herbicides identified 'CSM 388,' a very susceptible to *Striga* parasitization, as most tolerant to herbicide coatings. The herbicide prosulfuron was identified as a promising candidate for effective use for seed treatment.

Enhancement of pesticide residue analysis capabilities for quality assurance.

The capabilities of the Environmental Quality Laboratory (EQL) of the Central Veterinary Laboratory were increased, and a comprehensive five year plan to make it functional for a wide range of pesticides was prepared. The plan will create a Quality Assurance Program linking research and education, agriculture and consumers, and economic growth and environmental safety.

Initial collaboration with the EQL begin to build information needed for the Quality Assurance System, and to develop sampling and analysis capabilities for the most critical pesticide residue needs. A list of pesticides used in Mali was prepared. Standard Operating Procedures were developed for sampling soil and water, and for handling and storage of these samples. A workable bioremediation plan was devloped for managing laboratory chemical wastes. Initial extractions were performed to analyze DDT in water and to test for deltamethrin in green beans.

In a four-week training program, the director and principal resident scientist of the EQL developed skills in preparation of gas chromotography standards from 6 formulated pesticides; injection of organochlorine and organophosphorus pesticides on a gas chromatograph; calculation of standard dilutions; extraction of green beans fortified with deltamethrin using matrix solid phase dispersion; and extraction of soil samples and calculations of percent recovery from fortified soil samples.

Initiation of regionalization.

Several regionalization activities were carried out for phase I results. A training-of- trainers activity and farmer workshop was held with World Vision in San, in eastern Mali. Participants included farmers, World Vision technicians, agricultural field technicians, and IER scientists. This effort had an inter-CRSP aspect. Results of IPM CRSP research in Mali was presented, whle a demonstration of the construction of solar heaters and triple bagging storage was given by the Bean Cowpea CRSP-Cameroon. Another regionalization effort involved identifying other economic uses of the presses used to prepare neem extract with the manufacturer of the presses, an NGO, and Appropriate Technologies, Inc. (ATI). A poster series was developed to visually convey information about the breadth of use of the products of the neem tree for use in a future interCRSP series on seed protection.

Targeted Insecticide Application, Yellow and Blue Traps, Soap, and Neem for Control of the Insect Complex on Green Beans

Investigators: Gamby K. Touré[1], M. Noussourou[2], and R. Foster[3]
Collaborating scientists: Sissoko H. Traoré[1], J. S. Caldwell[4] and A. Yeboah[5]

Abstract

Vaseline on yellow or blue plastic and locally-prepared neem extract applied at flowering were compared with 1 or 2 applications of farmer-used synthetic insectides 'Sumcomby' (a fenitrothion / fenvalerate combination), or 'Decis' (deltamethrin) on 10 farmer's fields in two villages and at the Baguineda research station. Population densities of thrips (*Megatothrips* sp.) declined following pesticide applications, with significantly greater reductions in all treatments compared to the untreated control. Overall yields were lower in the untreated control than in the other treatments, with no significant differences between yields among IPM or synthetic insecticide treatments. At the Baguineda station, insect populations in treated plots were significantly lower than the untreated control 24 and 48 hours after treatment. At harvest, plots that received two applications of Decis had significantly less damage than the untreated control or one application of Decis, but were similar to IPM treatments. Yields of all treatments were significantly different from the control and plots treated with Decis had higher yields than those with traps. Blue sticky traps consistently caught more thrips than yellow sticky traps. Thrips population densities peaked at 50% flowering and stayed at high levels until the start of pod formation.

Objectives

1. To evaluate the effect of reduced insecticide, soap, neem, and yellow and red sticky traps on aphids, thrips, whiteflies and *Mylabris* spp. blister beetles on green beans;
2. To compare the effectiveness of two methods of preparing neem extract.

Green beans are the primary export horticultural crop in Mali. Aphids (*Aphis cracewora*), thrips (*Megatothrips* sp.), white flies (*Bemissia tabaci*), and *Mylabris* spp. are the principal insect pests of green beans. Farmers use the insecticide 'Decis,' at varying frequencies ranging from 2 to 6 times over the season on green beans. Reduction in pesticide use could reduce costs for farmers, and identification of alternative control measures not based on synthetic insecticides could help Malian farmers gain access to organic markets.

Research Methods

Five treatments were compared on 10 farmer's fields, 5 in Koren and 5 in Sanambele, near Bamako. Seven treatments were compared at the research station at Baguineda. The treatments in the farmer trials were:

(1) Control (no control measures);
(2) Vaseline on yellow plastic, insecticidal soap applied as needed and neem applied at flowering;
(3) Vaseline on yellow plastic, Sumcomby insecticide (supplied by exporter) applied at flowering;
(4) Two applications of Decis (farmer practice);
(5) One application of Decis at flowering.

Yellow plastic traps (750 cm^2 area) was covered with a 1:12 mixture of solid and liquid vaseline and placed in the center of a 5 m long row for control of leafminers, thrips, and whiteflies. Numbers of thrips on the traps were counted weekly at the seedling and flowering stages. No significant infestations of aphids or whiteflies were observed. Insecticidal soap was not used because aphid population did not warrant application. Neem, Sumcomby, and Decis were applied for control of thrips and blister beetles. Thrips population densities were assessed 24 hours before and 48 hours after pesticide applications.

Individual experimental units consisted of small areas (ca. 1 X 2 meters) with 40 to 70 plants per plot. Plots were planted in mid to late November, 1998 and harvested in mid

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January, 1999. Each of the five treatments was represented once at each farm, so the experiment was arranged in a randomized complete block design with farms as blocks. At harvest, beans were graded for damage, which could be caused by insects, diseases, vertebrate herbivores, or physiological factors. Yields of undamaged beans were determined for each plot.

The seven treatments evaluated at the research station at Baguineda are:
(1) Untreated control
(2) Yellow sticky traps
(3) Blue sticky traps
(4) Yellow sticky traps + Neem
(5) Blue sticky traps + Neem
(6) One application of Decis
(7) Two applications of Decis

The experiment was arranged in a randomized complete block design with four replications. Individual experimental units were 5 m^2. Insect densities in the plots were determined 24 hours before, 24 hours after, and 48 hours after insecticide treatment. At harvest, the percentage of pods with damage and the yield of undamaged plots were determined.

Results

In the farmers' fields, thrips populations declined in all plots following pesticide applications, probably as a result of plot to plot movement of the adult thrips. Reductions in thrips densities were significantly greater in all treatments than in the untreated control. All treatments provided similar levels of control. At harvest, there were no significant differences in the percentage of pods that were graded as damaged. Overall yields were lower in the untreated control than in the treatments, with no significant differences between yields among the four treatments. However, when yield was expressed on a per hill basis, the yields in the plots that received a single application of Decis were significantly lower than the other treatments. Orthogonal comparisons showed that except for percentage damaged pods, the untreated control was significantly different than the four treatments. The Decis treated plots were similar to the plots with traps for all variables. Neem plots were similar to plots treated with Sumcomby for all variables. Two Decis applications provided superior control than a single application. The increase in economic returns relative to the control from IPM treatments were greatest in plots treated with yellow sticky traps and neem and plots treated twice with Decis. Benefits of IPM treatments were greater at Koren than at Sanambele or Baguineda.

At Baguineda, insect populations were similar in all the treated plots and all were significantly lower than the untreated control 24 and 48 hours after treatment. When the percentage reduction from the pretreatment counts was determined, only the plots that received two application of Decis showed reductions significantly greater than the untreated control. At harvest, the plots that received two applications of Decis had significantly less damage than the untreated control or one application of Decis, but were similar to the other treatments. Yields were not significantly different. Orthogonal comparison showed all treatments to be different from the control and plots treated with Decis had higher yields than those with traps. Two applications of Decis resulted in less damage than one application. There were no differences between yellow and blue traps, and the use of Neem seemed to have little effect on the level of insect control achieved. Blue sticky traps consistently caught more thrips than yellow sticky traps in the study at Baguineda (Fig. 6). Fig. 7 shows that thrips population densities peak at around 50% flowering and stay at high levels until the start of pod formation. After pods have started to form, thrips populations diminish, probably because of the presence of fewer flowers for them to feed on.

Discussion

The results of the first year's data are very encouraging. In virtually all measures, the combination of sticky traps and neem is comparable to the farmers' standard practice, two applications of Decis. The levels of insect control, amount of pod damage, yields, and economic returns compare favorably. Although these data only represent one year's research and need to be corroborated with data from additional years, it appears that the use of mechanical control (sticky traps) and neem will allow growers to forego the use of synthetic organic insecticides without sacrificing yield or quality. This will allow growers to provide green beans for export that are free from residues of synthetic pesticides.

In the 1999-2000 growing season, additional data need to be collected to verify that the IPM practices will provide acceptable control under different conditions. It needs to be determined if the absence of significant aphid and whitefly populations was unusual, or if these two pest groups are only minor problems. More work needs to be conducted to compare the relative effectiveness of yellow and blue sticky traps. The preliminary studies showed more thrips being caught on blue traps, but it needs to be determined if the greater catch results in reduced thrips injury. Finally, we need to more accurately assess the causes of pod damage. In the first year's data, all types of pod damage were lumped together, including non-insect damage. Breaking out the types of pod damage will help us better understand the role of the various treatments in reducing the pod damage.

Project Highlight

The combination of sticky traps and neem is comparable to the farmers' standard practice, two applications of Decis, in levels of insect control, amount of pod damage, and yields.

Identification of Potential Biological Control, Targeted Insecticide Application, and Use of Neem for Control of the Insect Complex on Hibiscus

Investigators: Gamby K. Touré[1], M. Noussourou[2], and R. Foster[3]
Collaborating scientists: Sissoko H. Traoré[1], J. S. Caldwell[4] and A. Yeboah[5]

Objectives

This research had the following objectives:

1. To identify potential candidates for biological control of *Nisotra* spp. flea beetles on hibiscus;
2. To test the effect of reduced insecticide on the insect complex on green beans;
3. To test the effect of two formulations of neem on the insect complex on hibiscus.

IPM Constraints

The flower of hibiscus is used to make fresh drinks in Mali, and used in the manufacture of herbal teas in Europe and the United States. Hence, pesticide applications after flowering carry the highest risk of causing residue problems. Potential natural enemies of its insect pests have not been cataloged, or their effectiveness assessed. The coleopteran insects *Nisotra* spp. and hemipteran insects *Dysdercus* spp. are the main insect pests of hibiscus. Farmers apply Decis on hibiscus approximately every 10 days, for a total of 4-5 applications per season. OHVN is interested in using the commercial neem product 'Neem-Away' but lacks scientific data to assess its effectiveness. Locally-produced neem could be an alternative to the commercial neem product.

Research Methods

Biological control

This program was carrried out by IPM CRSP-supported graduate student Moussa Noussourou, as part of an M.S. thesis at the University of Mali. Prospections of farmers' fields around the Baguineda horticultural station were made during the 1998 hibiscus growing season, during the wet season (July-October). From this prospection, seven predators of the hemipteran *Nisotra* spp. or of thrips on hibiscus were collected, for which direct predation was observed in the field. During this same period, an observational plot was established at the Baguineda station to identify other predators. This plot was 1575 m^2 in area, divided into four replications. In each replication, 57 plants were checked in 1 m^2 sampling quadrants for the presence of the two species of flea beetles, *N. uniformis* and *N. pallida*, aphids, and predators.

Predators and *Nisotra* spp. insects were reared in boxes made of wooden frames and wire mesh. Initial rearing was done to observe all life cycle stages. This phase of the study was done at the Baguineda station during the 1998 rainy season. In late 1998 and early 1999, a facility was constructed at the Sotuba research station with a controlled light regime for the non-choice trials. In each cage, 7 *Nisotra* spp. specimens were placed in the cage with one of 9 predators identified from prospection in farmers' fields or from the observational plot. The number of days for the predator to consume all seven *Nisotra* spp. specimens was recorded.

On-farm pest management trial

The hibiscus production season is the rainy season (June/July to October), and information is not available at this time on the implementation of this trial.

Results

Biological control. A total of 17 types of insect pests were observed feeding on dah in farmers' fields: 2 Orthoptera, 8 Coleoptera, 2 Lepidoptera, and 5 Heteroptera. The two species of *Nisotra* were found to have differing feeding preferences, with *N. uniformis* dominant on red hibiscus and *N. pallida* dominant on white hibiscus.

A total of 16 above-ground entomophagous predators were identified, including 9 Heteroptera, 2 Diptera, and 5 Coleoptera. Predators of *Nisotra* spp. included *Orius* spp. (Anthocoridae) and 8 types of Reduviidae. The latter family included 4 species of *Rhinocoris* spp., two other genera, and two specimens unidentified to genus. Other predators observed on insect pests of hibiscus included 2 Orthoptera, 8

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Coleoptera, 2 Lepidoptera, and 5 Heteroptera. No entomophagous parasites were found, but approximately 5% mortality due to unidentified entompathogenic diseases was observed.

In non-choice tests, *Orius* sp.was not an effective predator, with 12 days required for consumption of 7 *Nisotra* sp. individual. However, two species of *Rhinocoris* spp. and one unidentified Reduviidae consumed 7 *Nisotra* sp. prey in 2 days or less. This unidentified Reduviidae has been sent to the British museum for definitive identification.

Training Output

The student successfully defended his thesis, "Identification of Potential Candidates for Biological Control of *Nisotra* spp. on Hibiscus (*Dah*) In Mali," in August 1999. Foster and Caldwell served as outside members of his committee, providing input into the research design and interpretation of results in September 1998 and Janaury 1999. In between and after these trips, Caldwell assisted in literature searches, and Foster assisted with identification of certain predators.

Project Highlights

Three species in the Reduviidae with promising rates of consumption (> 3 Nistora spp. / day) were identified based on prospection in farmers' fields, a planted observational plot, cage rearing, and non-choice trials.

Solarization, Compost and Biocontrol Measures for Seedling Diseases of Green Bean

Investigators: Therá M.[1], Diakité M. Diarra[1], and M. Morant[2]
Collaborating Scientists: Gamby K. Touré[1], J. Caldwell[3], and J. Stapleton[4]

Abstract

Pre-enriched samples of compost from farmers' fields and well-decomposed compost were plated and incubated at 35° C for 12 hours. Each set of compost was negative for *E. coli* and positive for coliform bacteria. The biocontrol agent *Trichoderma* spp. was isolated from soil collected from farmers' fields. On 10 farms in two villages and at two research station sites, comparisons were made between plots covered for 4 weeks with clear or black plastic, and plots receiving a botanical product of the local plant *Lonchocarpus* spp., farmers' compost, or well-decomposed compost. At the research station sites, additional treatments compared nitrogen and cabbage residue incorporated under clear plastic, and reduced watering frequency. Treatments had no effect on seedling emergence, number of plants per hill, or disease incidence at any location, but well-decomposed compost resulted in a 26% increase in yield compared to the farmer's compost which resulted in 18% less yield than the average yield of all other treatments. Disease incidence was increased with cabbage residue and nitrogen incorporation prior to solarization with clear plastic. Overall disease incidence was low (maximum 21%) at three of the four sites.

Objectives

1. Determine if method of composting animal manure could affect disease severity and also lead to microbiological contamination of beans
2. Evaluate effectiveness of compost, solarization, *Lonchocarpus* and cabbage residue for managing soilborne plant pathogens
3. Determine if *Trichoderma* spp. effectively manages soilborne plant pathogens, specifically *Fusarium* spp.

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IPM Constraints

Seedbed diseases in Mali reduce productivity of several horticultural crops, which are of vital importance to the economy. The main focus of this project is green beans, which are produced for export to France. Crop productivity, however, is hampered by soilborne pathogens, specifically, *Fusarium* and *Pythium* spp., respectively. Generally, these pathogens are managed through modifications of cultural practices such as altering soil conditions, as well as through use of resistant cultivars. At the test sites in Mali, the soil is typically highly oxidized, resulting in very low organic matter content, and has a high water holding capacity, thus compounding the problems with diseases. Increase of soil organic matter content by incorporation of animal or plant wastes has the potential for improving water percolation through the soil, enhancing population density and diversity of antagonistic soilborne microbes and ultimately, reducing disease incidence.

IPM strategies tested in Mali to manage pathogens in green beans include use of organic amendments (composted cattle manure), a biocontrol fungus, *Trichoderma* spp., cabbage residue, solarization, and a locally available botanical material from the plant *Lonchocarpus* spp. Several plant diseases have been successfully managed by employing similar strategies in the United States. High incidence and severity of seedbed diseases in Mali has also been attributed, in part, to improperly composted cattle manure. In addition, use of animal wastes for crop production could also, inadvertently, contribute to microbiological contamination of the produce.

The site team of scientists in Mali had to overcome several constraints in 1998, the first year of the project. Methods were not yet available in the Malian laboratory to successfully isolate *Trichoderma* spp. from Malian soil prior to the start of the growing season. Having developed a method and succeeded in isolating the biocontrol fungus in 1999, the scientists will prepare the inoculum and address this component of the study in the 1999 horticultural season. Additionally, cabbage residue was not available at the time of field preparation for planting green beans. However, because this is a non-selective pathogen control method, it may be possible to incorporate the residue in fields that could be used for growing green beans during the following season. Another major constraint is that Malian farmers water their beans twice on a daily basis and are not convinced that restricted watering will reduce disease incidence or severity. The moist, humid conditions are favorable to proliferation of soilborne pathogens such as *Pythium*, resulting in increased disease incidence.

Research Methods

Comparison of Farmers' Compost with Well-decomposed Compost

The source of the farmers' compost is cattle manure which farmers compost over a six-month period (farmers' compost) prior its use for production of green beans. Well-decomposed compost was obtained from IER and compared with farmer-prepared compost for prevalence of coliform bacteria and *E. coli*, respectively. A commercially available kit, obtained from IDEXX™ (Memphis, TN) was used to accomplish this task. Compost samples were collected from each participating farm and compared with well-decomposed compost provided by IER. A 1g sub-sample of each was serially diluted in Buffered Peptone Water and enriched at 35 °C for 12 hours. Following this enrichment period, the plate was inoculated and incubated at 35 °C for 12 hours, per the manufacturer's recommendation. Plates were scored for coliform bacteria and *E. coli*, respectively.

Cabbage residue, solarization and nitrogen for managing soilborne pathogens

This study was conducted at the Sotuba Research Station and included the following treatments: control, solarization with clear plastic, clear plastic + inorganic N, plastic + cabbage residue, plastic + cabbage + inorganic N. Where used, cabbage residue was incorporated into the soil and plots were covered with clear plastic for 4 weeks prior to planting the beans. Plants were evaluated for disease incidence by counting the number in each row that exhibited symptoms of infection.

Comparison of composts, *Lonchocarpus* and solarization for managing seedbed diseases

These studies were conducted with green bean export farmers in the villages of Sanambele and Koren, and at the Baguineda Research Station. Five farmers participated in trials conducted at the two villages. At each site, the treatments were, solarization for one month with black and clear plastic, respectively, application of *Lonchocarpus* (2.5 g/liter/plot), farmers' compost and well-decomposed compost. Two additional treatments (control and reduction in scheduling of watering) were added at the Baguineda study site. Compost was applied to the plots at approximately two weeks after seedling emergence by broadcasting the material to a thickness of approximately 5-cm onto the surface of the soil. Plots at Sanambélé and Koren were watered twice daily, including a late afternoon application of water, but at Baguineda, plants were watered on a need basis.

Efficacy of *Trichoderma* spp. for managing seedbed diseases

This objective was not addressed in the on-trials in 1998, due to the need to first develop methods to isolate the fungus from Malian soil. Soil was collected from several fields in the trial villages, a subsample of which was air dried prior to assaying for *Trichoderma* spp. A 1-g subsample was serially diluted and plated on modified one-half malt agar

(unpublished). Plates were incubated for 4-7 days at room temperature in the dark at which time white-light green colonies appeared. The organism was verified based on colony morphology and microscopic examination of the spores.

Analyses of trial data

Yield of different treatments was determined at harvest for the Baguineda, Koren and Sanambélé sites, respectively, but not at the Sotuba Research Center location. Data on disease incidence were subjected to square root transformation to harmonize variances. Combined analyses for common treatments were conducted for Baguineda, Korén and Sanambelé, but data for all treatments at Baguineda were also analyzed separately. There were five replications at the Baguineda Research Station and four replications at the Sotuba Research Station. All data were analyzed using the GLM procedure of the Statistical Analysis System (SAS).

Results

Effect of Composting Methods on Microbial Contaminants

All samples of farmers' and well decomposed composts were positive for coliform bacteria but negative for *E. coli*, indicating that the farmers' methods for composting the cattle manure was effective and adequate. Failure to detect *E. coli* also ensures that use of composted cattle manure will not contribute to microbiological contamination of green beans that are produced in soil that has been amended with this organic N source.

Green Bean Yield and Disease Incidence

Total yield was lowest at Baguineda and highest at Koren. However, there were twice as many plants in the plots of each village as there were in Baguineda, although the mean number of plants per hill was similar at each location. Overall, disease incidence was highest at Baguineda and lowest at Koren. Results for the two villages were similar; therefore, differences in yield may be attributed to a difference in spacing, which is reflected in lower yield in the Baguineda plots.

Treatments had no effect on seedling emergence, the number of plants per hill, or disease incidence at any location, but well-decomposed compost resulted in a 26% increase in yield compared to the farmer's compost. Similarly, plots treated with the farmers' compost produced 18% less than the average yield of all the other treatments. Although the composts appeared to be similarly decomposed based on the microbiological assay, there may be other inherent factors that are contributing the effect on yield. These factors could include a difference in pH, nutrient composition, or the composition of the compost itself. A difference in composition could be due to a larger quantity of added plant based material in the farmers' compost, which would result in a slower mineralization rate, hence a lower availability of nutrients for uptake by the plants.

At the Baguineda Research Station, treatments had no effect on emergence, plants per hill or disease incidence. However, yield obtained from the plots treated with farmers' compost was less than half than obtained when plots were solarized with black plastic or amended with *Lonchocarpus*.

Disease incidence at the Sotuba Research Station was greatest in plots in which cabbage residue and nitrogen were incorporated prior to solarization with clear plastic. However, the number of plants per hill was similar except for the plots treated with cabbage residue, indicating that the amendment may be inhibitory to plant growth. It is also possible that the cabbage residue may have been infested with organisms that were pathogenic to green beans, because the number of plants per hill was higher in plots that were covered with the plastic. Data obtained from this site were also variable, resulting in a high coefficient of variation, and may be attributed to variability among small plots that are in close proximity to each other.

Generally, disease incidence for 1998 was low. The maximum disease incidence in a single plot was 20% at Baguineda, 21% at Korén, and 9% at Sanambelé. Based on these results, it is apparent that more information on the prevalence of seedbed diseases is needed from other villages and over a longer period of time in order to better determine the extent to which these conditions were normal or abnormal.

Innovative Technologies for *Striga* Management

Investigators: B. Dembélé[1] and J. Westwood[2]

Abstract

Investigations were carried out to examine the potential for herbicides to be used as seed treatments of sorghum and millet to reduce *Striga* parasitization. During the visit of B. Dembélé to Virginia Tech, we undertook preliminary studies to select herbicides that may have efficacy as seed treatments and established appropriate application rates for these compounds. In addition, several Malian sorghum and millet varieties were screened to determine their relative tolerance to the selected herbicides. Subsequently, a pot-experiment testing these herbicides in *Striga*-inoculated soil was conducted at the Sotuba research station in Mali. Results from this experiment suggests that prosulfuron may be an effective herbicide for seed treatments, but results were clouded by unexpectedly low numbers of *Striga* in control treatments as compared to herbicide treatments. J. Westwood traveled to Mali and assisted in setting up field experiments at Sotuba (sorghum trial) and Cinzana (sorghum and millet trials).

Introduction

The parasitic weed *Striga* remains one of the major constraints to cereal production in sub-Saharan Africa. The need for new approaches to control this weed has been recognized by the IPM CRSP and efforts to alleviate crop damage from *Striga* have been conducted in Uganda and Mali during the first phase of the project (Oryokot et al., 1998; Dembélé et al., 1998). Previously, most of the research has focused on integrated cultural control measures. The current work seeks to develop an herbicidal approach as another tool for farmers.

The concept of treating a crop seed with herbicide in order to protect the young crop plant from parasitic weeds has been demonstrated in cowpea-*Striga*, and IR (imidazolinone-resistant) corn-*Striga* associations (Berner et al., 1994; Kanampiu et al., 1999). This strategy requires that the crop have sufficient tolerance to the herbicide such that it is able to germinate and grow normally while retaining a small amount of herbicide in its system. A parasite attaching itself to this crop, however, serves as a sink for compounds in the host phloem and accumulates toxic quantities of the herbicide, resulting in inhibited parasite growth. In this way the herbicide serves almost as a vaccine against the parasite and protects the seedling as long as non-metabolized herbicide remains in the crop system. Because the earliest *Striga* attachments to host plants have the greatest impact on yield, prevention of early *Striga* parasitization would be expected to significantly increase yields.

This herbicide seed treatment technique has not been tried in two of the most important *Striga* hosts in Africa, sorghum and millet. This research was undertaken in an effort to adapt this technique to these crops in the Mali.

Objectives

This research is designed to test the feasibility of using herbicide seed treatments to prevent early *Striga* parasitization of sorghum and millet. Specific goals are to:

1. test sensitivity of sorghum and millet seeds to several herbicides with potential efficacy as seed treatments.
2. identify sorghum lines with greatest tolerance to these candidate herbicides.
3. perform a first set of experiments studies in containers artificially inoculated with *Striga*.
4. put out field trials of herbicide-treated seeds in fields naturally infested with *Striga*.
5. assess the early efficacy of the technique by growing sorghum and millet in the presence of *Striga* in a semi-hydroponic system.

Research Methods

Establishing levels of herbicide tolerance

Investigation of Malian sorghum and millet varieties sensitivity to herbicides were conducted in the laboratory at Virginia Tech. Initially ten herbicides were tested to establish appropriate doses for seed treatments. Solutions of 0.001, 0.005 0.01, 0.05, 0.1% active ingredient were prepared for the herbicides 2,4-D amine, 2,4-DB, clopyralid, dicamba, picloram, and tryclopyr. Solutions of 0.1, 0.5, 1, 5, 10% active ingredient were prepared for chlorimuron, flumetsulam, halosulfuron, and prosulfuron. Seeds of sorghum (CSM 388) and millet (CZ Sanioba 03) were

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selected for those that were whole and appeared viable. Seeds (15) of each were treated by soaking for 5 minutes in the herbicide solutions. At the end of this time the seeds were removed from the vials and placed on paper towels to air-dry overnight.

Germination and early growth of the treated seeds were tested by germinating the seeds between layers of moist Whatman #1 filter circles in Petri dishes. Three days later germination had occurred for both sorghum and millet, and the number of germinated seeds was counted. Radicle lengths of germinated seedlings were categorized by counting the number of seeds in each of three classes: <5mm, 5-10mm, and >10 mm. Severe inhibition of radicle elongation was observed in some treatments, but germination was not highly affected. These results provided information leading to the elimination of some herbicides from further consideration and the establishment of appropriate herbicide rates to use in further experiment (Table 1).

Table 1. Herbicides and rates used in experiments.

Herbicide	Sorghum	Millet
	Herbicide rate (% active ingredient)	
2,4-DB	0.1 and 0.05	0.05 and 0.01
Dicamba	0.05 and 0.01	0.1 and 0.05
Clopyralid	0.1 and 0.05	0.1 and 0.05
Picloram	0.05 and 0.01	0.1 and 0.05
Prosulfuron	5 and 1	1 and 0.5

Assessing varietal tolerance to herbicides

Four varieties of sorghum ('CSM 388,' 'Tiemarifing,' 'CMDT 39,' and 'CMDT 45') and one variety of millet (Table 2) were treated with herbicides as described above (using the higher rate listed in table 1). Seed germination and radicle elongation were similarly determined except germination and growth was allowed to occur for four days before rating. For this experiment ten seeds were used per treatment and each treatment was repeated three times.

Table 2. Characteristics of sorghum and millet varieties used in experiments.

Sorghum	
CSM 388	Local *Striga* susceptible variety
Tiemarifing	Local well adapted variety; less *Striga* sensitive
CMDT 39	Local *Striga* tolerant variety for humid zone
CMDT 45	Local *Striga* tolerant variety for humid zone
Millet	
CZ Sanioba 03	Improved *Striga* susceptible variety

Experiments conducted in pots at the Sotuba station, Bamako

Bottomless plastic pots were half-buried in a field adjacent on the Sotuba station. Soil infested with *Striga* seeds was used to fill the pots. Sorghum ('CSM 388') or millet ('CZ Sanioba 03') seeds were treated as described with herbicides using the rates designated in table 1 and planted in these pots. Each treatment was replicated five times.

Data collected included crop height and stem diameter (measured at the base), time of *Striga* emergence, and number of *Striga* emerged from each pot. Count of emerged *Striga* plants were taken at approximately seven-day intervals starting a 43 d after planting.

Field experiments at Sotuba and Cinzana

Sorghum and millet varieties listed above were also treated with herbicides (as described) and planted in fields. Because of the absence of *Striga* strains adapted to parasitize millet in the Bamako region, the field plot in Sotuba was put out with sorghum only. To ensure the presence of sufficient inoculum, additional *Striga* seeds were placed in the planting hole at the time of sowing. In the vicinity of the Cinzana research station (300 km away from), farmers' fields were available with histories of both sorghum and millet cultivation (and corresponding parasitization by *Striga* strains). The field tests put out at Cinzanna were placed in farmer's fields known to have *Striga* infestations, thus ensuring realistic *Striga* inoculum levels. Sorghum and millet in these plots are managed identically to the surrounding farmer's crops, but work is carried out by research station personnel in the first year. Because this is the first year of testing the seed coating technique, it is important to establish the efficacy of the technique before having farmers use it. However, assuming that one or more of the herbicides gives promising results under real field conditions this year, farmers will carry out the technique in the subsequent trials. Because these plots were planted in July, data from these experiments is not available in time for the writing of this report.

Test of *Striga* ability to parasitize herbicide-treated sorghum and millet growth in a semi-hydroponic system

Initial tests of sorghum and millet growth in polyethylene (PE) bags was conducted in Blacksburg in May. Seeds of sorghum (CSM 388) and millet (CZ Sanioba 03) were germinated in Petri dishes between layers of filter paper. Seedlings were transplanted to the PE system where host root development can be observed as they grow on a moist filter sheet.

Supplies necessary for an experiment using the PE system were transported to Mali, and an experiment was set up in a laboratory at the Sotuba station. Seeds of sorghum and millet saved from the final round of treatment at Cinzana and germinated on filter paper were transplanted into bags that had been inoculated with *Striga* seeds.

Research Results

Establishing levels of herbicide tolerance

Because the seed-treating technique requires that the crop plant have a high level of tolerance to the herbicide, it was important to eliminate any compounds that are too phytotoxic to the host. Initial tests of one sorghum and one millet variety against ten candidate herbicides led to the selection of five to be used in further investigations (Table 1). This experiment also established the herbicide rates to be used, with the goal being to use the highest rate that does not cause significant injury to the crop. Since this distinction can be difficult to make in practice and may be affected by environmental conditions, two rates were selected. The sorghum and millet differed in tolerance to the herbicides so separate rates were established for each species.

Assessing varietal tolerance to herbicides

Four varieties of sorghum and one of millet that are adapted to Malian agriculture were tested for tolerance to the five herbicides. ANOVA indicated highly significant differences between sorghum varieties and between the herbicides, as well as in the interaction of these two parameters. The most tolerant (in general) was 'CSM 388,' followed by 'CMDT 45'. Since 'CSM 388' is very susceptible to *Striga* parasitization, it will be used in subsequent pot and field studies. The one millet variety tested was exposed to herbicide rates different from the sorghum (except for clopyralid), but showed good root growth in the presence of the herbicides.

The herbicides inhibited the growth of nearly all roots as compared to controls. However, the root growth of prosulfuron treated seeds was nearly equal to the control. This herbicide - even at such high concentrations - does not seem to greatly inhibit development of the seedlings.

Experiments conducted in pots at the Sotuba station, Bamako

The next step in assessing the value of seed treatments was to expose treated plants to *Striga*. This was done in large pots in the field near the Sotuba weed laboratory using soil artificially inoculated with *Striga* seeds. With respect to experiments with sorghum and millet, the herbicide treatments did not injure the crops sufficiently to show significant differences in plant height or stem diameter (data not shown). For sorghum, all herbicide treatments and the water control led to the first *Striga* appearance about 40 days after planting.

Significant differences were found among herbicide treatment effects on the number of *Striga* plants emerging on both crops (Figures 2 and 3). However the very low *Striga* counts on the control plants is a very unexpected and confused interpretation of the results. The control pots had the least *Striga* for the sorghum trial and were statistically inseparable from the lowest treatment in the millet trial. It is unclear at this time whether herbicide treatments could have induced host plants to be more parasitized or whether experimental errors could have contributed to this result. Field tests (data not yet available) should either confirm or refute this surprising result.

Among the herbicide treatments, plants from seeds exposed to the lower rate of prosulfuron had the least amount of *Striga*. This sulfonylurea herbicide is active at extremely low quantities and is readily translocated in plants. It is also very safe for sorghum and millet, and would appear to be the herbicide with the greatest potential for being adapted to the seed-treatment technique.

Field experiments at Sotuba and Cinzana

Field trials of the herbicide seed treatments were put out at two locations as described in the materials and methods section above. Data from these experiments is not available at the time of writing this report.

Test of Striga ability to parasitize herbicide-treated sorghum and millet growth in a semi-hydroponic system

The use of the PE bag or similar growth system is used in parasitic weed research because it allows observation of the early events in parasitization. Since this research is based on the concept that early *Striga* attachments will accumulate herbicide from the host and fail to develop, it is logical to test this hypothesis using such a system. The potential for growing sorghum and millet in this system was tested at Virginia Tech and the crops were found to grow well under these conditions. Supplies were subsequently taken to Mali and herbicide treated crop seedlings were grown with *Striga* seeds in this system. Staff at the Sotuba station were trained in this technique, but as no results are available from this experiment at this time.

Collaborative Exchanges

Bouréma Dembélé visited Virginia Tech from April 2-17, 1999.
James Westwood visited Mali, July 2-12, 1999.

Project Highlight

Initiated experiments on a potentially useful new strategy for the integrated control of *Striga* in sorghum and millet. The herbicide prosulfuron appears to have the characteristics to be effective in the control of *Striga* and initial results are encouraging.

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Assessment of Pests, Pesticide Usage, and Pesticide Residues on Green Beans, Hibiscus, and Tomato

Investigators: Gamby K. Touré[1], F. V. Dunkel[2], R. Foster[3], Traoré H. Koné[4], J. Cobb[5], and D. Mullins[5]
Collaborating Scientists: Diakité M. Diarra [1], D. Khibé[1], Sissoko H. Traoré[1], P. Hipkins[6], and John Caldwell[6]

Abstract

In Year 6 we accomplished: 1) Establishment of a new linkage with the Environmental Quality Laboratory [EQL, the national pesticide residue laboratory located within the Central Veterinary Laboratory (Laboratoire Central Vétérinaire, LCV) of Mali] and the IPM CRSP; 2) Assessment of pest pressure in fields of vegetable exporters in Mali; 3) The development of sampling methods and a sampling plan for evaluation of pesticide residues; and 4) Development of methods for analysis of deltamethrin and other pesticide residues on green beans, on other vegetable crops, and in soil.

Objectives

1. To assess types and numbers of pest insects and pesticide usage on green beans, hibiscus, and tomatoes;
2. To to verify times of highest pest pressure and develop thresholds for these periods;
3. To assess pesticide residues on green bean and hibiscus flowers.

IPM constraints

1. Hibiscus flower exports have increased from 25 metric tons in 1995 to over 200 metric tons in 1997 in Mali, in response to a strong and steadily increasing demand for herbal products on the world market (Results Review and Resource Request, US AID/Mali, 1998, p. 11). Malian farmers have developed a commercial relationship with a major producer of herbal teas and appear to be well-positioned to continue development of this specialty crop. However, it is not clear that the farmers understand under what grading standards, including pesticide regulations imposed by the herbal tea producer and by the FDA or other government regulatory body, their hibiscus flowers are judged. products are not meeting standards. It is also possible that production levels are just not meeting market demands. Standards, including pesticide residue tolerances for green beans, need to be known by farmers and scientific advisors.

2. Production of green beans for export is actually a newer activity and quantities exported have been increasing. During the last marketing year, Mali exported approximately 600 tons to France. Regional competitors such as Senegal and Burkina Faso exported upwards of 5000 tons during the same year (Chemonics International, Fintrac, and Winrock International. Mali SEG inception

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report/First Ann. Workplan, Oct. 1998, p.10). European vegetable brokers know that Mali is capable of exporting top quality green beans to their markets. However, inconsistency of quality and irregularity of supply have to date greatly hindered export market development. As with green beans, it is possible that grading standards under which the beans are being judged are not known or understood by the farmers and their products are not meeting standards, or that production levels are not meeting market demands. Standards, including pesticide residue tolerances for hibiscus, need to be known by farmers and scientific advisors.

3. Determination of pest pressure is labor intensive. This requires visiting the traps on a daily basis throughout the season, not just when pesticides are applied. It also requires identifying to species the insects trapped. This is time-consuming and often requires consulting a taxonomist who has specialized in that insect group.

4. It takes an extremely long time and requires very specific technical support to ensure that an analytical chemistry laboratory, such as one analyzing pesticide residues, is ready to receive and process samples accurately. In subsaharan Africa there are additional constraints due to the cost of solvents, lack of local suppliers, unreliability and high cost of electronic communications, and the lack of in-country infrastructure for equipment repairs, equipment maintenance, and solvent disposal. The existence of Internet servers does not guarantee access; infrastructure and computer access within institutions (both IER and the LCV) are limited to headquarters and/or directors' offices, because of high installation and recurrent costs.

5. In 1998, the EQL was equipped by USAID-Mali with state-of-the art equipment for pesticide residue analysis, but further support was needed in analysis procedures and program development to achieve the EQL's mandate. The Environmental Quality has a comprehensive mandate that reflects the needs of Mali and the West African region for the analysis of pesticide residues on crops, food, and medicinal products, and in water, soil, and sediments.

Research Methods

Research Methods for Assessing Pest Insects

Yellow plastic traps (750 cm^2 area) were covered with a 1:12 mixture of solid and liquid vaseline and placed in the center of a 5 m long row for control of leafminers, thrips, and whiteflies. Numbers of thrips on the traps were counted weekly at the seedling and flowering stages. For additional details of the experiment see the section of this report, "Targeted Insecticide Application, Yellow and Red Traps, Soap, and Neem for Control of the Insect Complex on Green Beans."

Search Methods for Information Related to Pesticide Residue Issues in Mali

In November 1998, we determined that our information needs for assessing pesticide usage on horticultural crops in Mali were similar to that of Dr. Haimatou Traoré of the EQL pesticide residue laboratory of LCV. We met with EQL director Dr. Haliamatou Traoré, explained to her our objectives, and together developed the following list of questions to guide our information search in Year 6:

1.0. Regarding the pesticide situation in Mali:
- 1.1. What pesticides are used in Mali and how to identify them (are there labels, is there a list of pesticides imported into Mali, is there a list of pesticides sold within Mali)?
- 1.2. Who sells pesticides to the farmers? What pesticides are sold to farmers?
- 1.3. What cultural practices are used for pest management in green bean and hibiscus flower production?
- 1.4. What are the main preharvest insects or other arthropods, weeds, and disease pests causing monetary loss to these farmers in these crops?
- 1.5. What are the main postharvest insects and other arthropods and microbial problems in the green bean/hibiscus export crop production?
- 1.6. Who regulates pesticide use in Mali? If regulations are violated, what are the consequences?

2.0. Is there currently a residue testing program in Mali? If so, what residue tests are done? Organophosphates? Organochlorines? Carbamates? Pyrethroids? Herbicides? (Specifically, is paraquat analyzed?) Mycotoxins?
- 2.1. What procedures (GC-MS, HPLC, Spectrometry, HP-TLC, Super critical fluid extraction) are used for these analyses?
- 2.2. What standards are used?
- 2.3. How many samples are analyzed per year? From which location are they obtained? What type of samples? Water, soil, market basket, export shipment?
- 2.4. What commodities are sampled?
- 2.5. What is the training of key personnel? What are their routine in-service training schedules and outside Mali annual training schedules?

3.0. Regarding the export market from which Mali can realize profit:

3.1. What are the regulations of the European Community for residues on green beans that Mali exports to Europe?
3.2. Who sets tolerances for pesticides and other toxins, e.g., aflatoxins, and microbial contamination, such as *Salamonella,* etc., in Europe?
3.3. Where are the markets for Mali-grown green beans in Europe? Are all in the European Community (EC)? Are some markets in England or other non-EC countries in Europe? Are there any markets outside of Europe? Are there any potentially new markets?
3.4. What are EC tolerances for hibiscus (dry flowers) used in tea?
3.5. What are the tolerances for pesticides, aflatoxins, and other toxins and microbial contamination that the US-FDA has imposed on hibiscus flowers to be used in tea, e.g., for the Celestial Seasonings, Co. and possibly other companies such as Stash and Lipton?
3.6. Pesticide residues are determinants of postharvest quality. What are the grading factors used to establish the price of hibiscus flowers? Of green beans? Who does the grading and where is it done?

We agreed on the following division of labor to address these questions. Dr. Dunkel's responsibility would be to obtain these tolerance levels. Dr. Yeboah, the economist member of our team, was to determine the timing and location of the market opportunity windows for these export products of Mali. Dr. Traoré was to determine laws and practices regarding pesticides and toxic residues within Mali. Drs. Gamby, Foster, and Caldwell were to determine the main preharvest insect pest targets of pesticides in relation to production practices of our crops of focus. Each of us in our interviews with the farmers from whose fields the samples were taken were to ask questions regarding their pesticide use in these fields (the fields not in the IPM CRSP experimental project).

Selection of Materials, Methods, and Equipment for Obtaining Pesticide Residue Samples and Development of Standard Operating Procedures for Sampling

Standard operating procedures (SOPs) are essential in any analytical situation. In pesticide residue determinations, often samples are brought to the analysis laboratory that have been obtained by a variety of methods. If comparisons are to be made between samples and inferences drawn, samples must be taken according to a strict set of procedures. It is for this reason that we developed the following SOP for obtaining soil and water samples from which inferences can be made about locations and times of high contamination of soil and water. These inferences are important for health of the rural, periurban, and urban population as well as for anticipating problems with the export fruit, vegetable, and tea markets.

Standard Operating Procedures (SOPs) #1.000 for Obtaining Pesticide Residue Samples

Overall hypothesis to be tested: Pesticide residues in export crops of Mali meet tolerances in the US market (hibiscus flowers), the European market (fresh green beans and hibiscus flowers for tea), and the urban Mali market (hibiscus flowers for tea and punch, fresh green beans, and tomatoes)

Pesticide Residue SOP #1.001. SOIL TESTING

Specific hypothesis to be tested:
There are soil residues which could endanger compliance with pesticide tolerances in these 3 crops.

Materials and methods:
To obtain the field samples, assemble the following materials:

* a cooler with locking top, ca. 23 liters
* 4 packages of blue ice frozen
* blocks of ice in waterproof containers (check space available in cooler after placing sample bottles in cooler)
* glass sampling containers chemically clean with teflon-lined or aluminum foil-lined lids
* a soil core sampler (a cultivator or trowel and knife will suffice if the soil core sampler is not available)
* tape (masking tape) to temporarily label samples in field (permanent labels will be added before storage in the lab)
* pencil (not pens since these are generally solvent soluble)
* enamel-coated metal pan or calabasse
* meter stick or metal tape measurer
* flag markers for sampling spots

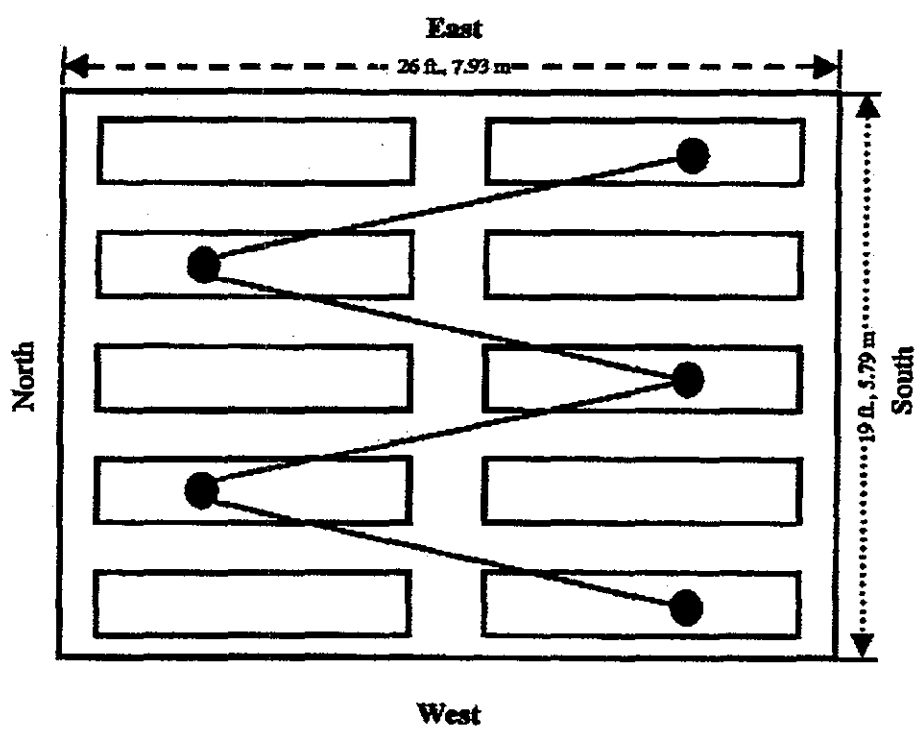
Procedures:

1. Measure the dimensions of the entire field to be sampled.
2. Step inside the field and make a "W" design (Figure 1) such that the design uses most of the field. At each point of the "W" take a sample. In the case of those fields that are made up of 10 separate beds, 5 parallel to each other, consider the entire area of beds to be one field on which the "W" is superimposed. Take samples below the soil horizon, remove stones
3. Fill jars 3/4ths full only (a total of 4 liters per each sample should be obtained).
4. Immediately (directly next to the sample site) place bottles in the cooler.
5. Keep bottles refrigerated at all times or frozen until analyses are to be run.

6. As soon as possible after obtaining the sample, place a permanent (word processed) label on the jars, cover the jars with aluminum foil (if jars do not have brown glass) and place a duplicate label on the outside of the aluminum foil.
7. Enter the sample information in the official laboratory log book for samples.

Soil sampling location and handling description. Based on the above procedures, we obtained samples in the following way. The sample location in a farmer's field in Sanambele. The field was part of the seedbed disease trial. Surrounding these experimental plots were 4 times more area of similar small plots of beans that had been planted several weeks earlier. These other plots had many white flies, but no flowers had bloomed, and we did not observe any thrips. As soon as we took each sample, we placed it in a local gourd container of the farmer (*calabasse*), and when 5 samples had been taken, we removed all stones. We found only small seeds, ca. 4 mm x 8 mm, possibly ungerminated seeds. Some harder pieces of soil seemed to be clay. The soil was very friable. We sampled between the rows. Because there was no soil sampler available, we used a hand hoe to make a hole and scraped soil from the entire 0-15 cm in depth into the lid of the jar and we used the lid to fill the jar. Jars (brought from Montana State University) were packed, the top covered with soil, and the lid screwed on tightly. We then labelled the sample bottles and placed them immediately in the cooler with ice that we had brought to the edge of the sample plot. Samples were handled, labeled, and wrapped according to directions in the above SOP. Samples were refrigerated in the field immediately after they were obtained until they were placed in a refrigerator at the EQL on November 23, 1998. On November 28, all samples were transferred to the freezer.

Figure 1. Sampling plan for obtaining soil samples for pesticide residue analysis.



Pesticide Residue SOP #1.002. WATER TESTING

Specific hypothesis to be tested:
There are pesticide contaminated water sources in the area within and near Bamako, Mali which could endanger human health and compliance with pesticide tolerances in the 3 target crops of hibiscus flowers (bound for the US market), fresh green beans and hibiscus flowers for tea (for the European market), and hibiscus flowers for tea and punch, fresh green beans, and tomatoes (bound for the urban Mali market).

Materials and methods:
To obtain field samples, assemble the following materials.

* a cooler with locking top, ca. 23 liters
* 4 packages of blue ice frozen
* blocks of ice in waterproof containers (check space available in cooler after placing sample bottles in cooler)
* glass sampling containers chemically clean with teflon-lined or aluminum foil-lined lids (4 liters per sample)
* tape (masking tape) to temporarily label samples in the field (permanent labels will be added before storage in the lab)
* pencil (not pens since these are generally solvent soluble)
* long handled enamel coated metal sampler (or, if it is a well, the bucket normally used to obtain the water from the well, normally.

Procedures:

1. Choose a time and place where there is known to be or suspected to be pesticide use or misuse.
2. Obtain sample from as close to the source of the contamination as possible.
3. Fill jars 2/3rds full only (a total of 4 liters per each sample should be obtained).
4. Immediately (directly next to the sample site) place bottles in the cooler.
5. Keep bottles refrigerated at all times or frozen until the analyses are run.
6. As soon as possible after obtaining the sample, place a permanent (word processed) label on the jars, cover the jars with aluminum foil (if jars do not have brown glass) and place a duplicate label on the outside of the aluminum foil.
7. Enter the sample information in the official laboratory log book for samples.

Initial water sampling loction and handling. Four identical samples were taken from one well of a vegetable farm located directly north of the LCV. The samples were obtained, handled, labeled, and stored according to the newly established SOP. Each was put in separate glass containers (0.98 liters each) at the site. Two samples were transported to Montana State University, and the other two other indentical samples were kept by the EQL. All 4 samples were refrigerated until 28 November 1998, at which time they were placed in a freezer at the EQL.

The samples taken to Montana State University were analyzed by the Analytical Laboratory at Montana State University in December 1998. The following analyses were carried out:

1. clorinated hydrocarbons:
   4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Aldrin, alpha-chlordane, gamma-chlordane, chloroneb, chlorothalonil, DCPA, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, HCB, heptachlor, heptachlor epoxide, lindane, methoxychlor, diclorvos;
2. nitrogen-containing herbicides:
   acetochlor, alachlor, atrazine, bromacil, butachlor, butylate, carloxin, cyanazine, cycloate; EPTC, hexazinone, imazalil, metolachlor, metribuzin, prometon, prometryn, pronamide, propachlor, propazine, simazine, tebuthiuron, terbacil, terbutryn, triallate;
3. phosphorus compounds:
   azinphos methyl, chlorfenvinphos, chlorpyrifos, demeton-S, diazinon, disulfoton, disulfoton sulfone, disulfoton sulfoxide, ethion, ethoprop, famphur, fenamiphos fensulfothion, fenthion, malathion, metalaxyl, methidathion, mevinphos, oxydemeton methyl, ethyl parathion, methyl parathion, Phosmet, sulprofos, terbufos;
4. phenoxy herbicides
   bentazon, 2,4,5-T, 2,4-DP, clopyralid, dicamba, 5-hydroxy-dicamba, diclofop methyl, dinoseb, MCPA, MCPP, PCP, picloram, silvex, and triclopyr;
5. pyrethroids
   cis-permethrin and trans-permethrin; trifluralin.

Plan for larger-scale soil sampling for pesticide residues. Sample at least 10 fields total, 5 in Dialacoroba (Baguineda)] and 5 in Sanambele. Use the "W" sample method, for 5 subsamples per field. Combine the subsamples from each field into a composite, remove stones, and fill sample jars so that there are 2 aliquots from each field. One aliquot will be held as a reserve sample and the other will be used for each analysis from which replicates will be taken for the analysis. Place these immediately in the freezer until the extraction process is begun.

Plan for larger-scale water sampling for pesticide residue analysis. Sample the wells in 10 fields total, 5 in Dialacoroba (Baguineda) and 5 field wells in Sanambele. For the initial sample, take 2X the amount needed (3-4

liters), for analysis at the Montana Pesticide Residue Laboratory.

Development of pesticide residue analysis capability in the EQL

The Management Entity supported an initial planning activity in January 1999 to assess the needs of the EQL to make it fully functional. In this activity, Dr. Donald Mullins (Virginia Tech, Department of Entomology) and Ms. Jean Cobb (Virginia Tech, Department of Biochemistry, Pesticide Residue Laboratory) collaborated with Dr. Halimatou Traoré, EQL director, from January 10 to 29, 1999.

Two EQL scientists, Dr. Halimatou Koné Traoré and Dr. Safiatou Berthé, spent four weeks for training and collaboration in pesticide residue analysis methods July 17 – August 14 at Virginia Tech. During this period, Dr. Traoré and Dr. Berthé worked with Jean Cobb of the Pesticide Residue Laboratory of the Department of Biochemistry, Don Mullins and Pat Hipkins of the Department of Entomology, John Caldwell of the Department of Horticulture, and staff of the Chromatography Laboratory, Department of Chemistry, Virginia Tech.

Results

Assessment of Types and Numbers of Pest Insects

No significant infestations of aphids or whiteflies were observed. Thrips population densities peak at around 50% flowering and stay at high levels until the start of pod formation. After pods have started to form, thrips populations diminish, probably because of the presence of fewer flowers for them to feed on.

Pesticide usage

Dr. Traoré assisted in preparing the Mali country report portion of the United Nations International Pesticide Survey. Dr. Traoré conducted and prepared a profile of the national capacity for management of chemical procducts. She used as a guide the following document: UNITAR. 1996. Préparation d'un profil national pour évaluer les capacités Nationales de gestion des produits chimiques. IOMC Inter-organization program for the sound management of chemicals. At this point (October 1999), 16 individual reports have been collected. A list of pesticides used in Mali has also been prepared.

Dr. Dunkel, Dr. Bouema Dembélé, Dr. Gamby K. Traoré, Dr. Traoré, and Mr. Bâ (OHVN field scout) developed a set of SOPs for sampling soil and water, and for handling and storage of these samples. We also developed an experimental protocol for determining the pesticide residues in a specific farming area.

During our interviews in the field and our subsequent discussions with the private sector, we learned that both the fields in which we conduct our present horticultural export research and the fields adjacent to them have experienced heavy pesticide use in the. This is a cotton growing area, and other areas which have cotton now or have had it in the past will likely have a similar history of heavy pesticide and defoliant use. Many of the pesticides used in the past have a long half life and the likelihood is that they are still present in the soil. Due to drift from pesticide application and to irrigation of fields with possibly contaminated water, it is also likely that fields adjacent to the former cotton fields will have high levels of these more persistent compounds. If so, it is possible that these compounds will show up in this year's crops of vegetables and flowers. Iit is important to determine to which pesticides our experimental crops are being exposed because of previous years' pesticide use.

In the summer of 1998 (just prior to the start of Year 6), there had been a media publicized event related to pesticide residues: the discovery of DDT in the public drinking water of the capital, Bamako. Although the initial report was not confirmed by subsequent analysis, this event indicates the risk that such contamination of public water could pose to one million people, or approximately 10% of the population of Mali. USAID Bamako has indicated several times that they would like to follow up on this finding.

Water Analysis

The water samples from one location were pooled and did not show any detectable levels of pesticides for which they were analyzed.

Development of pesticide residue analysis capabilities

During the January consultation, Dr. Mullins and Ms. Cobb provided instruction to EQL scientific staff on general aspects of pesticide residue analysis and management of Hewlett Packard Chemstation software for sample data analysis. Included in this program was review of documentation provided by the consultants, and discussions about the broader role of the laboratory in the overall network of Malian agencies. Discussed within the broader context were issues such as developing linkages between pesticide residue analysis and pesticide use through integrated pest management (rational pesticide use) activities and developing the infrastructure needed to maintain a state-of-the-art pesticide analytical laboratory.

Dr. Mullins drafted a workable bioremediation plan for managing laboratory chemical wastes that accounted for available supplies, technical know-how, and ease of use. The plan included drawings for fabrication of the needed disposal containers by on-site staff.
Ms. Cobb worked with Dr. Traoré the remaining two weeks with an emphasis on mastering the HP Chemstation software integral. Instrumentation training emphasis was placed on

the gas chromatographs and corresponding detectors (ECD, NPD, FPD, FID. The other cornerstone of these two weeks was initiating pesticide residue analyses. Two extractions were performed, the first to analyze DDT in water and the second to test for deltamethrin in green beans. These two extraction techniques were chosen because of the 1998 DDT drinking water scare in Bamako and to support the program of the IPM CRSP field research oriented towards green beans and its export market. Upon completion of the two extraction techniques, a documentation packet was compiled for each technique. Each documentation packet included a draft copy of an analytical method written specifically for the laboratory, printouts of GC chromatograms of pesticides, and calculations pertaining to percent recovery of pesticide residues in the fortified samples.

Following this work, at the request of USAID Bamako, a comprehensive workplan was developed for support over a five year period to the EQL, starting July 1999 (for details on this workplan, see the Year 7 IPM CRSP Workplan). This plan was submitted and approved by USAID Bamako in June 1999. The July-August 1999 training and collaborative research program was the first part of this workplan; remaining activities in year 1 of the EQL program will fall under IPM CRSP Year 7.

During the July-August 1999 training, Drs. Traoré and Berthé developed skills in the following techniques:

1. experience in preparation of gas chromotography standards from the following formulated pesticides: atrazine, Lorsban (chlorpyrifos), Dual (metolachlor), malathion wettable powder, DDT, and methyl parathion.
2. injection of organochlorine and organophosphorus pesticides on a Hewlett Packard 6890 gas chromatograph (GC) equipped with a nitrogen-phosphorus detector, autosampler, and Chemstation software.
3. calculation of standard dilutions (stock, fortification, and working standard concentrations)
4. preparation of fortification solutions for deltamethrin in green beans extraction
5. extraction of green beans fortified with deltamethrin using matrix solid phase dispersion, sample extracts injected on a Hewlett Packard 5890 GC equipped with an electron capture detector (ECD), autosampler, and Chemstation software.
6. extraction of soil samples using the General Soil Extraction method, using an N2 evaporator and a Tracor 540 GC equipped with an ECD for manual injections of the sample extracts, and calculations of percent recovery from fortified soil samples
7. indentification and accessing of literature available on the Internet
8. contacting and ordering supplies via email.

The team also obtained information on a new innovative approach to pesticide containerization prior to use by farmers. This approach uses containers that farmers attach directly to application equipment, so that they never have to handle pesticide. This eliminates the risk of contamination of farm containers, spills, and handling exposure. The team visited a commercial firm and observed this containerization process.

Drs. Traoré and Berthé learned how pesticide residue training is done by Cooperative Extension in Virginia. In September, a survey instrument was developed in French and English to obtain more information on sources of pesticides, distribution of pesticides, pesticide use, pesticide safety, and urban and non-agricultural pesticide use. This instrument will be pre-tested and finalized in November 1999.

Analysis of Residues on Green Beans

Green beans were sampled from the January 1999 harvest and stored in the EQL according to SOP procedures. Testing of lettuce samples in September 1999 with the AOAC modified method has provided good results. Solvent and supplies availability continues to be a constraint. The EQL has not been able to obtain needed solvents locally, and arrangements are being made to order and send them prior to the end of 1999 from the United States, while other channels are explored to establish a reliable mechanism for ordering from Mali.

Conclusions

1998-99 marks the start of the very important process of preparing for full scale operation of a state-of-the-art Pesticide Residue Analysis Laboratory for Mali. This year has linked the mission of this Laboratory with the goals of the IPM CRSP in Mali. Within one year, we expect this laboratory to be operational and answers to be forthcoming on the role of persistent pesticides used in cotton production to affect risks associated with vegetable, fruit, and tea production in adjacent fields.

Impact

Through additional support from US AID Bamako to the IPM CRSP for work with the EQL, two EQL scientists have begun to acquire the needed skills to enable them do extraction and computerized analysis of crop, soil, and water samples. The development of national capability in the EQL to analyze pesticide residues will assure the safety of agricultural products for home and market consumption in Mali and West Africa and for export to global markets that include the United States as well as Europe. These results will also serve as the base for the standardization (*homologation*) of pesticides used throughout West Africa, the development of strategies for the selective use of appropriate pesticides in the subregion, and the development of educational programs to help vendors and farmers use pesticides in a safe and more environmentally sound basis. A stronger awareness should develop over time in the general

public, both urban and rural, that residues from pesticide use and misuse can be a public danger. There will also be greater confidence that there is analytical support to verify claims of dangerous drinking water, such as occurred in summer 1998.

Networking Activities

Two major networking activities occurred this year. First, the IPM CRSP field research team was able to link up with the EQL pesticide residue analysis personnel to merge common goals for decreasing risks from pesticide misuse, pesticide application where other IPM techniques can provide equivalent or better protection, and loss of revenue from not meeting organic standards for exported agricultural products.

Second, Drs. Dunkel and Yeboah established linkages with growers, exporters and NGOs in Mali to discuss exchange information on needs related to pesticide residues and agricultural products in Mali.

Research Investigator Exchanges

In November 1998, L. Torma, director of the Chemistry Station Analytical Laboratory, Montana Agricultural Research Station, and H. Hieke, technician provided Dr. Traoré and the CLV Pesticide Residue Laboratory with reprints of their procedures in determination of chlorinated acid herbicides in vegetation using solid phase extraction cleanup and the use of multiresidue supercritical fluid extraction for determination of organophosphorus pesticides and chlorinated pesticides in soil. In addition, the Montana unit answered questions of CLV regarding fee schedules and analyses provided.

Dr. Dunkel received documents from Chemonics (Mali branch of international NGO supported by US AID), AGRO-NIGER, and CLV related to pesticide residues, pesticide production in Mali, export requirements, green bean grading standards for the European market, etc.

Research Information and Product Exchange

Impact of IPM CRSP-generated technology

The EQL has a set of field sampling procedures written in SOP format to use as as basis for sampling soil and water, and enhanced capabilities to carry out pesticide residue analysis. The comprehensive five year plan will enable it to provide to develop a full range of pesticide residue capabilities. These will include analysis techniques for organochlorine insecticides and fungicides (year 1), organophosphate insecticides (year 2), triazine herbicides (year 3), carbamate insecticides (year 4), and acid herbicides (year 5). The establishment of a collaborative scientific community with the above laboratories and programs at Virginia Tech will enable comparative methodology development studies to be undertaken, as well as facilitate the establishment of linkages with suppliers and sources of information, to put the EQL on a solid basis for long-term functionning after the end of the 5-year program.

The program will also develop a pesticide monitoring system for sampling and analysis of pesticides on agricultural products. This will begin with priority crops for export (green beans, hibiscus flowers, and mango) and local markets (tomato and lettuce). Testing of formulated pesticides will confirm the identity and quantity of active ingredients. This information will help the IPM CRSP's field research program with IER better target IPM field research to develop thresholds and alternative pest management strategies. This will result in a Quality Assurance Program linking research and education, agriculture and consumers, and economic growth and environmental safety.

The educational programs will be developed in partnership with the extension organization Opération Haute Vallée du Niger (OHVN), exporters, and non-governmental organizations for training pesticide applicators. This will be in effect research on the best modalities for pesticide education. Formation of a vendors' *ton* (association) will tap into their informal communication networks, and coupled with training in pesticides, harness those networks for IPM awareness and education. The objective will be to develop on-going, self-financed and self-guided programs for both farmers and vendors.

Regionalization is also an expected impact. The program will also build linkages in West Africa and with importing countries. Linkages will be established with other pesticide residue laboratories in West Africa for exchanges of results and collaborative methods development. Later in the program, neighboring countries will be invited to participate in a regional program designed to assist them in quality assurance. Contacts will be developed with regulatory agencies in Europe, with the objective of creating a pre-certification program similar to that developed by the IPM CRSP Guatemala site team for Guatemalan horticultural products exported to the U.S. Contacts with buyers and supermarkets handling Malian products, and with consumer groups interested in supporting developing country small-scale producers and organic production, will explore the possibility of obtaining consumer support for pesticide residue analysis, research, and extension programs, to make reduced pesticide and pesticide-free organic production more economic in Mali.

Other work under the program will include monitoring suspected poisonings of the general public, pesticide production workers, growers, and applicators, and assistance in cases of livestock poisoning due to pesticide-contaminated grains or forage. Since symptoms of poisoning in humans by anti-cholinesterase acting insecticides (organophosphates and carbamates) often mimic those of flu and malaria, it is possible that many cases of

pesticide poisoning in Mali are either misdiagnosed or untreated. Finally, the program will support a Malian graduate student in environmental monitoring and short-term training for Malian extension personnel involved in pesticide and IPM programs.

Through this new collaborative program in partnership with USAID and the IPM CRSP core research program, the EQL will not only acquire the technical skills needed to address pesticide residue analysis needs in Mali, but it will also develop the capability to serve as the premier laboratory of its type in West Africa. More than just participation in the global market, this program envisions building a new link in a global food system for the benefit of farmers, consumers, and the environment that supports us all.

Publications and Presentations

Journal Articles

Dunkel, F.V. and D.C. Richards. 1998. The effect of azadirachtin formulation on six nontarget aquatic macroinvertebrates. Environmental Entomology. 27:667-674. (Effects of pesticide residues on non-target organisms)

Videotapes

Dunkel, F.V. 1999. Assessment of pests, pesticide usage, and pesticide residues on horticultural crops for export and for urban consumption in Mali: Video introduction for the pesticide project of the IPM CRSP - Mali. 48 minute video containing the following:

Part I. Central Veterinary Laboratory, Pesticide Residue Laboratory, Bamako

* The facility
* Interview regarding pesticide residues, worker safety, and hazardous waste disposal issues in Mali with Dr. Haliamatou Traoré, director of the Pesticide Residue Laboratory

Part II. 1998-99 IPM CRSP field research in Sanambele

* Insect, weed, and suspected nematode problems in green bean production areas for European export
* Soil sampling procedure for pesticide residues
* Adjacent cotton production areas

Part III. Water Sampling for Pesticide Contamination in Farmer Wells

Part IV. Objectives of the IPM CRSP Pesticide Residue Project.

Presentations

Dunkel, F.V. 1999. Current perspectives on water quality, pesticide use, misuse, and residue accumulation in Mali, West Africa. Presentation for the students of Entomology 102. The Impact of Insects on Human Society: Global Perspectives. 29 March 1999.

Dunkel, F.V. 1998. Natural products: a pesticide residue problem for integrated pest management programs? Virginia State University. Petersburg VA. October 1998.

Project Highlight

Major progress has been made in moving a new, state-of-the-art pesticide residue analysis laboratory in Mali toward being able to receive and analyze samples. This has been made possible by additional funding support to the IPM CRSP from US AID-Bamako.

Appendix 1. Pesticides Used in Mali. (List provided by Dr. Halimatou Traoré, Director, Environmental Quality Laboratory, Central Veterinary Laboratory, 14 December 1998.)

Insecticides and fungicides	for cereal and peanut storage: cypermethrin, profenofos, omethoate, fenvalerate, deltamethrin, and phosphine for seed treatment of cereals and peanuts: heptaclor/TMDT, benlate/captafol/carbosulfan, dieldrin, chlorotalonil, metalaxyl/ carboxine/flurathiocarb for locust protection: HhCH, malathion, chlorpyriphos, finitrothion, bromophos, teflubenzuron, carbaryl, lamda cyahalothrine for general insect and/or fungal protection: pyrimiphos-methyl, endosulfan, propoxur, diazinon, bendiocarbe, deltamethrin, triazophoss, alphamethrin, chlorpyriphos ethyl, monocrotophos, omethoate, dimethoate, thirame, chlorotalonil, heptaclore/TMTD, benlate, captafol, cyfluthrin, omethoate, pyridaphenthion, phosethyl-aluminium, iprodione, isopropiolone, captafol, manebe, benomil, chlorotalonil, carbofuran, alphacymethrin
Rodenticide	chlorophacinome.
Herbicides	for cotton: paraquat, fluometuron for peanuts: dipromethrin, metolachlore for corn: atrazine/metolachlore for millet and sorghum: propazin/terbutulazine for rice: pretilachlore/dimetametryne and piperophos for general protection against weeds: salt of isopropylamine, glyphosate, terbuthylazine, fluometuron, promethrin, oxadiazon/propanil, bentazon/propanil, alachlor, fluometuron, dipropetryne/cetolachlore, cyanazine, propanil, diuron, alachlor, ametrine, 2,4-D.

Economic Analysis of Insect Control Trials on Green Beans

Investigators: A. Yeboah[1], K. Sissoko[2], Sissoko H. Traoré[2], and Gamby K. Touré[2]

Abstract

Economic data for the different treatments applied in the green bean insect management trial were collected in Mali. Values for items for which market prices were not readily available were estimated. The use of yellow traps in controlling insects on green beans was more cost-effective than the other treatments considered: the control, yellow traps plus neem oil, one application of Decis and two applications of Decis.

Objectives

The principal objective of this research is to determine the most profitable method for insect control with the objective of making a recommendation to farmers for adoption. Thus the main IPM constraint addressed is insect infestation of green beans.

Research Methods

The method of dominant analysis was employed where the different treatments were compared in terms of cost and benefits. The analysis was done for each village and then the average of the two villages. All values are in the local Malian currency of FCFA. Market price per kilogram of green beans was easily obtained and the cost for the various treatment items such as plastic, bamboo, Vaseline (solid and liquid), and Decis were also available. The cost of obtaining neem oil was, however, estimated. Due to the labor-intensive nature of producing this oil, the analysis considers two options: a total of one-work day and three-work days. The daily wage rate of 750 FCFA was used to evaluate the time component of this cost. 8 (the number of traps per hectare) and when appropriate the cost of rotating them was also estimated multiplied the cost per trap.

The results showed that the use of yellow traps only was the most profitable technology for each village and also for the average of the two. At the overall level, the net added benefit over the control was 2.831 million FCFA per hectare ($4,718 at 600 FCFA / U.S. $) for yellow traps and 3.122 million FCFA per hectare ($5,203) for yellow traps plus neem oil. However, the higher net benefit for the latter comes at a relatively higher cost per hectare mainly due to the opportunity cost for time for producing the neem oil.

Even when this time was conservatively estimated as 1 workday, the cost per hectare for this technology was 15,780 FCFA ($26.30) compared to 9,780 FCFA ($16.30) for yellow traps only. The marginal rate of returns were 28,955 per cent and 19,788 percent for yellow traps only and yellow trap/neem oil combination respectively. However, both technologies outperformed Decis whether it was applied once or twice.

The results are similar at the individual village level. At Sanambele, the use of yellow traps only was the most profitable technology with net additional benefits of 2.666 million FCFA per hectare ($4,443) compared to 2.540 million FCFA per hectare ($4,233))for yellow traps plus neem. The marginal rates of return were 27,266 and 16,100 percent respectively. The application of Decis was dominated at both levels of application. At Koren, however, the use of yellow traps and neem oil had a higher net additional benefit than the use of yellow traps alone [3.704 million FCFA per hectare ($6,173) versus 2.997 million FCFA per hectare ($6,173)]; the latter had a higher marginal rate of return (30,644 percent than the former 23,474 percent), compared with the control.

Project Highlight

Yellow traps are more cost-effective than the insecticide commonly used by farmers.

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Gender Issues of IPM Technologies Use and Adoption

Investigators: A. Yeboah[1], K. Sissoko[2], Sissoko H. Traoré[2], and Gamby K. Touré[2]

Abstract

Eight farmers were interviewed in Sanambele were interviewed in Koren on women's participation in different production and marketing activities, the role of women in the decision-making concerning the use of IPM technologies, and the participation of women in the marketing of green beans. The survey revealed that men are responsible for the application of insecticide, while mainly women and children do watering. Overall, owners of the farm irrespective of gender carry out production and marketing activities.

Objectives

It has been hypothesized that women have a strong interest in reducing pesticide use, because they perform many field tasks and are concerned about its potential hazards to their health and that of their children who are often with them in the field. It has also been hypothesized that men apply pesticides, but women perform most manual pest management activities, such as weeding, hand removal of insects, etc., as well as carry out watering which impacts on seedbed diseases. The principal objective of this research was to test the above hypotheses.

Research Methods

A three-page questionnaire was pre-tested in the two villages, Sanambele and Koren. These are IPM research villages where green beans are grown. The respondents were equally divided between research collaborators and non-collaborators.

The main findings included the following: Green beans are grown on individually owned fields and the owners did most of the work involved in production and marketing. However, the men are responsible for the application of insecticide even if a woman owns the field. On the other hand, mainly women and children do watering. All members of the family do harvesting and sorting. No application of herbicide was recorded. Storage, packaging, and transportation are done by Agro-Niger.

Decision-making is also done on individual basis. Fungicide application is done at the behest of Agro-Niger. The best quality product is purchased by Agro-Niger and the rest are sold either in Bamako or in nearby towns.

These findings do not fully support the hypotheses advanced above. The rate of pesticide application is the same for both men and women and mainly the owners of the farm irrespective of gender carry out production and marketing activities.

A major finding concerns the marketing of the crop. Despite the prevailing production constraints, farmers are able to produce great quantities of green beans. However, the current marketing arrangement is not adequate for all their production. For IPM technologies to have any major impact on the farmers, this marketing problem needs to be addressed. A farmers association is suggested as a possible solution. Such organization will facilitate accessing the marketing resources available in Mali. An example is the Agro-Enterprise Center, a USAID-funded project that among others has a Commercial Development Unit. This unit has the responsibility to provide agro-business with advice and support to improve their business performances. The principal objectives of the Center are:

1. Iincrease access to technologies and national, sub-regional and international market information;
2. Provide information technologies for production and processing;
3. Assure the promotion and marketing of fresh and processed products;
4. Strengthen agro-business skills, particularly in the area of business plan development in order to improve financial performance and access new sources of financing;
5. Highlighting the role of the private sector in agricultural development and promote a regional uniformity of quality standards.

We plan to expand this survey with a larger sample in year 7.

Project highlight

A gender difference with implications for insect and disease IPM was found in a preliminary survey, with men responsible for the application of insecticide, while watering primarily done by women and children.

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Regionalization of IPM Technologies

Investigators: Gamby K. Touré[1], F. V. Dunkel[2]
Collaborating Scientists: Diakité M. Diarra [1], D. Khibé[1], Sissoko H. Traoré[1], M. N'Diaye[2], C. R. Edwards[3], and John Caldwell[4]

Abstract

In Year 6 we accomplished: 1) investigation of the best means of sharing IPM technologies with farmers; and 2) stimulation of assessment by neighboring countries of IPM technologies developed in Mali. Use of farmer-produced neem kernel products for preservation of cowpea seeds was established in the villages of Mourdiah and Douagabougou (Circle Nara) and in Sirakorola and Dontieribougou (Circle Sirakorola) during IPM CRSP years 4 and 5. In Year 6, this technology was extended to farmers and agricultural field agents in the San area of Mali, an entirely different section of Mali. This technology was also demonstrated in the field in Mali to Bean Cowpea CRSP scientist (IRAD-Cameroon) and the scientific basis explained at the laboratory in Montana State University for the Cameroon scientist. The flow diagram for how profit could be obtained from the use of the manual neem kernel press was presented to several Malian-based groups with regional responsibilities, responsibilities with farmers and with West African entrepeneurs. The development of this profit model included the use of other local natural products (peanut oil, sesame oil, oil of poughere) with known economic value that could be produced in the same manual press. To each of these groups, the broad spectrum of products possible from neem were presented. One farmer-field agent group worked with us to create a series of poster concepts. The basic poster was designed. These regional-based groups to whom our IPM CRSP technologies were presented/demonstrated this year included: World Vision, a Malian branch of an international NGO; a Malian (Bamako) branch of a Washington, D.C. based NGO, Appropriate Technologies, Inc. (ATI); the Malian branch of an international for-profit NGO, Chemonics, currently strongly supported by US AID-Bamako funding; Malian branch of the US Peace Corps; and the extension organization Opération Haute Vallée du Niger (OHVN) . Plans for a market analysis/feasibility study were written by ATI, and the IER scientists and a US IPM CRSP scientist joined with a Cameroon scientist to conduct farmer schools, train-the-trainer sessions and develop extension material to be used regionally. The result was a method to integrate the byproduct of an IPM program into the economic base of the community and the region and have a broader effect thanonly in pest management.

Objectives

1. To determine the best means of sharing IPM technologies with farmers and encouraging farmer-to- farmer exchange of information.
2. Stimulate assessment by neighboring countries of IPM technologies developed in Mali.

IPM constraints

1. Regionalization needs to be developed into a researchable problem, and its place in the research process better defined.
2. Farmer-to-farmer transmission of the results of on-farm research is usually very effective but moves slowly if gatherings, field tours, or other organized mechanisms are not added to reinforce natural diffusion.
3. Regionalization beyond national boundaries is often limited by inadequate funding for travel and the high cost and unreliability of telephone, internet connections, and fax in West Africa.
4. Better means of involving biological research scientists in regionalization is needed. These scientists often believe they do not have the training or expertise to work with the private sector, and as a result do not know how best to extend their results through these avenues that could rapidly disseminate their results to a wider audience and increase impact.

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Research Methods

Selection of NGO and Other Groups to work with in Mali and Regionally

NGOs specifically recommended by US AID/Mali and/or by the INSorMil CRSP based in Mali were contacted. These included Chemonics and the Peace Corps. The IPM CRSP has been strongly encouraged to collaborate with Chemonics, but Malian scientists needed to develop a coordinated workplan with them. Green bean grower groups and exporters we contacted were then suggested by Chemonics. The IPM CRSP has had discussion with Peace Corps, and one Peace Corps volunteer participated in part of the 1994 PA, but this relationship had not progressed beyond exchange of information in subsequent years. We conducted a series of extensive interviews with both for-profit (Chemonics) and non-for-profit [Appropriate Technologies Inc. (ATI), World Vision, Groupe de Recherches et d'Applications Techniques (GRAT), and Peace Corps) organizations. We met with ATI directors in both the Mali (Bamako) branch and the Washington, D.C. headquarters.

Developing and Sharing of Information on the Use of the Manual Press to Produce Neem Kernel Extract

In Year 6 we used feedback from phase I collaborating villagers over the previous 5 years regarding the use of the press and related products to develop information for extension and uptake by other organizations based in Mali, but with regional ties. We shared this information with each organization, which in turn that which techniques they considered appropriate at the level at which they provide training. Peace Corps and World Vision indicated it will incorporate our results into their village animations (dramatizations) and demonstrations. Chemonics will work with producers that are positioning their products for export markets. We answered questions posed by the growers and exporters based on phase I on-farm trials and real-scale lab and greenhouse research with neem application techniques. In addition, we included in our set of interviews, extensive discussions with the scientists and economists at Institut d'Economie Rurale. Based on all discussions, we created a set of flow charts to summarize the commercializable products available from the press, and presented a plan for beginning the process of developing small businesses in the Malian villages using the purchased press. We also interviewed one of the project officers at USAID-Bamako regarding possible funding from USAID-Bamako for regionalization.

Research results

Identification of Malian-based Organizations Interested in Disseminating and Regionalizing our IPM CRSP Results

We received verbal or written plans for implementation from the following Bamako-based units:

1. **World Vision**
This organization plans to use the material we provided them in their training sessions for trainers (*agronomes*) in their target villages, primarily southeastern Mali. The first training-of- trainers activity and farmer workshop was held at the Catholic Youth Conference Center of San, in eastern Mali. Participants included farmers housed in the dormitory of the Center, World Vision technicians, agricultural field technicians, and IER scientists. The practical part of the workshop was held on-farm. Dr. Gamby and Justin Dembele (IER-Sotuba) demonstrated neem tree products that work in insect protection, based on phase I IPM CRSP research. They also gave a slide presentation for the farmers. Dr. Ntoukam (Bean Cowpea CRSP-Cameroon) gave a demonstration of the construction of solar heaters and triple bagging storage.

2. **Appropriate Technologies, Inc. [ATI]**
Since the press is already in use for production of sesame oil under the guidance of ATI in various areas of Mali, the focus will be on inclusion of neem extraction using the presses. ATI will need information on how to use the products of the neem kernel and how to preserve the pesticidal/ antimicrobial properties after processing. ATI will do a market feasibility study of village-produced neem products. ATI does not have a loan program, but ATI might find a group of women who have the cold manual press who would be willing to extend this information. Increasing profit by users is the main objective of ATI efforts in Mali. There are three parts to the current program of ATI-Mali: 1) to promote use of the manual press and expand its usage geographically; 2) to improve financial management, particularly in businesses that use the press; and 3) to extend information on use of the press via animatrices.

3. **Peace Corps**
The Peace Corps focus will be in the Health Sector so we need to provide them with information on the safe use of pesticides; the use of neem for antimicrobial soap and anti-dental caries dentifrice; water quality, particularly with respect to pesticides; and grain safety, particularly with respect to keeping mycotoxins below their action level.

4. **Chemonics**
Chemonics will play a major role in our IPM CRSP dissemination and regionalization (Activity II-2) this year because of their substantial support from

US-AID Bamako. In November 1998, Dr. Dunkel met with the Chief of Party, Dr. Andrew Lambert and the Agricultural Marketing Specialist, Geoffrey Livingston. Exactly what this role will be specifically in our project and what we will be providing for them is yet to be determined because the Malians have not yet an initial meeting with them. The niche of Chemonics in Mali is with entrepeneurs who are not primary producers, e.g., exporters of agricultural products produced by farmers.

5. **The Scientific Community in Mali**
Besides IER and EQL collaborating scientists who are part of the Mali IPM CRSP site team, this group will include natural and social scientists from the German organization, Gezellschaft für Zusammenarbeit (GTZ), Chemonics, Peace Corps, and the former Protection des Vegeteaux (Moussa Sissako, who participated in the 1994 PA, and others, now reassigned after a reorganization which split PV into a pesticide regulation part and an extension part foled into another extension structure).

6. **GRAT**
Since GRAT already provides assistance with the use of the press, we will simply provide GRAT with information on how to use the neem products produced by the press.

7. **OHVN (Opération Haute Vallée du Niger)**
Apparently OHVN already uses the press in sesame oil production. If so, our role will be to provide them with information about how neem products can be used and how to store these materials to retain maximum activity. US-AID Bamako thought they should be doing the market feasibility study because they have already done this with other commodities.

Written Plan to be Prepared by ATI for Dissemination of IPM CRSP technologies

NGOs, generally, are good marketeers. Government structures are not useful in this type of activity. GRAT, the Malian NGO, did work for ATI in the early 1990s with improved mortar and pestles for processing of millet, sorghum and maize. The project was managed remotely and although they were good on the research portion of the project, they had no experience with sustainable production. Bearing in mind these past experiences, the next step in the neem commercialization should be a financial analysis. An important question in this analysis is to determine how much neem is out there and what is the potential quantity that may be used. ATI and the IPM CRSP need to be proactive in exchanging information on this project. ATI and IPM CRSP Mali site scientists can exchange sound and video and photos by computer. ATI has agreed to prepare the following with input from the IPM CRSP Mali site team:

1. Work out finances for neem products
2. Define the probable market price range of neem products
3. Estimate consumer benefits, both on an individual basis and in a larger scale (Mali-wide). For example, how will commercialization of neem create jobs and profit for the rural economies, that is by creating revenues for small producers?
4. Determine where else in the world these types of neem products can be used. ATI can easily regionalize and internationalize them. ATI-Bamako will contact the Asia unit of ATI on these questions.
5. ATI will develop an idea paper (1-2 pages) to address these items.

Indentification of Other Value-Added Products Made from the Manual Press used to Produce Neem Kernel Extract

Two of the three products that were found to be efficacious against the preharvest and/or the postharvest pests in Mali identified in both the participatory assessment and in subsequent monitoring procedures were produced with the cold, manual press (Year 4 Annual Report on Postharvest Monitoring and Pest Management; Year 5 Assessment of Introduced and Natural Measures for (preharvest) Management of Insect Pests of Millet and Sorghum). These two materials were the neem kernel extract and the residue from neem kernel extraction. Producers in the four phase I research villages concluded that neem kernel extract was a good alternative for management of blister beetles, the head miner, the scarab beetle, and grasshoppers. During the interviews, however, we found that producers could not justify the purchase of a press for this purpose (= US$280 per press). We learned that presses are manufactured in two locations in Mali, Bamako and Mopti. Further discussion with two NGOs in Bamako (GRAT and ATI) revealed that these presses have already been introduced in parts of Mali for the production of peanut oil and sesame oil for cooking. Both of these seeds are produced in our phase I villages, but they are sold as a raw commodity without any value-added process on-farm. Peanut oil, villagers indicated, is used for cooking in these villages, but that which is available in the village market is currently commercially manufactured in Bamako. This peanut oil is relatively expensive for these village households. Sesame oil is also purchased in the local market and used for cooking, but considered relatively expensive. Another oil seed, poughere, can also be grown in these areas. Oil from poughere seeds is used for fuel (for household lamps) and as machine lubrication oil. Therefore, there are at least 6 commercializable products from one manual press: in addition to neem kernel extract for crop protection, and neem kernel extract for antimicrobial soaps within the home or for sale in the local market as a value-added product, there are peanut oil, sesame oil, fuel oil for

household lamps, and machine oil for lubrication. Increasing these commercial products through spread of press use could be viewed as a byproduct result of the development of IPM techniques in Sahelian and near-Sahelian areas..

Development of Regionalization Tools

During Year 6 a poster series was developed to visually convey information about the breadth of use of the products of the tree. This poster indicated how to prepare the products; how and when to apply them for preharvest protection; how and when to apply them to preserve seeds from harvest to planting; and other uses. We also wrote a prototype for a primarily diagramatic/visual technical bulletin that will be useful within the region when it is translated into Bambera, Fulfulde, and French. This bulletin will be part of an interCRSP series on seed protection.

Impacts

In the first 4 years of this project, we identified a local (harvestable within each village) natural product with pest management potential in preharvest and postharvest IPM systems in the Sahel and near-Sahelian areas of Mali. We have tested by-products of the plant and developed several formulations appropriate for use in villages in Mali. Full utilization of this plant, *Azadirachta indica,* however, requires the use of a press. A cold, manual press was introduced into the 4 villages where we conducted the Participatory Assessments in 1994 and have collaborated with the farmers in on-farm research since 1994. Operation of this manual press (owned by IER and brought to each village by the scientists and technicians for the farmers to test), the results with the various insecticidal products, and the labor involved in collecting that material (neem seeds) and preparing it for use were all considered positive by the farmers. Access to the manual press (not currently available in the villages), however, presented problems The main problem was, in Year 6, is now being solved by NGOs in the Sahel or near-Sahelian areas who already have encorporated the press for other oils into their program. Now, our research results will be used by these non-government entities to enhance their rural development programs.

World Vision is a international non-government, non-profit NGO which emphasizes rural development, with a branch in Mali. They provide credit through the use of direct loans and revolving loans, and financial management advice. Their staff includes 19 people in the base office in Bamako and about 200 "agronomes" or broadly trained agriculturalists (with what is equivalent to a B.S. degree) based in villages where World Vision has a program. These agriculturalists assist farmers with on-farm demonstratons and organization of cooperative groups. They are currently most active in eastern Mali, specifically in the areas of Bla, San, Koro, Sorotouna, and Yangasu. Successful internal regionalization within Mali will build confidence and experience in World Vision with IPM CRSP-generated technology, and thereby create groundwork for cross-national regionalization into other parts of Africa where they are active.

Conclusions

IPM CRSP field trials using ultra-low-volume application have been shown the effectivensess of locally produced neem kernel extract minus any dilutent. At this stage, the main constraint to adoption is how to enable farmers to gain access to the hand-held, battery operated, ultra-low-volume applicator at the time when it needs to be used. For this reason, in addition to demonstrating preharvest and postharvest efficacy of locally-produced neem kernel extract, developing a formulation/application technique for this material, and a plan for on-farm storage of the extract given the extreme conditions of heat experienced there, we have prepared a commercialization plan. This plan would provide for increased income to make more affordable to farmers the ULV applicator as well as the press needed to prepare the neem kernel extract. This, when implemented, would provide a ready, local source of neem kernel extract within the village when needed for preharvest and postharvest application on the farm.

Many times in IPM research, scientists stop with interpretation of field research and do not follow the practice through adoption or trace the actual economic impact of the IPM technique. In this case, adoption of neem kernel extract as a botannical pesticide was dependant on the availability of a press. This situation immediately moved the focus of the project into a commercial realm. For many field scientists it is uncomfortable to move from a focus on field plot or laboratory bench results to accomplishing goals in a commercial arena. A a result of this regionalization effort, we have demonstrated that this IPM technique can be moved into a commercial arena. We view this summary as a model that may be useful in West Africa and elsewhere in Africa.

Networking Activities

Workshops

1. Workshop for the Ethnopharmacology group (undergraduate students) from the University of Montana, Missoula held on 7 November 1998 in Bozeman MT (Montana State University [MSU] campus). Six graduate and undergraduate students and mentorees with an international focus presented a 3 hour workshop for students and faculty. The workshop was entitled "Adventures in Ethnopharmacology: From Village Elders to Toxicology Laboratory to Commercialization." Results presented included research using neem in integrated pest management systems. Another presentation, related to farmer participation, was titled, "Encountering, Capturing, and Scientifically Evaluating Traditional Wisdom." Video

segments were used from projects in several African countries, including Mali.

2. Using participatory IPM techniques, Dr. Dunkel conducted a one-day workshop in Petersburg, Virginia for farmers, Virginia State University scientists and administrators, agriculture Extension workers, in applying techniques used in African agriculture for pest management (primarily nematodes and soil fungi) in small vegetable farms in Virginia (October 1999).

3. Dr. Gamby and Dr. Georges Ntoukam, entomologist at IRAD (Maroua Research Center), Cameroon presented sessions for farmers and World Vision trainers in San, Mali (March 1999). These sessions included workshops on participatory on-farm research and integrated pest management.

4. Dr. Dunkel and her undergraduate mentorees presented their IPM research results for US and Mali-based projects for Dr. Ntoukam at Montana State University, 11 May 1999.

Research Investigator Exchanges

1. During a 3 day visit 11-13 May 1999, Dr. Dunkel exchanged recently published literature with and met with Dr. Georges Ntoukam, entomologist at IRAD (Maroua Research Center), Cameroon. Dr. Ntoukam is an entomologist working with cowpeas, sorghum and millet in northern Cameroon. He is also a member of the Bean Cowpea CRSP and , as such, is interested in our work on the botanicals used in the on-farm IPM CRSP trials with stored cowpeas in Mali. During his visit we wrote an extension bulletin to be used regionally in Mali, Burkina Faso, and Cameroon for safe storage of cowpea seeds.
2. Dr. Dunkel presented (poster) for scientists at IER-Sotuba and discussed nematode management in an integrated system with pesticidal green manure applications.

3. Dr. Dunkel facilitated group meetings and information exchanges at Virginia Tech and Virginia State University October 1998 to explore other insecticidal crops, e.g. *Tagetes minuta,* using the development of the neem tree as a model and to share results of our collaborative data. Faculty in Horticulture, Entomology, Biochemistry, Plant Pathology, and Soil Science participated. Principals of regionalization of IPM techniques, adaptation to differing agroecosystems, and participatory on-farm research were discussed.

Research Information and Product Exchange

Impact of CRSP-produced or recommended technology

Farmers now have a procedure for using neem kernel extract that can result in a fairly uniform application, that can use available equipment, and that does not use petroleum solvents that can be harmful, even fatal, to humans nontarget insects.

Farmers also have a plan for making available the press to produce the neem kernel extract by linking the use of the press with other commercializable products.

Seven groups in Mali other than IER are now interested in these technologies developed under the auspices of the IPM CRSP. One not-for-profit NGO (World Vision) has implemented a plan to use the technologies in their on-going farmer assistance program. Another NGO (ATI) has developed a plan for using our technologies with their sesame oil program in which they utilize the same manual press. Both of these NGOs have programs within the region outside of Mali and are well-positioned to regionalize the IPM CRSP technologies.

Assistance given to collaborating scientists

* Assisted in the laboratory testing of the miscibility resulting from village-produced surfactants for neem kernel extract.
* Drafted extension bulletin collaboratively with Bean Cowpea CRSP scientists on cowpea seed storage.

Publications and Presentations

Journal Articles

Jenkins, D.A., F.V. Dunkel, and K.T. Gamby. Storage temperature of neem kernel extract: Differential effects on oviposition deterrency and larval toxicity of *Callosobruchus maculatus* (F.)(Coleoptera: Bruchidae). In revision from Environmental Entomology with minor changes suggested by referees.

Kumar, A., F.V. Dunkel, M.J. Broughton, and S. Sriharan. Effect of root extracts of the Mexican marigold, *Tagetes minuta* (Asterales: Asteraceae) on six nontarget aquatic macroinvertebrates. Returned to Editor of Environmental Entomology with minor revisions suggested by referees. (This paper also presents a large set of data on the effect of "inert," petroleum-based solvents/surfactants on nontarget organisms in the environment. These are the same solvents used in commercial neem formulations. The paper, therefore, relates to the Malian village formulation of neem kernel extract with petroleum-based solvents.)

Jenkins, D.A., F.V. Dunkel, M.J. McClelland. J.E. Crites, and K.T. Gamby. Conquering miscibility problems of neem kernel extract for use in semi-subsistence crop

protection. In author review. To be submitted to the African Crop Science Journal.

Gamby, K.T., F.V. Dunkel, M.Diakete. [Protection of stored cowpeas with local plant materials in on-farm trials in Mali.] (in French). In author review. To be submitted to the African Crop Science Journal.

Gamby K. Touré, J.S. Caldwell, and C.R. Edwards. Use of Neem oil, *Bacillus thuringensis*, and Leaf Removal for Control of Blister Beetles on Pearl Millet In Mali. Author review completed. To be submitted to the African Crop Science Journal.

Dembélé, B., J.S. Caldwell, and J. Westwood. Lutte integrée contre le *Striga*: Evaluation participative de deux approches variétale et agronomique en milieu paysan au Mali. French version prepared by Dembélé; English version in preparation. To be submitted to Weed Technology.

Refereed Proceedings

Caldwell, J.S., Mme. Gamby K. Touré, M. Erbaugh, B. Dembélé, C.R.Edwards, and A. Diarra. 1998. Merging farmer knowledge and priorities with scientific knowledge and research methods for participatory development of IPM technology for control of blister beetles and Striga parasitic weed in Mali, West Africa. Pp. 1030-1037 in: Association for Farming Systems Research-Extension (AFSRE), Proceedings of the 15th International Symposium, Rural Livelihoods, Empowerment, and the Environment: Going Beyond the Farm Boundary. AFSRE, Pretoria, South Africa, 29 November-4 December 1998.

Working Papers

Gamby, D.T., F.V. Dunkel, and D.A. Jenkins. Postharvest alternatives in cowpea systems: Use of neem, other bioactive plant products, and insects-resistant varieties. IPM CRSP Working Paper. returned for revision (conversion from a symposium proceedings paper).

Extension Publications

Dunkel, F.V., G. Ntoukam, L.L. Murdock, and K. Gamby. Storage of cowpea seeds with neem oil. Technical Bulletin 5. IER, IRAD. In author review. (This is a prototype for a series of bulletins on other neem products useful in protection of cowpea seeds and in protection of cowpeas preharvest.)

Other Publications

Dembélé, B., A. Diarra, J.S. Caldwell, and Mme. Sissoko H.T. 1999. Integrated management of *Striga* parasitic weed in millet/cowpea association and adaptability of *Striga*-tolerant sorghum varieties under farmer conditions in Mali. Pp. 81-86 in: OIRD (eds.), Progress in IPM CRSP Research: Proceedings of the Third IPM CRSP Symposium, Blacksburg, VA.

Gamby, K.T., C.R. Edwards, J.S. Caldwell, and H.T. Sissoko. 1999. Approaches to blister beetle control on millet: botanical and biological agents, associational resistance, varietal resistance, and light and pheromone traps. Pp. 235-243 in: OIRD (eds.), Progress in IPM CRSP Research: Proceedings of the Third IPM CRSP Symposium, Blacksburg, VA.

Presentations

Dunkel, F.V. 1998. Adventures in Ethnopharmacology: from village elders to toxicology laboratory to commercialization. November 7, 1998.

Dunkel, F.V. 1998. The role of farmer-driven research in integrating local natural products into IPM systems. Seminar presented at the Agricultural Experiment Station, Virginia State University. Petersburgh VA. October 25, 1998.

Dunkel, F.V. 1998. Natural products for integrated pest management programs. Virginia State University. Petersburg VA. May 1998.

Caldwell, J.S. 1998. Merging farmer knowledge and priorities with scientific knowledge and research methods for participatory development of IPM technology for control of blister beetles and Striga parasitic weed in Mali, West Africa. Presented at 15th International Symposium of the the Association for Farming Systems Research, Pretoria, South Africa, 29 November-4 December 1998.

Training Output

Jenkins, D. (completed M.S. in Entomology at MSU-Bozeman, May 1998; currently a Ph.D. student at the University of Georgia-Athens) Spartanburg, South Carolina

Project Highlights

- We established a dissemination plan for our IPM results via the Mali Peace Corps and NGOs, both for profit (Chemonics) and non-for-profit (Appropriate Technologies Inc. and World Vision). Using all of our neem technologies developed, each of these units presented us with methods in which they will use appropriate techniques (from the IPM CRSP project) at the level with which they provide training. For example, the Peace Corps and World Vision will be incorporating our results into their village animations (dramatizations) and demonstrations. Chemonics will be working with

producers that are positioning their products for export markets.

- Use of neem kernel extract in the IPM programs in Malian villages will require the availability of a cold manual press in the village. We discovered that although these presses are manufactured in Mali, to be economical for village use, the press must also be used for other products with already established markets, e.g., sesame oil, peanut oil. In our target villages in the Sahelian and near Sahelian areas, we found that markets exist for these oils as well as the posssibility of a market for poughere oil pressed from local seeds. This oil is used for light and as fuel for small engines. Appropriate Technologies International (ATI) is already assisting farmers in using the press for sesame oil production. In Year 6 we assisted ATI in developing a plan for extension, commercialization, and feasibility (market price studies) with neem. Because of ATI's regional connections and international scope, this has excellent possibilities for regionalization of our IPM technologies in Mali.

- We implemented our dissemination plan for our IPM results by writing, collaboratively with a scientist at IRAD, an extension bulletin for use in Mali, Cameroon, and Burkina Faso and by creating, collaboratively with farmers, scientists, and field agents in Mali, a poster series featuring the uses of neem in IPM systems in Mali.

- We also implemented our dissemination plan by participating with other scientists from other countries in the West African region, in facilitating a train-the-trainers workshop in San region of Mali, organized by the NGO World Vision, involving farmers and "agronomes" or broadly trained agriculturalists who live in individual villages where World Vision has a program.

IPM CRSP Africa Site in Uganda

Site Chair: J. Mark Erbaugh[1]
Site Coordinator: Samuel Kyamanywa[2]
Deputy Site Coordinator: George Bigirwa[3]

The Collaborative Program: The Uganda Site operates under a Memorandum of Understanding with Makerere University Faculty of Agriculture. Dr. S. Kyamanywa, Chairman of the Crop Science Department, continues to serve as the Site Coordinator. He is functionally linked to the Ugandan National Agricultural Research Organization (NARO) through the Deputy Site Coordinator, Dr. G. Bigirwa. The Director General of NARO, Dr. J. Mukiibi, appointed Dr. Bigirwa as the IPM Coordinator for NARO in October 1998. In the recent reorganization of the Ministry of Agriculture and Animal Industries, all technology transfer (extension) activities now fall under the purview of NARO. The IPM CRSP team in Uganda consists of 4 co-PI's and 5 graduate students from the Faculty of Agriculture, 8 co-PI's from NARO and 4 extension agents, representing 8 separate disciplines. In addition, there are 7 USA based co-PI's who work collaboratively with Ugandan counterparts to plan and implement research activities. This multi-institutional and disciplinary program is coordinated by the Site Chair, Dr. Erbaugh at Ohio State University and administered locally by Drs. Kyamanywa and Bigirwa. In addition to the contact between the Site Chair and Coordinators each of the co-PI's are encouraged to maintain communication with their respective collaborators on individual research activities.

The IPM CRSP in Uganda is also working closely with five farmer associations, two each at research sites in Iganga and Kumi Districts, and an informal organization of tomato growers located in Mpigi District. Linkages with farmers, a cornerstone of this project, are maintained through on-farm trials, assessment and training activities and through contact with extension agents. This mode of operation has provided Ugandan research scientists with valuable on-farm experience and successfully raised their visibility in the rural areas.

IPM CRSP research efforts in Uganda are planned through a series of steps that seek to maximize institutional and farmer collaboration. An initial workshop was held on December 7-8, 1998, in Jinja, Uganda, with Ugandan co-PI's from Faculty of Agriculture Makerere University, the National Agricultural Research Organization (NARO) and the Ministry of Agriculture and Animal Industries' Extension Service to discuss progress and problems with the previous seasons' research activity implementation. This meeting also provided an opportunity to reassess and build upon the priorities originally established through the farmer participatory appraisal process, baseline survey, and farmer field pest monitoring activities. This on-going process of prioritization, evaluation and team building was aided by a visit to Uganda in December 1998 from Dr. S. Ramaswamy, a member of the IPM CRSP External Evaluation Panel (EEP). Co-PI's were then charged with discussing research plans for the upcoming season with collaborating farmer NGO groups and with USA based co-PI's. In early March another meeting of the IPM CRSP Uganda Site co-PI's and three USA based co-PI's was held in Mbale, Uganda to present brief progress reports, discuss priorities, and to develop draft work plans for Year 7. This draft work plan was then presented and discussed with Drs. Mukiibi, Director General NARO, and Sabiiti, Dean, Faculty of Agriculture, and Mr. R. Stryker, USAID/Kampala, before being presented by the Site Chair, Site Coordinator and Deputy Site Coordinator at the IPM CRSP Annual Meeting held at Purdue University in May, 1999. Another management component added this year was a Research Reporting Workshop held in Mbale, Uganda, in late August 1999. At this meeting 15 research papers prepared by co-PI's and graduate students were presented and critiqued. It is hoped that this workshop will fulfill the request and promise contained in the External Evaluator's report: "Everyone of the players involved in the (Uganda Site) IPM CRSP appears to be in synch, supporting each other's research activities to the extent that significant returns are expected".

The planning and implementation of IPM CRSP activities in Uganda also involves co-PI communication and collaboration with the local USAID Mission, the International Center for Insect Physiology and Ecology (ICIPE), the Rockefeller foundation through the Makerere University Legume Improvement Program, germplasm exchanges with three IARCs including IITA, CIAT and CIP and the founding of a Grey leaf spot collaborative network that includes several IPM CRSP USA and Ugandan co-PI's, CIMMYT/Harare, Rockefeller Foundation and several Universities in South Africa. Collaborative activities with ICIPE and the Rockefeller Foundation have provided opportunities to cost-share several graduate student training programs at Makerere University.

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[2] Makerere University
[3] NARO

IPM Constraints: The primary constraint to IPM adoption in Uganda is the lack of proven alternatives to multiple applications of chemical pesticides, particularly for important legume crops in Eastern Uganda, but also for newly added horticultural crops. The capacity of the Ugandan research system to develop IPM alternatives has been historically impeded by research fragmentation among the various institutions and by weak links between research scientists and farmers. During the initial participatory assessment and the later baseline survey farmers indicated a strong dependence on and use of multiple sprays to control pests and diseases on cowpea and groundnuts. Research efforts by the IPM CRSP have developed agronomic, and reduced spray alternatives for these crops, and, in the case of groundnuts have popularized a disease resistant variety. The presentation of research results by 15 co-PI's and graduate students in August demonstrated progress towards the development of IPM technologies for most priority crops. Another constraint is the lack of data on incidence and severity of pests and diseases. Farmer field pest monitoring results provided important documentation of the unrecognized importance of bean fly as a critical pest on beans. A survey of maize diseases demonstrated the importance of gray leaf spot. Remaining constraints are to sustain research momentum, to broaden impacts, and, to convince key policy makers that IPM is economically and socially viable. These constraints are intertwined, and require a redoubling of effort to document, disseminate and publish results. The recently completed follow-up assessment will help provide some of this information but greater attention needs to be applied to economic evaluations of IPM technologies. Several of these efforts have potential for impact in the United States. Perhaps the best example from the Uganda Site is the work being done on identifying genetic resistance to gray leaf spot, the number one foliar disease of maize in Uganda and in the US corn belt.

Institution Building: The IPM CRSP's emphasis on process, including research planning and farmer participation, and the locally recognized need to advance multi-institutional and disciplinary research have been recognized by several administrators as a key contribution of the IPM CRSP to agricultural research in Uganda. Another indicator of IPM's institutionalization is the creation of a new department of Crop Protection at Makerere University. Dean Sabiiti gives partial attribution to the IPM CRSP for stimulating the demand for this department.

Four Ugandan graduate students have made substantial contributions to on-farm data collection and to IPM CRSP activities as a whole. In a recent conference at Makerere where 38graduate students from the Faculty of Agriculture presented their research findings, two IPM CRSP graduate students placed first and third in a competition for best presentation. The graduate student training being done by Makerere University was another aspect of Uganda Site activities commended in the external evaluation report. Dr. George Bigirwa spent several weeks with Dr. R. Pratt, at the Ohio Research and Development Center entering and analyzing data from their survey of maize diseases. This collaboration has resulted in three papers being presented at the All African Crop Science Society meetings.

There were 8 trips made to the Uganda Site this year by USA based co-PI's. In addition Mr. Tom Debass, graduate student from Virginia Tech joined Drs. Erbaugh, Warren and Bhagsari to participate in the work plan development meeting, training of baseline enumerators program; and to collect data for his Masters thesis. Drs. Erbaugh, Gebrekidan and Luther also participated in the research results conference held in August. Drs. Pratt and Willson made individual trips to pursue their collaborative research activities.

Networking: In-country networking between the two primary agricultural research institutions in Uganda is promoted by the functional links between the Site and Deputy Site Coordinators, who remain in close contact through their respective heads, the Director General of NARO, and the Dean of the Faculty of Agriculture at Makerere. The Site Coordinator always ensures that USA based scientists make a courtesy visit with both the DG and the Dean and the Site Chair always meets with these two gentlemen to update them on progress and to seek their support on various issues that arise. Additionally, the composition of the Uganda team includes scientists from all the major research institutes in the country including Kwanda, Naumulonge, Serere and Kabanyolo research institutes. Also, meetings are regularly held and updates are provided to USAID/Kampala and the technical assistance personnel attached to the primary agricultural project in Uganda, the IDEA Project. As a result of his IPM CRSP involvement, Dr. Kyamanywa was invited to participate in a USAID consultancy which examined the USAID/Uganda Agricultural Sector Pesticide Procedures Guidelines and, Dr. Willson was asked to make contributions to the Quick Reference Guide for Crop Chemicals being produced by the IDEA Project.

Regional networking takes the form of communication, participation and occasional collaboration with other organizations and professional societies. Drs. Pratt and Erbaugh presented IPM CRSP acknowledged papers at the recent meetings of the All African Crop Science Society meetings held in Casablanca, Morocco, as did 2 Uganda co-PI's and 4 Makerere graduate students. The IPM CRSP was the only CRSP represented at this meeting. Drs. Erbaugh and Caldwell, Site Chair for Mali, presented papers at the 15th International Symposium of the Association for Farming Systems Research-Extension held in Pretoria, South Africa. Again, the IPM CRSP was the only CRSP represented at this meeting. ICIPE has cost shared the training of a graduate student with IPM CRSP, and Dr. Charles Omwega from ICIPE, participated in Mbale Workshop where research results were presented. The Site Chair and Coordinator also

held discussions with Dr. K. Gallagher, Senior IPM Officer of the Global IPM Facility, an entity initiating farmer field schools in Uganda and other countries in East Africa. Networking also continues with the Rockefeller Foundation. Joint activities with the Rockefeller Foundation occur via the Makerere University Grain Legume Program. Most recently, at the meeting in Morocco, the Grey Leaf Spot Network for East and Southern Africa was established with important inputs from Dr. Pratt and leadership provided by IPM CRSP co-PI Dr. Adipala. At the organizational meeting the IPM CRSP's pioneering work in this area was acknowledge. Finally, the Africa IPM-Link continues to provide a network for dialogue across the continent on issues pertaining to IPM.

Selected Research Accomplishments:

1. Field trials with cowpea in Eastern Uganda established that the major diseases were viral (Cowpea mosaic virus), scab (*Sphaceloma* sp.), yellow blister (*Synchytrium dolichi* (Cooke), cercospora leaf spot (*Cercospora cruenta and C. canescens*) and powdery mildew (*Erysiphe polygoni* DC). The major insect pests were pod sucking bugs (*Riptortus* spp., *Nezara viridula*, *Acanthomia* spp. and *Anoplocnemis* sp.) and *Maruca* sp. and Blister beetle (*Mylabris* spp.). Trial treatments included effect of plant density, planting date and minimal pesticide application on disease severity and pest infestation. Trials indicated that a spacing of 60 x 20 cm. and planting at the on-set of rains significantly reduced disease severity and insect pest infestation. In addition, the minimum spray schedule consisting of two insecticide spray applications (as compared to the farmers' practice of using six applications) resulted in the highest yield and income.

2. *Striga* parasitism of sorghum can be minimized by using an integrated striga management strategy consisting of a striga tolerant sorghum variety, Seredo, modest fertilizer application, two hand weedings and interplanting with *Celosia argentia*, locally known as *Striga* chaser. Results indicate that use of a resistant/tolerant sorghum variety coupled with moderate dose of nitrogen (80kgN/ha) and weeding twice is the best approach to reduce the level of Striga attack and increase sorghum yield. Interplanting sorghum with *C. argentia* is an affordable alternative when farmers cannot employ use of improved varieties and fertilizer. The impact of interplanting sorghum with cowpea compared with interplanting with *C. argentia* on striga emergence was not significantly different. However, the cowpea intercrop reduced sorghum yield while *C. argentia* increased yield. This is explained by the cowpea growth habit of climbing the sorghum thus reducing sorghum height.

3. Development of an integrated disease and pest management package for groundunts indicated that the improved variety *Igola-1* was more resistant to rosette disease and Cercospora leaf spot compared to the two unimproved local cultivars despite the recording of high aphid populations. Thus, the resistance of *Igola-1* is directed to the virus and not the aphid vector. Close plant spacings recorded higher incidences and severities of leaf spot but lower rosette incidences and severities. Therefore the medium plant spacing of 45 x 15 cm along with the *Igola-1* variety is recommended to control both diseases. Foot rot and thrips were not affected by plant spacing.

4. *Chilo partellus* was found to be the predominant stem borer species in Eastern Uganda on maize and sorghum, and in importance is has surpassed *Busseola fusca* in Iganga District. Yield losses caused by stem borers on maize in Iganga were found to range between 212 and 440 Kg/ha. Intercropping maize with beans offers moderate levels of control on stem borer infestations. *Cotesia sesamiae* was the most common local parasitoid found. The introduced parasitoid, *Cotesia flavipes*, multiplied and released in a collaborative activity between the IPM CRSP and ICIPE, has been established and causes parasitism of up to 23% in Iganga and 18% in Kumi on *C. partellus*.

5. Seed dressing to control bean fly (*Ophiomyia* sp.) and root rots (*Fusarium soolani* and sp. *Phaseoli*) increased bean grain yields by 75%-156%. Diazinon was as effective in reducing bean fly damage as Endosulfan. Use of the fungicide Benlate as a seed dressing was not as effective in controlling root rots as use of Endosulfan supporting other observations that root rot infection is related to bean fly incidence. The impact of seed dressing is more pronounced under drought stress conditions. Earthing-up at first weeding reduced bean fly damage and increased grain yield between 32%-35%. The practice of earthing-up is recommended for small-scale bean production. Over 100 farmers near research sites in Iganga have been exposed to the practice of seed dressing and earthing-up through a combination of on-farm trials, farmer open-days, and the development and distribution of fact sheets.

6. Treatments testing the efficacy of selected biorationals, solarization and a synthetic insecticide to control damage by bruchids (*Acanthoscelides obtectus* and *Callosobruchus* spp.) found that beans admixed with Mexican marigold (*Tagetes* spp.) and *L. camara* dust had the highest bean damage level whereas beans mixed with tobacco dust had the lowest damage level. The performance of tobacco, Actellic, ash and solarization in reducing bean bruchid damage did not differ significantly. The most effective treatments for cowpea included solarization, and admixing with tephrosia and tobacco. Unlike in beans, solarization method did not affect cowpea seed germination/viability. Farmers in seven districts (Iganga, Kumi, Soroti, Katakwi, Lira, Apac, and Mpigi) have adopted solarization and admixing beans with tobacco leaf powder; and solarization and admixing of cowpeas with tephrosia or tobacco leaf powders.

7. Tomato growers ranked late blight (*Phytophthora infestans*) and bacterial wilt (*Ralstonia solanacearum*) as their most important disease problems during a participatory assessment held with growers in Mpigi District, March 1999. The PA also established that most farmers sprayed their tomatoes twice a week throughout the growing season. First season on-farm disease surveillance and pest-monitoring trials indicated that late blight was the most prevalent disease and thrips (*Megolurothrips sjostedti* (Trybom) the most prevalent insect pest. Three tomato clones tolerant to bacterial wilt were identified and introduced into on-farm trials. Farmers have already taken seed from these trials for use in their own fields. First season on-station trials on alternative methods to control late blight provides preliminary evidence that transplanting seedlings into a cover crop (Sirato) may provide protection by spores spread by rain splash on soil.

8. Longe-1, a commercial open pollinated variety demonstrated more resistance to maize streak virus than local varieties and out yielded local varieties. Intercropping did not significantly reduce maize streak disease incidence.

9. The profitability of growing maize as a monocrop versus intercropping with beans was evaluated using partial budgeting. The most profitable practice was to grow the improved and streak resistant maize variety Longe-1 in a monoculture providing the highest net cash benefit with an added return of USD 257/ha compared to the local maize monocrop with an added net return of USD 107/ha compared to intercropping with beans. The local maize monocrop yielded the lowest net benefit of about USD 10/ha compared to its intercrop. Intercropped Longe-1 added USD 159 in net returns per ha compared to the local maize intercrop.

10. Yield loss assessments derived from on-farm trials demonstrated that the prevailing yield loss due to stalk borers on a total stand basis was only 3%. If the same criterion is applied to the level of foliar stand injury observed by farmers, the prevailing yield loss on a total stand basis would be 2%. In general, farmer observations of pest activity on maize demonstrated that termites are a more significant problem than stalk borer. As a result, IPM CRSP activities on maize have shifted to a greater programmatic emphasis on termites than on stalk borer.

11. An important result of the farmer field pest monitoring program has been farmer training for their subsequent participation with on-farm trial experiments. Farmers participating in the process of collecting crop monitoring data become familiar with the importance of sampling procedures, record keeping, and develop an awareness of the systematic process required to participate in agricultural research. Since an important goal of participatory agricultural research is to empower farmers to learn, adapt, and to become active investigators, the contribution of this model program should be recognized.

12. Gray leaf spot (*Cercospora zeae-maydis*) resistant germplasm was identified with acceptable agronomic performance in both Ohio and Uganda. Breeding efforts to utilise disease resistance of tropical germplasm were successful and cooperative evaluations revealed suitable agronomic performance across temperate and tropical environments when breeding lines were testcrossed with temperate maize inbred testers.

13. A follow-up baseline questionnaire to obtain information on pests, pest management practices and socio-economic factors associated with knowledge, awareness and practice of IPM was administered to 200 farmers in Iganga and Kumi Districts in Uganda. Preliminary data analyses indicate that 63% of the respondents are using

pesticides on field crops. Pesticide usage is more common in Kumi than in Iganga district. Among the IPM CRSP focal crops that include maize, beans, groundnuts, sorghum, and cowpea, the most commonly sprayed crops are cowpea and groundnuts. In both districts, men are more likely than women to purchase and apply pesticides. However, within the household, women are commonly involved with pest management decisions.

14. Fifteen advanced potato clones with diverse backgrounds were screened for resistance/tolerance to bacterial wilt, one of the most serious diseases of potatoes worldwide and in Uganda. Five of the 15 genotypes, evaluated on the principle performance indicators of yield, plant survival, minimum rotting tendency and number of plants that survive till maturity, appear to be promising. The clones in order of performance are: 388575.9, 390854.11, 388575.5, 390018.3 and 388574.6. Future selection will involve tuber and culinary characteristics along with the initiation of intercropping trials.

AN ASSESSMENT OF THE OCCURRENCE AND MANAGEMENT OF COWPEA DISEASES AND PESTS IN EASTERN UGANDA

Principal Investigators: E. Adipala[1], H. Warren[2], M. Orawu[1]
Collaborating Scientists: S. Kyamanywa[1], M. Erbaugh[3]

Abstract

Two field experiments were conducted for three seasons at two on-farm sites in Kumi district, eastern Uganda. The first trial examined the effect of plant density and time of planting on occurrence and development of major diseases and insect pest infestation. The second trial compared the use of insecticide alone, and a combination of insecticide and fungicide for control of insect pests and diseases. The highest viral disease severities were recorded at spacings of 90 x 20 and 120 x 20 cm in comparison to 30 x 20 and 60 x 20 cm. The contrary was true for most of the fungal diseases. Disease severities generally increased with delayed time of planting, which coincided with increased rains. Pesticide application had a significant (P<0.05) effect on severities of the diseases. The highest severity was recorded on unsprayed plots in comparison to sprayed plots. Higher numbers of insect pests were recorded at 3 weeks after on-set of rains and at 30 x 20 cm than on-set of rains and wider spacings. Unsprayed plots had highest numbers of insect pests compared to sprayed plots. From the results, close spacing (60 x 20 cm) and planting at the on-set of rains reduced disease severity and insect pest numbers. Generally, pesticide application controlled most of the diseases and insect pests.

IPM Constraints

Cowpea is a legume of considerable importance in Uganda. However, its production is seriously curtailed by a multitude of field insect pests and diseases, resulting in low yields, less than 400 kg/ha (Sabiti *et al.*, 1994; Adipala *et al.*, 1997). Throughout the tropics, pests are the leading cause of low yields, accounting for up to 75% loss in grain yield (Omongo *et al.*, 1997). Diseases are also important, sometimes accounting for up to 25% loss in grain yield (Edema and Adipala, 1996). The diseases of economic importance on cowpea in Uganda include viral diseases such as Cowpea mosaic virus disease, scab (*Sphaceloma* sp.), yellow blister (*Synchytrium dolichi* (Cooke) Gaum), common rust (*Uromyces appendiculatus* pv *vignicola*), bacterial blights, (*Xanthomonas vignicola* and *Pseudomonas syringae*), zonate leaf spot (*Dactuliophora tarri* Leakey), anthracnose (*Colletotrichum lindemuthianum* Sacc. and Magnus Bri. and Cav.), Ascochyta blight (*Ascochyta phaseolorum* Sacc.), Cercospora leaf spot (*Cercospora cruenta* and *C. canescens*), foot rot (*Fusarium solani* (Mart.) Sacc.), pod mold (*Cladosporium vignae* M.W.Gardner), phyllosticta leaf spot (*Phyllosticta phaseolina* Sacc.), powdery mildew (*Erysiphe polygoni* DC.), and fusarium wilt (*Fusarium oxysporium* f. sp. *tracheiphilum* (E.F.Smith)

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W.C. Snyder and H.N.Hans (Emechebe, 1975; Singh and Allen, 1979). The relative occurrence and importance of these diseases, and common pests under farm conditions are, however, not well known. Also, little has been done to develop farmer-friendly management practices against these constraints. For example, it is not clear how cultural practices, like plant densities and time of planting impact on occurrence of cowpea diseases and insect pests infestation. Furthermore, farmers in eastern Uganda sometimes use up to 8-10 sprays per season to control insect pests, but this is not based on economic thresholds, and appear excessive (Karungi, 1999).

Objectives

i) To determine the effect of plant density and time of planting on occurrence and development of major diseases, and, insect pests infestation of cowpea.

ii) To determine the effectiveness of minimum pesticide application in management of major diseases and insect pests of cowpea.

Research Methods

The study was carried out on-farm in Kumi district during the long and short rains of 1998 and 1999. Two separate experiments were set up. The first experiment determined the effect of plant density and time of planting on the occurrence of major diseases and of insect pests infestation of cowpeas. The experimental design was a split-split-plot in which planting time was in the main plot, cowpea varieties in the sub-plots and spacings in the sub-sub-plots. Each sub-sub plot measured 3 x 3 m and was separated by 2 m alleys. Four spacings; 30 x 20, 60 x 20, 90 x 20 and 120 x 20 cm, and seven cowpea varieties; TVX3236, TVX274-02, IT82D-522-1, IT85F-1987, IT82D-716 (improved lines), Icirikukwa*i* and Ebelat (local types) were used, and the treatments replicated three times.

The second experiment studied the effect of minimal pesticide application on cowpea diseases and insect pests. The experimental design was a split-plot with cowpea varieties in the main plots and pesticide application in the sub-plots. Each sub-plot measured 3 x 3 m and was separated by 2 m alleys. The seven cowpea varieties used in the first experiment were also used in this experiment. The pesticide treatments included unsprayed control, fungicide + insecticide and insecticide alone. The fungicides used were Dithane-M45 (Macozeb 80% wp), at the rate of 30g/15l and Benlate (Benomyl) at the rate of 15g/15l applied as a tank mixture. The insecticide, Ambush (Cypermethrin) was applied at the rate of 45ml/20l. The pesticides were applied using a knapsack sprayer (Cooper Pegler, CP15) starting at 23 days after cowpea emergency and was continued at 10 days interval until physiological maturity.

For each experiment, 10 plants from the two middle rows were selected randomly for disease assessment. Severity of each disease was rated using a scale of 1-5 where; 1 = 0% (no disease) to 5 =>50% (very high). The number of pod sucking bugs (PSB) per ten randomly selected plants in each plot and number of Maruca larvae per 20 flowers/buds per plot were counted and recorded. These were the common pests on cowpea. The data were subjected to analysis of variance (ANOVA) using Mstatc computer package, and significant differences were compared using LSD at P= 0.05.

Results

Experiment 1: Effect of plant density and time of planting cowpea on disease severity and pest infestation. Only the main effects are presented in this report, as more detailed statistical analysis is still in progress. Severity of viral diseases were markedly higher at wider spacing (120 x 20 cm), whereas fungal diseases were more severe in the close spacing (30 x 20 cm) (Table 1). Also, disease severities were significantly higher ($P<0.05$) in the late planted cowpea, compared to those planted at the on-set of rains (Table 2).

Table 1: Effect of plant density on severity (%) of major cowpea diseases

Spacing (cm)	Viral diseases	Scab	Yellow blister disease	Cercospora leaf spots	Powdery mildew
30 x 20	18.0	11.7	20.8	23.0	17.3
60 x 20	20.5	11.9	20.7	19.4	14.5
90 x 20	23.1	13.0	20.4	19.8	17.6
120 x 20	24.2	11.8	22.6	21.3	14.0
LSD(5%)	1.6	NS	0.8	2.4	3.5
CV%	4.5	23.2	2.4	7.1	13.6

NS = not significant

Table 2: Effect of planting time on severity(%) of major cowpea diseases

Planting time	Viral diseases	Scab	Yellow blister disease	Cercospora leaf spots	Powdery mildew
On-set of rains	17.5	4.6	19.0	16.3	7.3
3 weeks after on-set of rains	25.4	19.7	23.3	25.4	24.4
LSD(5%)	1.5	4.3	0.8	2.5	3.8
CV%	4.5	23.2	2.4	7.1	13.6

Experiment 2: Effect of minimal pesticide application on disease severity and pest infestation. As expected, fungal disease severities were only reduced where fungicides were applied. Both the sole insecticide and insecticide + fungicide treatments reduced Maruca and PSB infestations, and markedly increased grain yields. The economics of each of these practices is being investigated. Significantly higher numbers of pod sucking bugs and Maruca larvae were recorded in the closer spacings than in the widely spaced cowpea. Similarly, higher numbers of pod sucking bugs and Maruca larvae were recorded when planting was done 3 weeks after on-set of rains than at the on-set of the rains (Table 3).

These results are in agreement with earlier work done by Gethi and Khaemba (1991).These authors reported that close spacing favoured insect pests for colonisation of cowpeas. In the case of Maruca, the dense planting also provides good shelter against natural enemies and adverse weather conditions (Oghiakhe *et al.*, 1991). The low Maruca infestation on early planted cowpea has been attributed to the canopies which are not attractive to Maruca. In case of sufficient rainfall, plants grow vigorously to attain dense canopies which favours Maruca infestation (Oghiake *et al.*, 1991) (Table 4).

Table 3: Effect of plant density and planting time on abundance of major cowpea insect pests

	Pod sucking bugs/ 10 plants		Maruca larvae per 20 flowers	
Spacing (cm)	Onset of rains	3 weeks after onset of rains	Onset of rains	3 weeks after onset of rains
30x20	8.7	15.3	2.0	4.1
60x20	8.3	8.7	0.7	1.3
90x20	6.6	6.3	0.6	0.7
120x20	4.7	6.0	0.3	1.0
LSD(5%)	2.9		1.5	
CV%	23.1		87.6	

Table 4: Effect of pesticide application on severity (%) of selected major cowpea diseases and Maruca and pod sucking bugs infestation

Treatment	Viral diseases	Scab	Bugs/10 plants	Maruca/20 flowers
Control	37.5	18.3	10.7	2.3
Fungicide + Insecticide	18.3	6.7	5.7	1.3
Insecticide	17.5	15.0	3.3	0.7
LSD(5%)	9.6	7.1	4.5	1.1
CV%	22.0	41.8	46.1	51.5

Conclusion

Since the spacing of 60 x 20 cm and planting at the on-set of rains significantly reduced disease severity and insect pests infestation, this practice could be recommended to farmers. The minimum insecticide spray schedule could also be recommended for control of the post- budding pests.

Project Impacts

- Farmers are now aware of the major cowpea diseases and insect pests and will likely use this knowledge to guide disease and pest management on cowpea.
- The minimum spray schedule if adopted could reduce pesticide usage and increase farmers yields and income.

Networking Activities

Part of this work was presented during the IPM CRSP workshop held in Mbale, Uganda, 27-28 August, 1999, and during the Faculty of Agriculture and Forestry, Makerere University Annual Graduate Student Workshop held 1 –3 September, 1999.

Publication

Draft paper is under review for Journal submission.

Training output

MSc. Student, M. Orawu has completed his two years training and is left with final thesis write up.

Project Highlights

- The use of minimum pesticide (insecticide) sprays have been shown to be effective in controlling two key insect pests of cowpea, Maruca and pod sucking bugs.
- Close spacings lowered the severity of viral diseases, but encouraged the spread of fungal diseases.

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EFFECT OF PLANT SPACING AND HOST GENOTYPE ON DISEASE AND PEST OCCURRENCE ON GROUNDNUT IN UGANDA

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Abstract

Rosette and Cercospora leaf spot diseases are the major constraints to groundnut production in Uganda. On-farm experiments were carried out in Eastern Uganda to design an integrated package to control both diseases. Different cultural measures (Plant density and planting date), number of chemical sprays and use of resistant varieties are being studied through farmer-participatory research to establish their effectiveness in the control of the diseases and expose farmers to these technologies. Preliminary results indicate that *Igola-1* is very resistant to both rosette and Cercospora leaf spots. Plant spacing has shown significant effect (P=0.05) on both the diseases. Closest spacing of 30 x 10 cm (1999A) and 45 x 15 (1998B) had the lowest incidences of rosette but highest severities of Cercospora leaf spots, while the wide spacing (60 x 30 cm) had the highest incidences of rosette and lowest severities of Cercospora leaf spots. Foot rot and thrips were not affected by plant spacing.

IPM Constraints

Groundnut (*Arachis hypogea* L.) is perhaps the most important grain legume crop in Sub-Saharan Africa. In Uganda, groundnuts are the second most widely grown grain legumes, the first being beans (*Phaseolus vulgaris* L.) (Busolo-Bulafu, 1990). They occupy 175,000ha with an annual output of 140,000 tonnes.

Diseases are regarded as major constraints to groundnut production throughout Sub-Saharan Africa (Subrahmanyam *et al.*, 1992). Rosette virus disease is the most important followed by early leaf spot (*Cercospora arachidicola* Hori) (Smith, 1984; Reddy *et al.*, 1990). Others which deserve mention are bacterial wilt disease (*Ralstonia solanacearum*), rust (*Puccinia arachis*), and stem rot (*Sclerotium rolfsii*) (Busolo-Bulafu, 1990). Rosette virus disease is spread by aphid vectors *Aphis craccivora* Koch (Homoptera, Aphididae) in a persistent manner (Hull and Adams, 1968). Although rosette disease epidemics are sporadic, yield losses approach 100% whenever the disease occurs early in the season (before flowering) (Subrahmanyam *et al.*, 1992).

Efforts to improve productivity of groundnut have emphasised use of host resistance (Smith, 1984; Busolo-Bulafu, 1990; Nigam and Bock, 1990). In Uganda, the variety *Igola-1* was released as rosette resistant and high yielding but its adoption is still limited and the mechanism of resistance to the disease is not clear. Preliminary studies by Adipala *et al.* (1997) indicate that the resistance might be directed to the virus rather than the aphid vectors. Other control measures against rosette include, manipulating plant density and planting date (Subrahmanyam, 1983; Sandhu *et al.*, 1985; Ramaniah, 1989), use of chemicals (Davies, 1975), eradication of volunteer crops (Reddy, 1984) and intercropping (Mukibbi, 1982). In case of Cercospora leaf spots, control also emphasises use of resistant varieties (Smith and Litrell, 1980), chemical sprays (Smith, 1984) and the same cultural practices as rosette (Kannaiyan *et al.*, 1989; Subrahmanyam, 1990). The use of chemicals in particular has not been well investigated. An IPM CRSP participatory appraisal in 1995 indicated that farmers were spraying groundnut against rosette at weekly interval starting at 10 days after emergence. However, to achieve high yields, it is now recognised that a better approach is to adopt an integrated management package (Cole, 1985). Such a package usually aims at minimising use of chemicals while harvesting the complimentary benefits of especially the cultural practices. Unfortunately, little is known about effectiveness of the individual disease management components, and more so, their interactive effects on the development of rosette and cercospora leaf spot diseases.

Objectives

The broad goal of this study is to develop an integrated disease and pest management package for groundnuts. Specific objectives are:

1) To reduce pesticide usage on groundnut.
2) To establish the effect of varietal resistance and cultural practices in management of groundnut rosette and Cercospora leaf spots.
3) To establish level of damage due to leaf miners, thrips and foot rot on groundnut in Uganda.

Research Methods

As part of a larger project on Integrated Pest Management system for groundnut diseases and pests, we investigated the

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effect of use of variety resistance and planting density in the management of groundnut rosette and Cercospora leaf spots. Effect of planting date and different spray schedules on the two diseases is also being evaluated. The study is also examining the importance of leaf miners, thrips and foot rot on groundnuts in Uganda.

Three groundnut varieties, i.e., an improved variety *Igola-1* (resistant), and two local varieties *Etesot* (moderately susceptible) and *Erudurudu* (very susceptible) were grown. The trials were conducted during the second rains of 1998B (October to February) and first rains of 1999A (March to August). Three on-farm sites were used in Kumi while only two were used in Iganga in 1998B. In 1999A two on-farm sites were used in each zone. Kumi is about 150km East of Iganga. The sites in each district were approximately 10 km apart and were considered as replicates.

The experiment was laid out in a split plot design with varieties in the main plots and the different plant spacing in the sub plots. Actual plot sizes varied depending on amount of land available. The groundnut varieties were grown at four different plant spacings during the first season, i.e., low density (60cm x 30cm, 6 plants/m^2), intermediate density (60cm x 20cm, i.e., 8 plants/m^2), and (45cm x 30cm, i.e., 7 plants/m^2), and high density (45cm x 15cm, i.e., 15 plants/m^2). The experiment was repeated in 1999A (March-July) but only three plant spacings were evaluated, i.e., 60 x 30 cm (6 plants/m^2), 45 x 15 cm (15 plants/m^2) and 30 x 10 cm (33 plants/m^2).

Data collection commenced two weeks post germination and continued weekly for eight weeks. For rosette incidence was assessed basing on the scale used by Adipala *et al.* (1998). For Cercospora leaf spots severity the nine point scale of Subrahmanyam *et al.* (1995) was used. Leaf miner damage, foot rot damage, aphid infestation and thrips infestation were also assessed. Leaf miner damage assessment was based on a score scale of 0 – 100%; where1= <20% (low damage), 2= 20-50% (medium damage) and 3 = >50% (severe damage). Foot rot damage was assessed basing on incidence of the disease per two centre rows of each experimental unit. Thrips infestation was assessed at a weekly interval starting at budding stage. Sampling for thrips was based on 20 flower buds/flowers per experimental unit, depending on the crop growth stage. The flower buds/flowers were put in vials containing 50% ethanol and later dissected under a microscope to separate the plant parts from nymph and thrips. The thrips (nymphs and adult) found were counted and recorded. Aphid infestation was assessed basing on a scale of 1-5, where 1= no aphids, 2= >10 aphids/plant, 3= 10-50 aphids/plants, 4= >50-100 aphids/plant, and 5≥100 aphids/plant, at a weekly interval beginning one week after groundnut emergency. Data were analysed statistically with version C of MSTAT Statistical package (Michigan State University) and means were separated using the Least Significant Difference (LSD) test at 5% probability level.

Results

Table 1 shows the effect of different plant spacings on the incidence of rosette, severity of cercospora leaf spots, aphid infestation, thrips infestation and yield. There was a significant (P= 0.05) effect of spacing on rosette incidence (Table 1), the spacing of 60 x 30cm having the highest incidences and 30 x 10 cm the lowest. Similarly, spacing had a significant (P=0.05) effect on Cercospora leaf spots severity with the closest spacing (30 x10 cm) recording the highest severity and the widest spacing (60 x 30 cm) the lowest. Aphid populations were generally low, but the effect of crop spacing was significant at P=0.05. On average the low plant density (60 x 30 cm) had the highest aphid infestations compared to the close spacings. There was no significant effect of spacing on root rot damage and thrips infestation. Likewise, there was no significant effect of spacing on yield. However Table 1 indicates that the closest spacing (30 x 10 cm, 1999A) gave the highest yields. The yields of 1998B were very low as a result of very severe drought in second season of 1998.

Table 1. Effect of plant density on the occurrence of the major pests and diseases of groundnut (Data pooled over two locations)

Spacing (cm)	Rosette incidence (%)	Cercospora leaf spots severity (1-9 scale)	Footrot incidence (%)	Thrips/20 flower buds	Aphid infestation (1-5 Scale)	Yield (kg/ha)
60 x 30	39.2	3.9	3.3	146.2	2.3	954.0
45 x 15	29.3	4.5	2.3	171.9	2.2	1678
30 x 10	14.5	5.2	2.4	172.4	1.7	2180-
CV%	5.3	8.1	55.1	10.7	16.7	35.7
LSD(5%)	10.2	1.1	NS	NS	0.05	NS

Table 2 shows the effect of host genotype on the occurrence of the major pests and diseases of groundnut in Uganda. Among the three varieties, *Erudurudu* was the most affected by rosette, while *Igola-1* and *Etesot* were least and moderately affected, respectively. *Erudurudu* had the most leaf spots while *Igola-1* had the least and *Etesot* moderate, basing on a score scale of 1-9. There were no varietal differences on aphid infestation, thrip infestation, root rot

damage and yield. However, yields were highest in Kumi and lowest in Iganga probably due to ecological differences.

Table 2. Effect of host genotype on the occurrence of the major pests and diseases of groundnut (Data pooled over two seasons and locations)

Variety	Rosette incidence (%)	Cercospora severity (1-9 Scale)	Foot rot incidence (%)	Aphid infestation (1-5 scale)	Thrips infestation	Yield (kg/ plot)
Igola-1	2.8	2.3	3.2	2.1	167.5	2895
Erudurudu	43.8	5.3	3.5	1.8	177.0	477
Etesot	33.3	3.2	1.8	1.9	146.2	1297
CV%	58.4	10.3	49.6	5.2	13.6	87.8
LSD(5%)	26.6	2.4	NS	NS	NS	NS

NS= Not significant

Discussion

Our results clearly indicate that the improved variety *Igola-1* was generally more resistant to rosette and Cercospora leaf spots compared to the two unimproved local cultivars. On the other hand, *Erudurudu* was most susceptible and *Etesot* moderately susceptible to both rosette and Cercospora leaf spots. However, high aphid populations were recorded on *Igola-1* yet this particular variety had the least incidences of rosette infection in both seasons. These results are in agreement with our earlier results reported by Adipala *et al.* (1998).

Yield was highest for *Igola-1* (resistant to both diseases) and lowest for *Erudurudu* (susceptible) a strong indication that use of resistance not only reduced disease level but also increased yields though not significantly. For all varieties the plant spacing of 30 x 10cm produced the highest yield. The preliminary findings suggest that use of host resistance coupled with close spacing (30 x 10 cm) should be included as part of IDM. However, other control packages appear necessary for the management of thrips and other pests. Additionally, close spacing increased cercospora leaf spot incidence thus requiring that other control components be developed for leaf spot management. Investigations are continuing, and more elaborate analysis of data is going on.

We are also evaluating the effects of time of planting on development of rosette and cercospora leafspot epidemics. In addition, we are developing minimum spray schedules for both diseases.

Project Impact

Farmers now appreciate the effect of plant spacing on disease development and yield. Most farmers are adopting the technology of close spacing to control rosette and obtain more yields. *Igola-1* has gained popularity both in Kumi and Iganga districts because of its resistance to rosette and high yields. Farmers are now able to recognise other pests of groundnut like thrips and leaf miners and the damage they cause.

Networking

NARO, Makerere University and Extension Departments organized field days to allow other farmers see the groundnut trials. Part of this work was presented during the IPM CRSP workshop held in Mbale, Uganda, 27-28 August, 1999, and during the Faculty of Agriculture and Forestry, Makerere University Annual Graduate Student Workshop held 1 –3 September, 1999.

Project Highlights

- *Igola-1* (improved variety) had significantly lower incidence and severity of both groundnut rosette and Cercospora leaf spot compared to the local varieties (*Erudurudu* and *Etesot*).
- *Igola-1* out-yielded the local varieties
- High groundnut plant density reduced aphid and rosette incidence but increased cercospora leaf spot severity.
- Foot rot and thrips were not influenced by plant density.
- Resistance of *Igola-1* and *Etesot* to rosette is directed to the virus and not the aphid vectors.

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CERCOSPORA ZEAE-MAYDIS RESISTANCE AND STALK STRENGH OF SELECTED TROPICAL MAIZE LINES TESTCROSSED TO CORN BELT TESTERS

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Abstract

Cooperative research on host resistance and breeding between U.S. and Ugandan researchers was facilitated by testcrossing selected tropical breeding lines from the OSU program with Corn Belt maize inbreds. We describe the gray leaf spot resistance and rind puncture resistance of breeding lines, testcrossed with Corn Belt maize inbred testers B73 and Mo17 which represent important Corn Belt heterotic groups. Replicated performance evaluations in Ohio, and in the mid-altitude region of Uganda, have revealed selections that are resistant to *Cercospora zeae-maydis* and of acceptable agronomic quality. Use of a modified force gauge (rind penetrometer) was undertaken to ensure data on stalk quality was obtained when natural stalk rotting organisms and stem-borers were not present.

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Objectives

To examine the impact of GLS disease severity on stalk; strength and economic yield; To examine the degree to which stalk integrity is impacted by combined action of stemborers and GLS; To identify sources of resistance to GLS in tropical adapted maize germplasm

IPM Constraints

Lack of resistant maize germplasm to prevent reduced yields due to pests and diseases; Need for improved screening techniques to select resistant germplasm with strong stalks.

Research Methods

Introduction: GLS rapidly spread throughout East Africa in the last few years and it now poses a serious threat to stable production of maize. The maize breeding program at OSU, and the CIMMYT maize breeding programs already were selecting breeding materials for resistance to GLS and provided a means for a rapid response by the NARO maize program to evaluate potential sources of resistance. Stem borers and gray leaf spot were identified as serious threats to maize production in Uganda. Insect tunneling activity in the stem, and high severity of gray leaf spot, are considered to increase the incidence of stalk lodging, but data are lacking with respect to the affects of gray leaf spot. In the U.S. Corn Belt, growers are typically advised to perform a "squeeze test" at the base of the stalk to monitor the integrity of the stalk during the fall following if gray leaf spot infestation has been high. It was considered possible that a method to quantify stalk quality might reveal genotypes with weak stalk strength in a more objective manner than the "squeeze test." It was also considered desirable to determine whether a measure of stalk strength would be useful in characterizing large numbers of accessions being screened for gray leaf spot resistance.

Materials and Methods

$F_{2:5}$ progenies from the cross Hi34 (University of Hawaii yellow maize release derived from Antigua-2D) and Tzi17 (IITA white maize release derived from RppSR-TZ) were planted in the field in 1997 and testcrossed to inbreds Mo17 (Lancaster Sure Crop heterotic group) and B73 (Reid Yellow Dent heterotic group). In 1998 testcrosses were planted near Apple Creek, Ohio in non-tilled maize stubble, in May, and near Kamenyamiggo in Masaka District, Uganda during October. Twenty four B73 and B73 testcrosses were planted in Uganda and 14 B73 testcrosses were planted in Ohio. Ten B73 testcrosses were the same in each test. Local checks were included in each test. Trials were planted in a randomized complete block design with three replications at Apple Creek and four replications at Kamenyamiggo. Similar disease inoculation and severity assessment protocols were used in each location. At approximately V6 to V8 stage of development (Ritchie et al, 1989) a pinch of ground infected leaves (Uganda) or infected oat kernels (Ohio) were inserted into the whorl of all plants. Disease severity assessments (plant leaf area affected or PLAA) were made on the middle leaves of five randomly selected plants from each replication three times in Ohio and five times (post-flowering) in Uganda. Yield data were obtained by machine harvest in Ohio and by hand harvest in Uganda. Stalk penetrometer resistance data were obtained using an Accutek force gauge modified according to methods described by Sibale et al (1992) on the same plants rated for disease reaction. Stem strength of the test materials was evaluated two times in each location, typically about one week before and after flowering. Final plant stands were recorded and prior to harvest the number of stalks broken below the ear was recorded. Stalk lodging as a percentage of broken plants was calculated. Average rind puncture resistance values were calculated for correlation analysis with lodging susceptibility values.

Results

Gray leaf spot development at the 1998 ATI site started before the onset of flowering and developed to high levels in the susceptible checks as the season progressed. Severity of GLS in Uganda was not as high as in Ohio. Post flowering ratings at ATI (9/01) showed 50% of the mid-leaf of susceptible hybrids were infected with gray leaf spot. Many OSU breeding lines, when combined with inbred Mo17, showed levels of resistance equivalent to that of resistant commercial hybrids. Resistance has been observed in lines e.g. OSU:973005 that also display good stalk strength. (Table 1.) At the late season rating period in Uganda, testcrosses with Mo17 showed lower GLS mean severity values than did testcrosses with B73 (4.5% vs. 8.5% respectively).

Yield values of test crosses and checks in Uganda were low due to unfavorable weather (drought). The range of yield in Uganda was from 2.1 to 3.1 Mg/ha and there were no significant differences among the entries and NZ checks. (Tables 1-3). In Ohio, the mean yield of the testcrosses was 8.8 Mg/ha and that of the leading commercial check hybrids was 12.3 Mg/ha. Average lodging of testcrosses in Uganda was 1% and in Ohio was 25%. The very low levels of lodging ath the sites where rind puncture resistance was determined precluded meaningful correlation analysis between rind puncture resistance and lodging data. Correlation analysis was performed and found to be near zero, but caution should be used in making any conclusions because so little lodging was observed in both tests. Correlation analysis of rind puncture resistance values obtained for the same set of testcrosses evaluated in both locations showed a fairly high positive correlation (0.68) indicating fairly consistent values are obtained for genotypes across macroenvironments. Caution should be used do to

the small sample size however (n=10). One may conclude, based on testing across broad environments, that the best breeding selections, when testcrossed with Corn Belt maize inbreds, Mo17 and B73, were disease resistant and competitive with local check varieties in Uganda but not in Ohio. The best lines have been selected for further breeding purposes.

Table 1. GLS tolerance and stalk strength of selected tropical breeding lines x temperate inbred testcrosses in Ohio during 1998 season.

	Rind Resistance Force			
ENTRY	7/24 (kg)	9/02 (kg)	AVG (kg)	GLS PLAA 9/01 (%)
PIONEER Hi-Bred Brand 3394	3.2	3.0	3.1	48
PIONEER Hi-Bred Brand 3352	4.7	4.0	4.3	21
PIONEER Hi-Bred Brand 33418	4.2	3.4	3.8	20
DEKALB Brand 683	3.2	3.2	3.2	10
Mo17 x OSU:973001	4.4	3.5	3.9	6
Mo17 x OSU:973002	4.1	3.4	3.8	6
Mo17 x OSU:973004	4.6	3.2	3.9	5
Mo17 x OSU:973005	4.3	3.7	4.0	6
Mo17 x OSU:973008	3.4	2.8	3.1	6
Mo17 x OSU:973009	3.4	2.9	3.1	7
Mo17 x OSU:973010	3.8	3.2	3.5	9
Mo17 x OSU:973011	3.4	2.9	3.2	7
Mo17 x OSU:973012	3.7	2.6	3.1	13
Mo17 x OSU:973013	3.6	2.7	3.1	11
Mo17 x OSU:973014	3.2	3.4	3.3	7
Mo17 x OSU:973015	3.7	3.5	3.6	8
Mo17 x OSU:973019	3.9	3.5	3.7	4
Mo17 x OSU:973021	3.4	3.1	3.3	8
Mo17 x OSU:973022	2.6	3.1	2.9	8
Mo17 x OSU:973023	3.6	3.0	3.3	9
Plot AVG	3.7	3.2	3.5	11
Comm. Check AVG	3.8	3.4	3.6	25
Testcross AVG	3.7	3.2	3.4	8

Table 2. GLS Severity of B73 testcrosses to Hi34/Tzi17 Progenies Evaluated in Uganda during 1998-99

Entry	GLS PLAA (%) (UGAN)
B73 x OSU:973004	10
B73 x OSU:973006	3
B73 x OSU:973007	9
B73 x OSU:973008	9
B73 x OSU:973009	7
B73 x OSU:973010	7
B73 x OSU:973011	7
B73 x OSU:973012	7
B73 x OSU:973013	7
B73 x OSU:973014	9
B73 x OSU:973015	9
B73 x OSU:973019	9
B73 x OSU:973021	8
B73 x OSU:973023	7
AVG	8.5
std. dev.	2.12

Table 3. GLS Severity of Mo17 testcrosses to Hi34/Tzi17 Progenies Evaluated in Uganda during 1998-99

Entry	GLS PLAA (%) (UGAN)
Mo17 x OSU:973004	5
Mo17 x OSU:973008	6
Mo17 x OSU:973009	6
Mo17 x OSU:973011	4
Mo17 x OSU:973012	4
Mo17 x OSU:973013	5
Mo17 x OSU:973014	5
Mo17 x OSU:973015	5
Mo17 x OSU:973021	6
Mo17 x OSU:973022	4
AVG.	4.5
std. dev.	0.71

We have not experienced sufficient disease severity or stemborer infestation to fully evaluate the efficacy of using the rind penetrometer for measuring stalk strength. While conclusive results are lacking, it would appear that a potential use of the penetrometer would be to eliminate accessions with poor stalk strength from the breeding program (Tables 4-6).

Table 4. Mo17 testcrosses to Hi34/Tzi17 Progenies Evaluated in Ohio and Uganda during 1998-99- Stalk Strength Evaluations Among Common Lines in both Tests

Entry	Oh rat. 1 Rind Res. force (kg)	Oh rat. 2 Rind Res. force (kg)	Oh Mean Rind Res. force (kg)	Ug rat. 1 Rind Res. force (kg)	Ug rat. 2 Rind Res. force (kg)	Ug. Mean Rind Res. force (kg)
Mo17 x OSU:973004	4.6	3.2	3.9	4	4.2	4.1
Mo17 x OSU:973008	3.4	2.8	3.1	3.2	3.8	3.5
Mo17 x OSU:973009	3.4	2.9	3.1	3.7	3.5	3.6
Mo17 x OSU:973011	3.4	2.9	3.2	3.1	3.7	3.4
Mo17 x OSU:973012	3.7	2.6	3.1	3.2	3.5	3.4
Mo17 x OSU:973013	3.6	2.7	3.1	3.4	3.3	3.4
Mo17 x OSU:973014	3.2	3.4	3.3	3.3	3.5	3.4
Mo17 x OSU:973015	3.7	3.5	3.6	3.3	3.9	3.6
Mo17 x OSU:973021	3.4	3.1	3.3	3.4	3.6	3.5
Mo17 x OSU:973022	2.6	3.1	2.9	3.6	3.7	3.7
AVG			3.4			3.9
std. dev.			0.71			0.32
Corr. Oh/Ug						0.68

Table 5. Performance of Hi34 x Tzi17 F5 breeding lines in testcrosses with B73 and Mo 17 testers at two locations in Ohio during 1998.

		Mean 2 loc.		
		Yield	Stalk	Grain
Tester	Selected Lines	Mg/ha	Lodging (%)	Mois. (%)
B73	**Hi 34 x Tzi 17 F5a**	9.6	17	24
B73	**Hi 34 x Tzi 17 F5b**	10.3	18	23
B73	**Hi 34 x Tzi 17 F5c**	10.9	13	24
B73	**Hi 34 x Tzi 17 F5d**	10.0	29	23
B73	**Hi 34 x Tzi 17 F5e**	10.2	22	23
B73	**Hi 34 x Tzi 17 F5f**	10.3	29	22
	mean	10.2	21	23
Mo 17	**Hi 34 x Tzi 17 F5a**	10.5	23	24
Mo 17	**Hi 34 x Tzi 17 F5b**	8.3	14	23
Mo 17	**Hi 34 x Tzi 17 F5c**	10.4	33	24
Mo 17	**Hi 34 x Tzi 17 F5d**	7.8	47	23
Mo 17	**Hi 34 x Tzi 17 F5e**	7.8	48	21
Mo 17	**Hi 34 x Tzi 17 F5f**	7.2	35	20
	mean	8.7	33	23
	Mean all entries	8.8	25	23
	Pioneer Hi-Bred Brand 3394	12.3	3	17
	B 73 x Mo 17	11.4	38	19

Table 6.Gray leaf spot severity of selected Hi34 x Tzi17 breeding lines, parent and checks at disease nursery, 1999.

Entry	GLS (%)
Hi 34 x Tzi 17 F5a	5
Hi 34 x Tzi 17 F5b	0
Hi 34 x Tzi 17 F5c	20
Hi 34 x Tzi 17 F5d	0
Hi 34 x Tzi 17 F5e	5
Hi 34 x Tzi 17 F5f	0
Hi 34	10
Tzi 17	20
B 73	60

Impact

Identified GLS resistant germplasm with acceptable agronomic performance in both Ohio and Uganda.

Networking Activities

Participated in meetings on the formation of a Gray leaf spot Network for East and Southern Africa.

Workshops

The Ugandan site coordinator and his assistant attended the annual meetings of IPM CRSP held in West Lafayette, Indiana, May 5-9, 1999.
Prof. Ekwamu attended the IPM CRSP workshop in Jinga during August 1999 and presented a paper on this subject.

Research Investigator Exchanges

Dr. Bigirwa worked with Dr. Pratt on the survey results during May 1999 in Wooster Ohio.
Dr. Pratt visited the test sites in Uganda during June 1999.

Research information and product exchange

Assistance was given to collaborating scientists with support of inoculation protocols, spreadsheet development, and statistical analyses.

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Training Output

Dr. George Bigirwa conducted data analysis for several weeks in my lab.

Project Highlight

Breeding efforts to utilize disease resistance of tropical germplasm were successful and cooperative evaluations revealed suitable agronomic performance across temperate and tropical environments when breeding lines were testcrossed with temperate maize inbred testers.

DISEASE DEVELOPMENT AND PROGRESSION IN COMMERCIAL AND LOCAL MAIZE VARIETIES UNDER MONOCROPPING AND INTER-CROPPING SYSTEM WITH BEANS

Investigators: G.Bigirwa.[1], H. Warren.[2], S. Kyamanywa.[3], T. Kalule[4]

Abstract

Disease development and progression in commercial and local maize varieties under mono-cropping and inter-cropping system with beans was monitored during the second season of 1998 (1998B)and first season 1999 (1999A). Gray leaf spot was the most predominant disease with the highest incidence of 63.3% and 90% in the 2 seasons occurring on all varieties irrespective of the variety of maize and cropping system. Longe 1, the improved variety was more resistant to maize streak virus and higher yielding compared to the local variety. Inter-cropping maize with beans did not reduce maize streak incidence and severity as earlier reported by some people. Area under disease progress curve (AUDPC) was more precise in detecting differences in disease reaction among treatments.

Objectives

The trial was set-up with 2 objectives:

- To compare the performance of a commercial open pollinated variety (Longe 1) with local variety under 2 cropping systems.
- To monitor the development and progression of maize diseases in sole and intercropped maize.

IPM Constraint

Maize is a major cereal crop in Uganda used for both food and cash purposes. In 1994 it was the second most important foreign exchange earner for the country next to coffee (Ministry of Planning & Economic Development, 1995). The crop has steadily been increasing since 1985 both in hecterage and production. However, yield per unit area seems to be stagnant, averaging about .2 t/ha (CIMMYT, 1994). This is attributed to factors like wide use of local unimproved maize varieties. It is believed that 60% of the maize grown is local unimproved, 35% improved open pollinated and 5% hybrids (Bantayehu and Brhane, 1991). Other factors responsible for the low yields include pests and diseases, low plant populations partly due to inter-cropping systems; declining soil fertility and drought (Bigirwa, 1995).

Research Methods, Results and Impacts

Methods: Four trials were implemented on-farm in Iganga district; 2 in Bulamagi sub-country and 2 in Baitambogwe sub-county. Planting was carried out on September 13th and 14th for the 1998 season and 10th -11th April for the 1999 season. Although the 1999 trial was almost similar to the 1998 one, there were a few differences; i) the number of replications changed from 2 to 3, ii) treatments changed from 4 to 5 to include sole beans; iii) a reference trial was established at Namulonge Research Institute to ensure that the bean yield data is obtained.

Two varieties, Longe 1 a commercial open pollinated and farmers' own variety were used. Each variety was grown as mono-crop and an inter-crop with beans (K132). Each plot measured 10m x 8m. Maize was planted at the recommended spacing of 75cm x 60cm, 2 plants per hill. Fertilizers, nitrogen (DAP) and phosphorous were applied at the rate of 60 and 45 kg per hectare respectively. Plots were kept weed free by regular hand hoeing. Bean (variety K132) was planted at a spacing of 75cmx10cm, one plant per hill and one row of beans between 2 rows of maize.

Recording of maize diseases commenced 50 days after planting and this was done regularly at an interval of 14 days. A total of 5 recordings were made in 1998 and 4 in 1999. Two approaches were used in recording diseases. Incidence of the most predominant disease (gray leaf spot) was determined in each plot by counting the number of diseased plants in every 10 plants. This was repeated 3 times in different positions of each plot.

In the second approach, 10 plants were randomly selected in each plot and tagged for periodic assessment of five diseases; maize streak virus, gray leaf spot (*Cercospora zeae-maydis*), northern leaf blight (*Exserohilum turcicum*),

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rust (*Puccinia sorghi*) and diplodia leaf blight (*Sternocarpella macrospora*). Severity was assessed using a scale of 1-5 (1= no or minor infection, 5= very heavy infection) for all diseases except for gray leaf spot where the Smith scale was used (Freppon *et al.,* 1996) which estimates disease severity in percentages on ear leaves. Disease progression was monitored 5 times in the growing season.

Incidence data were arcsine transformed to harmonize variances (Steel and Torrie, 1980). Data were subjected to analysis of variance (ANOVA) using MSTATC statistical software (Freed *at al.*,1988).

Results

The second season of 1998 (1998B) was characterized by a dry spell with insufficient rainfall throughout the season. This greatly affected the development of fungal diseases. From the usual 8 diseases recorded, only five were considered important; maize streak virus (MSV), gray leaf spot (GLS), northern leaf blight (NLB), tropical rust and sternocarpella leaf blight. However, first season of 1999 (1999A) was slightly better in terms of rainfall reliability.

Gray leaf spot was noted as the most predominant disease with average incidence of 63.3% and 90% in 1998B and 1999A respectively, occurring on all varieties irrespective of the variety and combination (improved or local, sole or inter-cropped). Tropical rust and GLS showed a significant increase with time compared to the other diseases. There were no significant differences in disease reaction except for maize streak. MSV severity was significantly higher in the local variety than in Longe 1 irrespective of the cropping system (Tables 1 and 2). This trend of events implies that the local variety lacks resistance to maize streak virus as opposed to the improved variety. No significant differences were observed between the local sole and local inter-cropped with beans. This is the third time in a row getting similar results. It can be concluded that earlier reports that inter-cropping maize with beans reduces maize streak severity and incidence (Bill, 1999) is not correct.

Table 1. Maize disease severity under sole and inter-crop with beans, 1998B

	MSV[a]		GLS		NLB		PP		SMAC	
Treatment	Sev.[b]	AUDPC[c]	Sev.	AUDPC	Sev	AUDPC	Sev	AUDPC	Sev	AUDPC
Longe	1.6 ± 0.1	35.7 ± 2.0	20.5 ± 1.1	89.4 ± 4.7	1.8 ± 0.1	63.5 ± 2.1	1.3 ± 0.1	50.6 ± 2.0	1.4 ± 0.1	5.1 ± 2.0
Longe + beans	1.5 ± 0.1	36.6 ± 0.8	20.8 ± 2.0	92.1 ± 4.1	1.9 ± 0.0	62.4 ± 4.5	1.3 ± 0.0	49.5 ± 1.0	1.4 ± 0.0	49.5 ± 1.1
Local	3.6 ± 0.2	69.1 ± 4.3	21.9 ± 2.3	99.9 ± 3.8	1.5 ± 0.1	59.9 ± 2.0	1.4 ± 0.1	53.7 ± 2.1	1.4 ± 0.1	53.1 ± 2.1
Local + beans	3.4 ± 0.1	64.5 ± 5.4	22.0 ± 1.7	93.5 ± 2.3	1.7 ± 0.1	60.0 ± 1.5	1.3 ± 0.1	49.4 ± 2.2	1.4 ± 0.1	51.1 ± 1.7

[a] MSV= Maize streak virus, GLS=gray leaf spot, NLB=Northern leaf blight
PP= Puccinia polysora rust, SMAC=Sternocarpella macrospora leaf blight
[b] Sev = Severity on 1-5 scale except for GLS (smith scale)
[c] AUDPC= Area under disease progress curve

During the 1999A season, the level of MSV was noted to vary among farms, being highest at Kulata and Mukalazi, with scores of 3.3 and 3.2 respectively as opposed to 2.3 at Byekwaso and Kisseke. The interaction between farmer and crop combination was highly significant (P=0.000). In all instances, it was higher in the local variety irrespective of being sole or inter-cropped.

Variations were observed in plant stand during 1998B with Longe 1 having a better stand than the local variety. Higher yields realized by Longe 1 can partly be attributed to this. However, even in situations where the stand of the 2 maize varieties was almost equal, Longe 1 still out yielded the local variety. The 1999A results confirm this since there were no disparity in plant stand. In all instances, the mono-crop gave higher yields than the inter-crop (Tables 2 and 3). The yields in the inter-crop could have been compromised by the competition of the two crops. Bean yields were generally poor and no significant differences were observed when inter-crop with the 2 maize varieties.

Table 2. Maize disease severity under maize sole and inter-crop with beans, 1999A

	MSV		GLS		NLB		SMAC	
Treatment	SEV	AUDPC	SEV	AUDPC	SEV	AUDPC	SEV	AUDPC
Longe	1.7±0.2	1.9±0.1	37.4±3.6	44.6±4.0	1.9±0.1	4.6±0.1	1.8±0.1	3.8±0.1
Longe + Beans	1.9±0.2	2.0±0.1	33.4±2.9	43.0±3.8	1.9±0.1	4.4±0.1	1.7±0.1	3.7±0.1
Local	3.6±0.2	3.8±0.2	30.2±4.7	42.4±5.3	1.6±0.1	4.2±0.1	1.7±0.1	3.8±0.1
Local + Beans	3.9±0.1	4.2±0.2	27.6±3.4	34.3±3.6	1.7±0.1	4.2±0.1	1.6±0.1	3.8±0.1

[a] MSV= Maize streak virus, GLS= gray leaf spot, NLB= northern leaf blight, SMAC= *Sternocarpella macrospora*
[b] sev= severity on 1-5 scale except for GLS the Smith scale was used
[c] AUDPC= Area under disease progress curve

Table 3. Yields (kg/ha) of maize and beans under sole and inter-cropping system, 1998B

Farmer	Treatment	Maize plants harvested	Yield kg/ha Maize	Bean
	Longe	58.7	5354.0 ± 243.0	
	Longe + beans	55.3	4985.7 ± 467.1	524.7 ± 65
Byekwaso	Local	47.7	4309.7 ± 513.0	
	Local + bean	53.9	4512.3 ± 462.9	389.8 ± 79
	Longe	54.0	4984.0 ± 343.6	
Kisseke	Longe + beans	43.0	4657.0 ± 550.1	998.5 ± 143
	Local	35.7	3969.7 ± 779.0	
	Local + beans	39.8	3325.7 ± 117.4	1004.5 ± 54
	Longe	43.3	5714.7 ± 561.9	
Mukalazi	Longe + beans	43.0	4651.3 ± 285.7	_____[a]
	Local	35.3	3149.0 ± 287.3	
	Local + beans	26.0	3550.0 ± 392.5	_____
	Longe	53.3	3222.0 ± 453.0	
Kulata	Longe + beans	46.7	3116.7 ± 645.2	752.6 ± 92
	Local	41.0	2298.7 ± 618.1	
	Local + beans	35.7	1872.0 ± 326.2	602.7 ± 1

[a]It was not possible to get bean yield at Mukalazi because of drought

Three methods were used to establish the effects of diseases on the 2 maize varieties in the various combinations. These were; assessing severity using a 1-5 scale, area under disease progress curve (AUDPC) and incidence. The 3 methods showed significant differences in reaction to MSV but with NLB it was only the severity scale and AUDPC, while for *Sternocarpella macrospora* it was only with AUDPC.

Disease development at Namulonge was low compared to Iganga. This was attributed to the hash weather conditions which prevailed. This too was reflected in yield. Iganga has an average of 6919.2 kg/ha as compared to Namulonge with an average yield of 5342.8 kg/ha (Table 4). Maize yields were generally high irrespective of the treatment. Significant differences (P=0.004) were observed among treatments with the improved variety, Longe 1 out yielding the local. In all instances, the sole crop gave higher yields than the intercrop. Bean yield differences observed were due to high plant stand in a sole crop vis-à-vis inter-crop, but no significant differences were observed from an inter-crop with local variety or improved (Table 4). Even at farmers' level no differences were observed.

Table 4. Yields (kg/ha) of maize and beans under sole and inter-cropping system, 1999A

Farmer	Treatment	Mean of maize plants harvested	Yield kg/ha Maize	Beans
	Longe	62.5	8744.7±949.7	
	Longe + beans	60.6	8566.7±1038.7	347.9±105.7
Byekwaso	Local	49.0	6355.6±1512	
	Local + bean	59.0	4889.8±781.3	422.4±107.4
	Bean		1226.3±157.0	
	Longe	62.7	8505.8±267.9	
	Longe + beans	60.3	7056.8±1402.5	350.7±107.5
Kisseke	Local	59.3	8075.5±342.5	
	Local + bean	57.3	6894.3±1317.6	359.1±61.2
	Bean		1097.8±345.1	
	Longe	50.3	7197.5±724.7	
	Longe + beans	53.0	6364.7±433.5	605.1+120.4
Mukalazi	Local	51.3	5630.9±409.1	
	Local + beans	52.0	5455.9±1253.1	649.7±121.5
	Bean		1350.1±280.5	
	Longe	51.3	7040.2±364.4	
	Longe + beans	52.0	7798.9±1453.7	915.5+266.7

Table 4 *continued*

Farmer	Treatment	Mean of maize plants harvested	Yield kg/ha Maize	Beans
Kulata	Local	55.8	5796.8±1388.4	
	Local + beans	52.0	5733.3±354.9	512.2±151.5
	Bean		1182.9±65.3	
	Longe	48.6	5512.0±161.1	
	Longe + beans	51.3	5102.5±587.9	394.4±117.3
Namulonge	Local	54.9	4889.8±781.3	
	Local + beans	50.8	5867.0±1042.1	
	Beans		875.7±334.6	

Impacts

The study has had direct impacts on participating farmers who now understand the attributes of the improved variety (resistance to maize streak virus, high yields and early maturity which enables it to escape drought). The neighbouring farming community too, has come to appreciate the technologies demonstrated. The strategic positioning of the fields by the road sides, field days and fact sheets have helped the project meet its objectives disseminating the required technologies. Through regular training sessions, farmers were able to appreciate and learn to tell the different maize diseases particularly, MSV, NLB and GLS. The project has contributed to the wide adoption of the improved variety (Longe 1); it has also reunited the working relationships among NARO, university researchers, extensionists and farmers.

Networking Activities

Workshops

i) Maize research priorities and experience: Maize streak virus disease within the maize based cropping system. March2-3, 1999, Jinja, Uganda.

ii) Year seven workplan development meeting was held in Mbale Uganda, 5-6

iii) Visited Ohio State University to conduct data analysis and results of this work was presented in IPM CRSP in country Workshop held in Mbale.

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- Warren .H., Willson .H., Kyamanywa .S. and T. Kauma (1999), Effects of intercropping maize with beans on maize disease development and progression. Abstract to be in the proceedings of IPM CRSP Uganda in-country workshop.

Highlights

- Longe-1 more resistant to maize streak virus than the local varieties.
- Longe-1 out yielded the local farmers' variety.
- Intercropping did not significantly reduce maize disease incidence

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STEM BORER INFESTATIONS ON MAIZE AND ESTABLISHMENT OF *COTESIA FLAVIPES* (HYMENOPTERA: BRACONIDAE) IN EASTERN UGANDA

Investigators: Kyamanywa, S.[1], Matama-Kauma,T.[2], Ogwang, J.[3], Willson, H[4].
Collaborating Scientists: Omwega, C. O.[5], Erbaugh, M.[6]

Abstract

Two studies initiated during the second season 1997, were continued in 1998, and during the first season of 1999 in Eastern Uganda in Iganga and Kumi districts. On-farm trials were conducted in Iganga to determine the incidence and yield loss caused by stem borers on maize under mono and intercropping systems. A survey to determine the relative abundance of the stem borer species complex and the establishment of an exotic parasitoid *Cotesia flavipes* was also continued. Results obtained indicated that stem borer infestation is between 15-25% and intercropping reduced stem borer infestations. Yield loss assessment based on single stalk analysis indicated that stem borers cause a loss of 212 Kg/ha and yield loss was high in the sole crop compared to the intercrop. Furthermore, the results showed that *Chilo partellus* is the predominant stem borer species followed by *Busseola fusca*. *C. partellus* accounted for 60% of the stem borer species in Iganga and 80-90% in Kumi. It was established that *C. partellus* has overtaken *B.fusca* in Iganga. Several indigenous parasitoids of stem borers were encounted during the study, with *Cotesia sesamiae* being the most common, however, causing low parasitism. The introduced braconidae *Cotesia flavipes* was recovered from all sites of release in all the cropping seasons. *C. flavipes* caused parasitism of up to 22.6% in Iganga and 17.7% in Kumi on *C. partellus*. The study confirmed that *C. flavipes* is established in Eastern Uganda.

Objectives: The objectives of the study were: To determine stem borer incidence and associated maize yield loss under mono and intercropping systems; To determine the relative abundance of the stem borer species complex and their natural enemies; and, to introduce and monitor the establishment of *Cotesia flavipes* Cameron for the biological control of *Chilo partellus*.

IPM Constraint: The lepidopteran stem borers are generally considered as the most damaging pests of maize and sorghum in mainland Africa (Mohyuddin and Greathead, 1970). Several species of stem borers occur, however, *Chilo partellus* Swinhoe (Pyralidae), *Busseola fusca* Fuller (Noctuidae), *Sesamia calamistis* Hampson (Noctiudae) and *Eldana saccharina* Walker (Pyralidae) are the most important (Girling, 1978; Okoth and Kalule, 1990). Work on research stations has indicated yield losses of 60% on sorghum (Starks, 1969) and up to 37% on maize (Kalule *et al.*, 1994). Although chemical control has been shown to reduce stem borer damage (Mathez, 1972; Warui and Kuria, 1983; Kalule *et al.*, 1997), maize and sorghum are mainly grown by subsistence farmers who in most cases can not afford the cost of pesticides. Hence the need for developing a pest management system that is less costly for farmers and more environmentally friendly. Intercropping is a component of such a system that has been reported to reduce

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[6]Sociologist, Ohio State University, USA

stem borer damage (Omolo and Seshu Reddy, 1985; Minja, 1990; Ampong-Nyarko *et al.*, 1994a). Therefore, this study investigated the effect of intercropping maize with the common bean *Phaseolus vulgaris* and the yield losses caused by stem borers on maize.

All stem borer species, with the exception of *C. partellus*, are indigenous to Africa. *C. partellus* is an exotic borer from Asia which has invaded the sub-saharan region overtaking the indigeous stem borers in some places (Overholt et al., 1997; Kfir, 1997). Local natural enemies have extended their host range to include this pest, but the rate of parasitism is low. This renders *C. partellus* a good candidate for classical biological control. *Cotesia flavipes* Cameron is a parasitoid of *C. partellus* in its aboriginal region and part of this study addressed the re-association of *C. flavipes* with its host.

Research Methods: The studies conducted in the second rains of 1997and first rains of 1998, were continued in the second rains of 1998 and first rains of 1999 in Iganga and Kumi districts. In each district two sub-counties were selected based on information provided by the District Agricultural Offices and IPM CRSP activities (Erbaugh *et al.*, 1995), which indicated that they were the main maize growing areas of the district and farmers were organised in groups. The sub-counties were Baitambogwe and Bulamagi in Iganga, and Bukedea and Malera in Kumi.

Incidence and damage of stalk borers on improved maize in intercrop and sole cropped systems.

On-farm trials were conducted at Baitambogwe and Bulamagi Sub-counties in Iganga District. In each sub county, two farmers were selected for participation in the study. Two maize varieties Longe 1 and local maize (degenerated Kawanda composite), and a common bean variety K132 were used. Maize was planted at a spacing of 75x60 cm, 3 seeds/hole which were later thinned to two plants per hole. For the intercrop, one row of beans was planted between 2 rows of maize at a spacing of 10 cm between plants and one seed per hole. The maize and beans in the intercrop were planted simultaneously. During the first rains of 1999, beans were also planted as sole crop at a spacing of 50x10 cm, one seed per hole. At planting, DAP fertilizer was applied at a rate of 70 Kg/ha and Urea was applied as side dressing at a rate of 70 Kg/ha when the maize was knee high. The experiment was a factorial laid out in a randomised complete block design (RCBD) with 3 replications and was repeated on 4 farms.

Sampling began at three weeks after plant emergence and continued up to pysiological maturity. Ten plants ,randomly selected per plot, were uprooted, examined for stem borer damage and number of plants showing damage recorded. The plants were then dissected to expose the larvae and pupae which were counted and recorded. During sampling 10 plants showing stem borer damage per plot were tagged and later harvested. At harvesting, an area of 9 sq.m per plot was harvested from which yield/ha was determined. Yield loss was determined using the single stalk method (yield of healthy plant - yield of infested plant). Data were subjected to ANOVA and a t-test used to seperate the means.

Survey of cereal stem borers and estabishment of *Cotesia flavipes*

In Kumi three farmers growing maize or sorghum were selected per sub county and two per sub county in Iganga (the farmers involved in the on-farm trials). The parasitoid, *C. flavipes* reared at ICIPE, in collaboration with the National Agricultural Research Organization (NARO) had been released in the study area between January and August of 1998. To monitor its establishment, sampling was carried out three times per season. On each sampling occasion, 40 plants showing stem borer damage were sampled per farmer. These were dissected to expose stem borer larvae and pupae. The larvae and pupae obtained were sorted into species, recorded and placed in vials, then transported to the laboratory at Namulonge. Larvae were reared on maize stems until larvae died, pupated or parasitoids emerged. Parasitoids were identified at ICIPE and Namulonge based on the male genitalia. Percentages of stem borer species, abundance and parasitism were calculated.

Results: Stem borer incidence and larval density as influenced by cropping system is shown in Figures 1a and b. The percentage of plants infested were significantly higher in the sole crop than in the intercrop during the first rains of 1999 (Fig. 1a). There were no significant differences in percent number of plants infested between the sole and intercrop during the second rains of 1998. Larval density however, was significantly different during the second rains of 1998 and first rains 1999; the intercrop had fewer larvae than the sole crop (Fig. 1b). Yield data showed that maize grown as a sole crop had higher yields than maize intercropped with beans (Table 1). Stem borers caused a yield loss of 212 Kg/ha equivalent to 4-5 % yield loss per hectare. Grain yield loss was consistently higher in the sole crop than in the intercrop (Table 1).

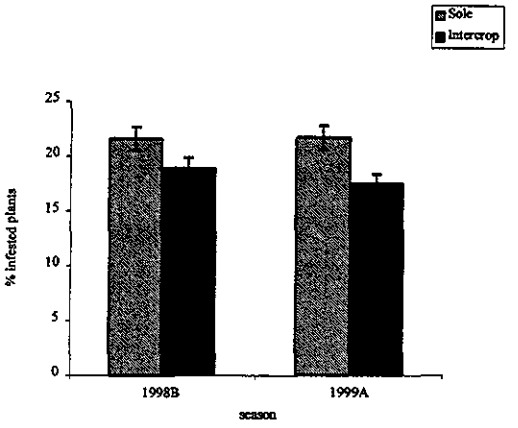


Fig. 1a. Stem borer incidence on maize under sole and maize/bean intercrop systems during the second rains of 1998 and first rains of 1999 in Iganga district.

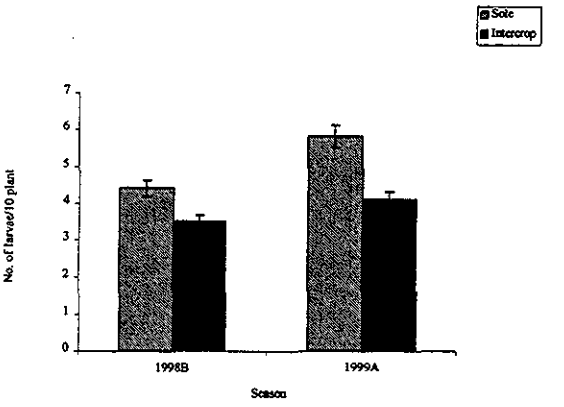


Fig. 1b. Larval density of stem borers on maize under sole and maize/bean intercrop systems during the second rains of 1998 and first rains of 1999 in Iganga district.

Table 1. Influence of stem borer damage on maize yield under mono and intercropping systems at Iganga in eastern Uganda

CROPPING SYSTEM	GRAIN YIELD KG/HA	GRAIN YIELD LOSS KG/HA	% YIELD LOSS
1998B			
MAIZE SOLE	4216.9+1434	212.7	5.3
MAIZE + BEANS	3980.0+1455	196.9	4.7
T-VALUE	NS		
CV (%)	20.6		
1999A			
MAIZE SOLE	8603.9+1939	439.5	4.9
MAIZE + BEANS	7178.7+1915	289.9	3.9
T-VALUE	NS		
CV (%)	20.4		

Four stem borer species *C. partellus*, *B.fusca*, *S.calamistis* and *E.saccharina* were found infesting sorghum and maize during the study in the two districts. Figure 2 shows the relative abundance of the 4 stemborers. During the second rains of 1998 and first rains of 1999, *C. partellus* was the dominant stem borer species in Iganga at 60% followed by *B.fusca* at 30%. *S. calamistis* and *E. saccharina* occured regularly but in low populations (Figure 2). The same trend was observed in Kumi where *C. partellus* was predominant during the 2 seasons accounting for 80-90% of the stem borers collected (Figure 2).

Fig.2a. Relative Abundance of the different stem borer species in Iganga and Kumi Districts during the second rains of 1998 and first rains of 1999

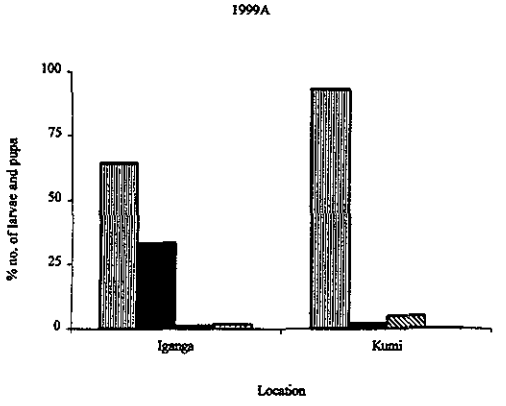
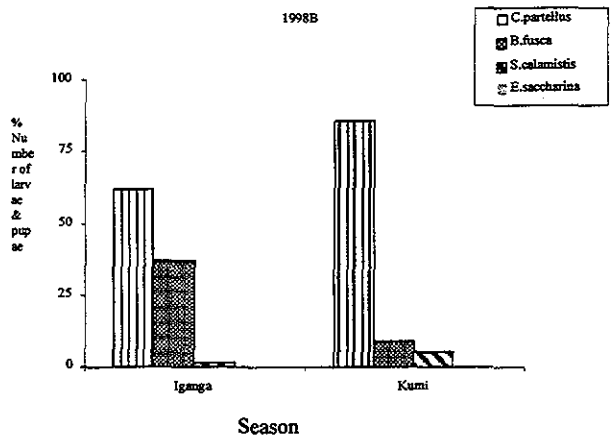


Fig.2b. Relative Abundance of the different stem borer species in Iganga and Kumi Districts during the second rains of 1998 and first rains of 1999



Several stem borer parasitoids were found and they are presented in Table 2. With the exception *Eurytoma* sp which was encounted once, all parasitoids were recovered several times during the study.

Table 2. Parasitoids recorded on stem borers of maize and sorghum during the cropping seasons (1997-1999) at Iganga and Kumi farms in Eastern Uganda

Parasitoids		Stage parasitized	Species parasitised	Site where recorded
Braconidae	*Cotesia sesamiae* cameron	larva	**C.p/B.f/s.c*	Iganga/Kumi
	Cotesia flavipes cameron	larva	*C.p/S.c*	Iganga/Kumi
Mermithidae (Nematode)	*Hexamermis* sp	larva	*C.p/B.f/S.c*	Iganga/Kumi
Ichneumonidae	*Dentichamias busseolae* Heinrich	pupa	*C.p/B.f*	Iganga/Kumi
Ichneumonidae	*Procerochasmias nigromaculatus* Hein.	pupa	*B.f*	
Eulophidae	*Pediobius furvus* Walker	pupa	*C.p*	Iganga/Kumi
Europtomidae	*Eurytoma* sp	pupa	*C.p*	Kumi
Hyperparasitoid				
Ceraphronidae	*Aphanogmus fijiensis*	cocoons	*Cotesia* spp	Iganga/Kumi

**C.p = Chilo partellus; B.f = Busseola fusca; S.c = Sesamia calamistis*

Larval parasitism on the different stem borer species is presented in Table 3. All stem borers were parasitised except *E.saccharina*. Parasitism in Iganga increased in the second rains of 1998 and first rains of 1999 when it rose to 18.7% and 25.5% respectively compared to 1997 and early 1998 (Table 3). Figure 3 shows percentage parasitism by *C. flavipes* and *C.sesamiae* on *C. partellus* in Iganga and Kumi districts. After *C. flavipes* release, it was recovered from all the release sites but the rate of parasitism varied from season to season. Highest parasitism by *C. flavipes* was recorded during the first rains 1999 in Iganga at 23% and in Kumi during the first rains of 1998 at 26% (Figure 3). It was also observed that the rate of parasitism by *C. flavipes* on *C. partellus* was greater than that of *C.sesamiae* except during the second rains of 1998 in Iganga.

Table 3. Number of larvae collected (n = 3rd-6th instars) and percentage stem borer parasitism (%) during 1998 and 1999 at Iganga and Kumi

Species	1998B		1999A		1998B		1999A	
	n	%	n	%	n	%	n	%
C.p	298	16.1	314	33.1	424	34.9	502	21.9
B.f	168	22.6	182	14.3	34	47.1	7	0
S.c	9	33.3	9	33.3	29	3.4	12	33.3
E.s	2	0	17	0	1	0	1	0
Total	477	18.7	522	25.5	488	33.8	522	21.8

C.p = Chilo

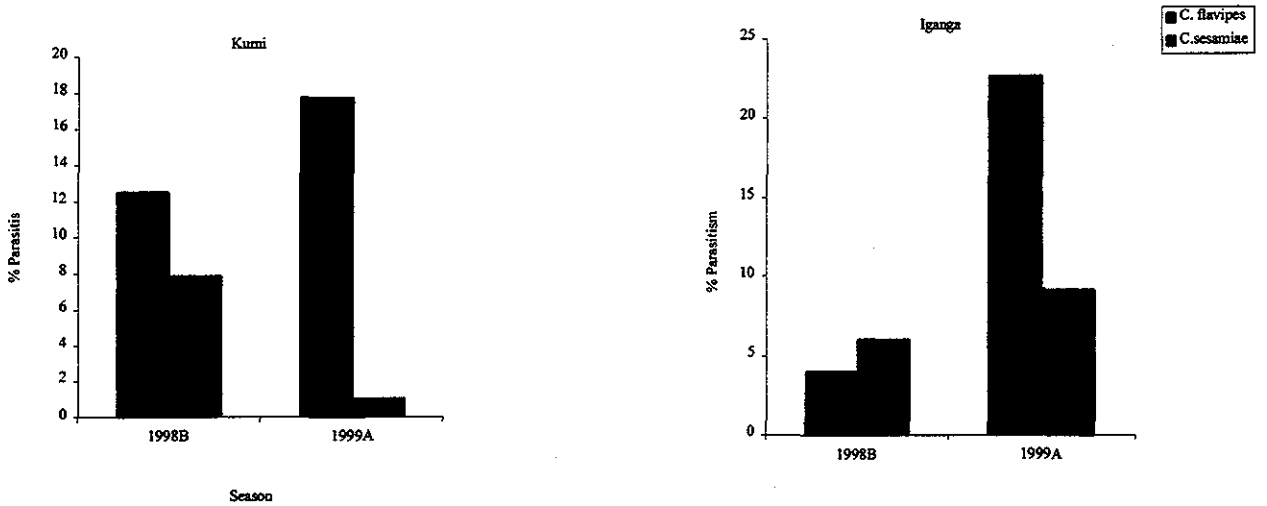


Fig.3 Percentage Parastism by Cotesia flavipes and Cotesia sesamiae on Chilo partellus during 1998 and 1999 in Iganga and Kumi districts

Discussion

There were significant differences in stem borer infestation due to the cropping system. Intercropping reduced stem borer infestations on maize although the results were not significant for all seasons. The results of intercropping on stem borer infestations has been contradictory. Minja (1990) and Ampong-Nyarko *et al* (1994a) registered a reduction in stem borer damage in plots where sorghum was intercropped with cowpea. However, Dissemond and Weltzein (1986) and Natarajan *et al*, (1991) recorded no significant differences in stemborer infestations between the intercrop and the sole crop. Similarly, Skovgard and Pats (1996) recorded very small differences when sorghum was intercropped with cowpea. This study demonstrated that intercropping maize and the common bean can reduce stem borer infestations. It was also found that grain yield loss was low in the intercrop compared to the sole crop. Therefore, the influence of intercropping appears to vary depending on location, season and crop combination. In this particular case, the maize-bean intercrop system can be recommended as a component of integrated stem borer management package.

During the period of this study, *C. partellus* was found to be the most abundant stem borer species in Eastern Uganda. Earlier studies by Ingram (1958) indicated that *C. partellus* was the most common in Teso (Kumi) and North Busoga becoming noticably less common in south Busoga (Iganga). Where as *B.fusca* was not as common as *C. partellus* it was widely distributed and extremely common in Busoga. The apparent reversal in stem borer abundance in Iganga is not clear. But it appears that *C. partellus* has displaced the indigenous stem borer *B.fusca*. This relates to observations made by Overholt et al (1997) that the exotic stem borer *C. partellus* seems to be displacing the indigenous species *Chilo orichalciliellus* at the Kenya coast. Similarly the displacement of *B.fusca* by *C. partellus* in some parts of South Africa has been reported (Kfir, 1997).

The results further indicated that after the release, *C. flavipes* was recovered from all release points with parasitism reaching 22.6% in Iganga and 17.7% in Kumi (Figure 3).

This confirms that *C. flavipes* has established well in eastern Uganda. The drop in percentage parasitism by *C. flavipes* in the second rains 1998, is perhaps due to the process of colonisation. As observed by Overholt's (1998), population densities of *C. flavipes* are related to the size of the geographical area with a suitable habitat. Hence the parasitoid disperses to all suitable habitats, and any increase in subsequent densities may take much longer, because dispersal has counteracting influence on increases in density (Overholt *et al.*, 1997). It is therefore important to look at both population density of the parasitoid in the area of release and its spread into the surrounding areas.

The impact of *C. flavipes* on stem borer damage can not be assessed at this point in time since it has to be allowed time for its populations to stabilise. However, where this parasitoid has been established it took at least 3-5 years to have an impact on borer damage (Overholt, 1998).

The survey also showed that *C.sesamiae* frequently parasitises all the borer species except *E.saccharina* but the magnitude of parasitism was low. *C.sesamiae* can therefore be augmented to boost parasitism on *B.fusca* that is not a suitable host of *C. flavipes*.

Impact

The study has that shown *C. partellus* is the most important stem borer of maize and that its parasitoid *Cortesia flavipes* has established itself in Iganga and Kumi. Therefore, the parasitoid is likely to reduce the damage by *C. partellus* and increase maize yield.

Furthermore, a graduate student has been trained in biological control. She is likely to have an impact in pest management.

Networking

Dr. Omwega of ICIPE attended the IPM CRSP conference at Mbale.

Highlights

Chilo partellus was found to be the predominant stem borer species in Eastern Uganda and it has overtaken *Busseola fusca* in Iganga. Intercropping offers some control on stem borer infestations. Yield losses caused by stem borers on maize in Iganga were found at between 212 and 440 Kg/ha. Several local parasitoids were found but *Cotesia sesamiae* was the most common. The introduced *Cotesia flavipes* has established and causes parasitism of up to 22.6% in Iganga and 17.7% in Kumi.

Presentations

Presented a paper entitled "Establishment of *Cotesia flavipes* Cameron, A braconidae parasitoid of *Chilo partellus* Swinhoe attacking maize and sorghum in eastern Uganda" during the IPM CRSP conference and the 2nd Annual Graduate Seminar, Faculty of Agriculture, Makerere University. This paper was rated as the best overall out of 38 presentations and the student given a certificate of recognition.

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MANAGEMENT OF BEAN FLY (*OPHIOMYIA* SP) AND ROOT ROTS ON BEANS BY SEED DRESSING AND EARTHING-UP DURING WEEDING

Investigators: Kyamanywa, S.[1], H. Willson [2]
Collaborating Scientists: Opio, F.[3], V. Kasenge[4], J.M. Erbaugh [5]

Abstract

On farm trials were continued during the second rains of 1998 and first rains of 1999 in Iganga district, to determine the effect of seed dressing, earthing-up and intercropping on bean fly (*Ophiomyia* sp) incidence and damage on beans. Unlike the previous trials (4th and 5th IPM CRSP Annual Report), the effect of different seed dressing chemicals on the pest were compared. The seed dressing materials included Diazinon, Benlate and Endosulfan. Earthing-up; intercropping and seed dressing significantly reduced damage on beans by *Ophiomyia* sp. The effect was most pronounced on the seed dressed plots followed by the earthed-up plots and least on intercropped ones. Seed dressing with Endosulfan was the most effective in reducing bean fly symptoms compared to either Diazinon or Benlate. Seed dressing increased grain yield between 77% to 156%, and earthing-up increased grain yield between 25% and 32%. Intercropping did not increase bean grain yield.

Objectives

The objectives of the study were: (i) To compare the effects of earthing-up, seed dressing and intercropping on bean fly damage and bean root rot with farmers methods. (ii) To determine the effect of different seed dressing chemicals in controlling bean fly damage. (iii) To compare the effect of controlling bean fly and root rots on yield of beans.

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IPM Constraints

The bean fly is the main pest of beans in Iganga district where it causes severe losses in grain yield. Damage is characterised by swelling of the stem collar, yellowing of leaves and severe infestation leads to seedling mortality. It is believed that bean fly damage predisposes beans to root rot infestations. Hence controlling bean fly damage may result in reduced damage by root rots. IPM CRSP trials during the second rains of 1997 and first rains of 1998 indicated that seed dressing with Endosulfan reduced bean fly damage and increased grain yield by 72 % to 213%. This trial was repeated in the 2nd rains of 1998 and 1st rains of 1999 with the intention of considering the efficacy of two other seed dressing materials. The objective was to determine the control efficacy of other chemicals, besides Endosulfan, for seed dressing.

Research Methods

The study was conducted during the 2nd rains (October to December) of 1998 and 1st rains of 1999 in Baitambogwe and Bulamagi sub-counties of Iganga district. Six farmers, three farmers from each sub county, were involved in the study. The treatments included untreated bean seeds grown in a sole crop; Earthing-up (ridging) at first weeding in a sole crop; Seed treated with Endosulfan; Bean intercropped with maize; Seed treated with Diazinon; Seed treated with Benlate; and Bean seeds treated with both Endosulfan and Benlate. In the Endosulfan treatments, bean seeds were mixed with Endosulfan (a.i 35 w/v) at a rate of 10 ml in 2 litres of water for 20 kg of seed. For the Diazinon treatment, the seeds were mixed with the chemical at a rate of 28ml per 14 kg of seeds. Each treatment was planted in a plot of size 8m by 10m, and replicated two times on each farmer's field. A similar variety of bean, K 132, was planted by all farmers. Planting was done on 15th September 1998 and 27th March 1999. The farmers maintained the experiment while the scientists collected the data.

Data collection started at two weeks after bean emergence and continued at two weekly intervals for one and half months. Data collected included:- (a) Number of plants with yellowing symptoms per twenty plants per plot; (b) Bean plants damaged by bean fly per 20 randomly up-rooted plants; (c) Bean plants with root rot damage out of 20 randomly up-rooted plants; (d) Bean plants infested by aphids per 20 plants; (e) Pupae per 10 plants; and (f) grain yield at harvest taken from 2 x 2 metres quadrants.

Results

Seasonal incidence of bean fly on beans in Iganga districts.
The incidence of bean fly symptoms, damage and pupae in the two seasons are shown in figure 1. The proportion of plants showing yellowing symptoms, the number of plants with bean fly root damage, and the number of pupae per plant were higher in the second rains of 1998 than in the first rains of 1999. Over 85% of the bean plants manifested root damage due to bean flies in the 2nd rain season of 1998 as compared to about 10% of bean plants infested in the first rains of 1999. Similarly, over 35% of the plants showed leaf yellowing symptoms in the 2nd rains of 1998, while in the 1st rains of 1999 there were no plants displaying yellowing symptoms. The differences in infestation between the two seasons are associated with weather conditions and planting time.

Effect of earthing-up, seed dressing and intercropping on bean fly damage and incidence
Treating seeds with insecticides before sowing, earthing-up at first weeding and inter-cropping significantly influenced bean fly incidence and its damage (Table 1). In the 2nd rains of 1998, the proportion of plants damaged by *Ophiomyia sp*, and pupae density were significantly higher in the non-seed treated plots compared to the rest of the treatments. In the 2nd rains, however, the of bean fly damage and pupae density between non-treated, earthing-up, and inter-cropping were not significantly different. This is perhaps because of the low infestation level in the first rains of 1999.

Diazinon was less effective in reducing the damage of bean fly and its pupae population density compared to Endosulfan (Table 1.). Nevertheless its use resulted in significantly lower bean fly damage compared to non-treated plots, earthing-up and inter-cropping. Seeds treated with Benlate, resulted in a significant reduction in bean fly damage compared to non treated seeds, but was not significantly different from earthing up and inter-cropping.

Table 1: Effect of seed dressing, Earthing –up and intercropping on damage by, and population density of, bean fly

Treatments	2nd rains 1998		1st rains 1999	
	%Plant damaged by bean fly	No. pupae /10 plants	%Plant damaged by bean fly	No. pupae /10 plants
Not seed treated	81.1±34 a	25.0±11 a	10.1±8 a	1.9±2 a
Earthing-up	59.4±44 b	15.8±12 b	10.1±8 a	1.8±2 a
Seed treated with Endosulfan	16.8±24 e	2.5±4 d	0.06±1.6 c	0.1±0.3 c
Intercropped with maize	58.5±42 b	15.7±13 b	7.6±6 ab	1.4±2 ab
Seed treated with Diazinon	51.6±40 c	14.4±10 bc	2.3±2 c	0.3±0.5 c
Seed treated with Benlate	58.6±41 b	15.6±10 b	5.7±5 b	0.8±1 bc
Seed treated with Endosulfan and Benlate	45.5±34 d	9.3±8 c	2.1±4 c	0.3±0.8 c
LSD	4.13	5.89	3.30	0.77

In the 2nd rains of 1998, seed dressing with Endosulfan had the lowest incidence of plants with yellowing symptoms and root rots, compared to all other treatments (Table 2). Nevertheless the differences in incidence of yellowing plants between plots treated with Endosulfan, Diazinon and Benlate were not significant. In the 1st rains of 1999, however, there were no plants with yellowing symptoms.

Table 2: Influence of seed dressing, earthing -up and intercropping on incidence plant yellowing symptoms, and root rots averaged over sub counties and season.

	2nd Rains 1998		1st Rains 1999	
Treatments	% Plants yellowing	% plants with root rots	% Plants yellowing	% plants with root rots
Not seed treated	37.3 a	16.3 a	0.0	4.7
Earthing-up	18.0 b	12.7 a	0.0	5.6
Seed dressed with Endosulfan	2.5 d	4.0 b	0.0	4.7
Intercropped with maize	13.5 bc	4.7 b	0.06	5.0
Seed treated with Diazinon	7.5 cd	5.0 b	0.00	7.5
Seed treated with Benlate	9.3 cd	12.0 b	0.00	2.8
Seed treated with Endosulfan and Benlate	13.0 bc	4.5 a	0.00	3.4
LSD	8.6 *	6.0	-NS	NS

Averaged over the two seasons, earthing-up, inter-cropping and seed dressing with Endosulfan, resulted in reducing plant yellowing symptoms by 22.2%, 21.4% and 64.7% respectively. Similarly there was a 12%, 14.3% and 89.2% reduction in plants with bean fly root damage in earthing-up, inter-cropping and seed dressing treatments respectively. The same reduction trend was observed for pupae density (Table 3).

Table 3: Reduction in bean fly damage by various treatment averaged over seasons and sub-counties

	Percentage Reduction in:		
Treatments	Plants showing yellowing symptoms.	Plants with bean fly root/stem damage	Pupal population density
Not seed treated	0.0± 0	0.0±0	0.00±0
Earthing-up	22.2 ±18	12±11	7.52±17
Seed treated with Endosulfan	64.7±37	89.2±8	96.0±4
Intrecropped with maize and not seed treated	21.4±30	14.3±13	21.2±11

The incidence of root rots, in 2nd rains of 1998, between Earthed-up and inter-cropped plots was not significantly different. While the incidence of root rots in Endosulfan, inter-cropping, and Diazinon treatments was significantly reduced compared to the untreated plots. Surprisingly, Benlate did not reduce root rots significantly. Similarly, combining Endosulfan with Benlate did not give full protection to the beans against root rots.

The incidence of *Aphis fabae* was generally higher in non-seed treated plots than in the other treatments. During all seasons inter-cropping had significantly lower incidence of *Aphis fabae* than the rest of the treatments. Seed dressing in general reduced the incidence of bean aphid. Earthing up did not influence aphid infestation on beans.

Effect of seed dressing, Earthing-up and intercropping on yield

All treatments, except intercropping, significantly increased bean grain yield per hectare (Table 4). Seed dressing with Endosulfan had the highest yield, followed by Diazinon, then the combination of Diazinon and Benlate, and finally Earthing-up. Intercropping did not significantly increase yield.

Table 4: Effect of Earthing-up and seed dressing on grain yield of beans per hectare

Treatment	Grain yield per hectare (Kg)			
	2nd Rains 1998		1st Rains 1999	
	Kg/ha	% increase in yield	Kg/ha	% increase in yield
Not seed treated	555 ± 433 de	0.0	1208 ± 172 d	0.0
Earthing-up	735 ± 274 cd	32.4	1520 ± 207 c	25.8
Seed dressed with Endosulfan	1425 ± 150 a	156.0	2145 ± 165 a	77.5
Intercropped with maize	210 ± 103 e	-62.1	1229 ± 176 d	1.7
Seed treated with Diazinon	1275 ± 150 ab	129.5	2041 ± 213 a	69.1
Seed treated with Benlate	802 ± 236 cd	44.6	1750 ± 218 bc	44.8
Seed treated with Endosulfan and Benlate	945 ± 57 bc	70.2	1976 ± 301 ab	63.5
LSD	360		235.5	

-ve show low in grain yield in comparison with untreated plot.

Discussion

The results of the two growing seasons have demonstrated that even under farmer management, use of seed dressing reduced the incidence and damage of been fly on field beans, and increased grain yield between 77% to 156% depending on the season. Earthing-up also reduced bean fly density and increased yield between 25% to 32.4%. Although intercropping reduced bean fly damage, it depressed bean grain yield.

The impact of seed dressing was more pronounced during the second rainy season, which usually receives less rain than the first one. This difference seems to be associated with drought conditions in the first and second rains. Usually second rains have relatively more dry spells than first rains; as observed by Hill (1975) bean fly infestation is more serious in a bean crop under drought stress. Another factor, however, is time of planting. Although it was not one of the factors studied, the present data seem to indicate that the bean crop planted between 3 to 4 weeks after the on set of rains in 1997, 98a, 98b were more damaged by bean fly than those planted on time, immediately after on set of rains. Therefore the use of seed dressing would, particularly, be important if sowing is to be late or where drought spells are more frequent.

Diazinon was as effective in reducing bean fly damage and increasing bean yield as Endosulfan. Diazinon therefore, is an alternative to Endosulfan.

It had been expected that use of Benlate, a fungicide, would significantly reduce damage by root rots compared to seed dressing with Endosulfan. The contrary was observed. Ensosulfan suppressed root rot more significantly than Benlate. This supports Letourneau's (1992) observation that bean infection with root rots, particularly *Fusarium Soolani* &. sp *Phaseoli* was related to bean fly incidence. Therefore control of beanfly is an important step in controlling root rots in beans. The present results have clearly demonstrated seed dressing with insecticides has great potential in increasing bean yield. Therefore what needs to be done is development of an appropriate mechanism that will promote safe use of seed dressing materials at the farm level. Earthing-up at first weeding (2 to 3 weeks after germination) increased bean yield between 20-30% which is significant at the farmers' level. It should therefore be encouraged especially for small bean plots.

Impact

Bean grain yields on seed dressed and earthed-up plots were demonstrably higher compared to the untreated bean plots, resulting in adoption of seed dressing technology by farmers in groups we have been working with. To ensure that the technology is disseminated on a larger scale, this technology has been passed to the IDEA Project (IDEA is a USAID funded project). IDEA is now conducting nation wide demonstration trials for bean growers. IPM CRSP and IDEA have produced a fact sheet and posters for use by extension workers. It is hoped that adoption of this technology will boost bean production in the region, leading to reduction in malnutrition and poverty.

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Networking:

- The results of this study were presented to scientists and extension workers in a two days' conference held in August, 1999.
- In collaboration with the National Bean Programme through CIAT and IDEA Project, 10,000, facts sheets

on bean fly management have been produced and are now being distributed to farmers.

- Through my affiliation with the IPM CRSP; I was included as part of a 3-man consultancy team which examined the USAID/Uganda Agricultural Sector Pesticide Procedures Guide.

Publication and Presentations

Kyamanywa .S., Byabagambi .S., Ogenga-Latigo and H. Willson (1999). Effect of Fertilizer Application and Mulching on Bean Infestation and Damage by Bean fly (*Ophiomyia sp*). in proceedings of the Fourth African Crop Science Conference:Casablanca, Morocco 11th-14th October, 1999.

Project Highlights

- Seed dressing against bean fly increased bean grain yield by 75%-156%.
- Seed dressing reduces the incidence of bean root rots.
- Diazinon was as effective in reducing bean fly damage as Endosulfan.
- The impact of seed dressing is more pronounced under drought stress conditions.
- Earthing-up reduced the damage of bean fly and increased grain yield by between 35-32%.
- All farmers (over 100) in the participating groups have been introduced to IPM methods of controlling bean fly.
- Over 10,000 fact sheets and posters on management of bean fly have been published and are being distributed to farmers and Extension Agents nationwide.

ON-FARM POST-HARVEST MANAGEMENT OF BRUCHIDS IN BEAN AND COWPEA

Investigators: J.A. Agona[1] and H.R. Willson[4]
Collaborating Scientists: Silim-Nahdy[2], S. Kyamanywa[3]

Abstract

The 2nd season's trials were conducted on bean and cowpea bruchid management in Iganga and Kumi districts, respectively. The efficacies of solarisation, tagetes, tobacco, Lantana camara leaf powders; ash and Actellic 1% dust admixtures were evaluated against bean bruchids. The efficacies of solarisation, tagetes, tephrosia and tobacco leaf powders; ash, vegetable oil and Actellic 1% dust admixtures were compared against cowpea bruchids. Farmer participatory approach in technology validation was adopted; and 10 farmers from Iganga and 6 farmers from Kumi were actively involved. Farmers in seven districts (Iganga, Kumi, Soroti, Katakwi, Lira, Apac and Mpigi) have already adopted solarisation and admixing beans with tobacco leaf powder; and solarisation and admixing of cowpeas with tephrosia or tobacco leaf powders.

Objectives

To test and evaluate the efficacies of selected biorationals, solarisation and synthetic insecticide to manage bean and cowpea bruchids in storage.

IPM Constraints addressed: Grain damage due to bruchids *Acanthoscelides obtectus* and *Callosobruchus* spp. during storage

Research Methods

On-farm validation of promising bruchid techniques identified on-station was conducted under farmer-managed storage conditions in Iganga and Kumi districts. Farmers' new season's harvests were used exclusively. The botanicals applied on beans and cowpeas were processed from harvested leaves that were dried in the shade and ground into powder. Leaves were used because of easy availability; shade drying was to avoid rapid volatilization of inherent active ingredients; and in the powder form to increase activity surface area. The grains were divided into 1-kg working samples by the coning and quartering method. The initial damage levels prior to treatment application were determined.

The grains were placed in cotton bags and admixed with botanicals at the rates of 2% w/w. Ash application was at the rate of 2% w/w; vegetable oil admixing at the rate of 5ml kg^{-1}; and Actellic 1% dust was applied at the equivalent rate of 50g per 100 kg of grain (0.50g kg^{-1}). Solarisation was conducted

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by following the method used by Agona and Silim (1998) to disinfest the grains. Solarisation period was maintained for a minimum of 2 hours, and it was repeated monthly.

The damage levels of the grains were determined monthly during the entire 3-month storage period. Bruchid damaged grains were defined as those with distinct insect emergence holes. The effect of treatment application on seed viability and moisture content was determined.

Depending on the commodity investigated, the number of replicates per treatment was represented by the number of farmers involved in technology validation. Data were analysed as completely randomized design (CRD) and completely randomised block design (CRBD) using MSTATC statistical package.

Research Results

There were significant differences in the efficacies of the different treatments applied to control bean bruchid infestation during storage. The highest bean damage levels were noted on beans admixed with tagetes, and the least on tobacco-admixed beans. In all the treatments, bean damage was recorded at 0% during the first month of storage, and built up depending on the type of treatment applied. There was no significant difference ($P>0.05$) in damage levels between the non-treated beans and those admixed with tagetes or *L. camara* after 3 months of bean storage. Likewise, the performance of tobacco, Actellic, ash and solarisation in reducing bean bruchid damage did not vary significantly.

On cowpeas, damage levels by bruchids varied according to the type of treatment applied and storage duration. The best treatments that reduced damage levels significantly included solarisation and admixing grains with tephrosia or tobacco. The effectiveness of the botanicals, however, decayed with protracted storage duration. Unlike in beans, solarisation method did not affect cowpea seed germination/viability.

Impacts

Since the application of some of the treatments on grain legumes reduced bruchid damage levels significantly, and thus ensuring the extension of the storage duration for more than three months, it is anticipated that farmers will earn more money, by prolonging the market period. Additionally, the production levels of the two food crops will go over and above domestic requirements for food and cash, since storage pest problem *inter alia*, will be contained. Farmers from other neighbouring districts: Lira, Apac, Soroti, Katakwi and Kamuli, due to knowledge spillover, are already applying some of the bruchid management techniques in grain preservation.

Networking Activities

Workshops organised:
Result findings have been communicated to farmers, traders and extension agents during a 3-day workshop on storage pest management in Rakai district, 20th-22nd, September, 1999. Organized two sessions of Master trainer of trainers workshop for BUCADEV (Buganda Cultural and Development Foundation) and AFRICARE (NGOs) on the use and application of solarisation and botanicals in grain preservation.

Research information and product exchange:
Currently I am supervising a MSc student registered at Makerere University, who is conducting a study on field management of post-podding pests and bruchids of cowpeas using biorationals, an area of study that was recommended from the current research sub-project.

Publications and Presentations

A paper entitled "Integrated management of bean and cowpea bruchids on-farm" is currently under review for publication in an international journal.

Project Highlight

In 1998/99, IPM CRSP Uganda found solarisation a very effective disinfestation technique in controlling all the bruchid life stages on beans and cowpeas. On beans, however, this pest control method is recommended for grain treatment only, but not for seed. However, on cowpeas, solarisation does not impair seed viability.

DEVELOPMENT OF AN INTEGRATED STRIGA MANAGEMENT STRATEGY FOR SMALL-SCALE SORGHUM FARMERS IN UGANDA

Investigators: J. Oryokot.[1], B. Gebrekidan[2], J. Robert Olupot[3]
Collaborating Scientist: D.S.O. Osiru[4]

Abstract

Experiments were conducted during the second rains (September-December) of 1998 and the first rains (March-July) of 1999, as a continuing activity to develop an integrated *Striga* management package for small-scale sorghum farmers. Interplanting *Celosia argentia*, (a *Striga* 'chaser',) in sorghum, a tolerant sorghum variety, moderate nitrogen fertilizer application and hand weeding were evaluated for *Striga* management. During the second rains of 1998, there were six treatments, while in the first rains, 1999, the number of treatments was increased to twelve so as to determine the main effect of each component in the proposed package. In 1998, the lowest *Striga* count was recorded in a combination of the tolerant sorghum variety (Seredo), nitrogen fertilizer applied at a rate of 80 kg Nha^{-1}, interplanting *Celosia argentia* in sorghum and two hand weedings. This was closely followed by a combination of Seredo, *C. argentia* and two weedings without nitrogen. There were however, no significant differences in yield. In 1999, a combination of Seredo, nitrogen fertilizer and two hand weedings resulted in the lowest *Striga* count and gave the highest sorghum yield. *Celosia argentia* was investigated in a separate experiment using a susceptible sorghum variety, locally known as Inoke and it was compared with intercropping sorghum with cowpea. Results indicated that inter-planting *C. argentia* with sorghum significantly lowered the number of *Striga* plants emerging and slightly increased the yield of sorghum. Results of the economic analysis indicated that treating the farmers' sorghum variety with fertilizer and weeding twice was not cost-effective since it gave negative returns, while combining Seredo with other proposed management practices gave increased net income. Farmers' variety gave positive returns when inter-planted with *C. argentia*.

Objectives

The overall goal is to develop an integrated *Striga* management package for small-scale sorghum farmers that minimizes sorghum yields due to *Striga* parasitism and to evaluate this package on-farm. The specific objectives were;

a) to study the effect of combining some selected agronomic management options in the suppression of *Striga* and increasing sorghum yield.
b) to evaluate the effectiveness of *Celosia argentia* in the suppression of *Striga*.

Research methods

Second rains, 1998

The research was undertaken on-farm with six treatments consisting of:

i) Farmers' variety with farmer management (broadcast and weeding once).
ii) Seredo with farmer management.
iii) Farmers' variety with fertilizer applied at 80kgNha-1 and interplanted with *C. argentia*.
iv) Seredo with fertilizer.
v) Seredo with fertilizer and interplanted with *C. argentia*.
vi) Seredo with *C. argentia*.

The trial was planted on five farmers' fields with two farmer groups; BUWOSA and Kachede UNFA, both in Bukedea/Kumi district. Farmers constituted replicates. Field preparation consisted of plowing two times and leveling with a hand hoe. Plots measured 12m x 9.8m. Treatments were randomly allocated in each farmer's field. Other than plots with farmer practice, where the crop was broadcast, sorghum was sown at the recommended spacing of 60cm x 20cm. Nitrogen fertilizer CAN (Calcium Ammonium Nitrate) was applied to the relevant plots at the rate of 80 kg Nha^{-1}, at planting.

First rains, 1999:

Two experiments were conducted; to evaluate the efficacy of different management options, and to investigate effect of *C. argentia* on *Striga*.

Experiment I: The effect of sorghum variety, nitrogen fertilizer and hand weeding on *Striga* infestations.

Field preparation and the number of replicates were as in the above season. The size of plots was reduced to 5.6m x 5m due to the increased number of treatments. The factors; crop variety, nitrogen fertilizer and hand weeding were applied at

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two levels each and arranged in a typical factorial combination. The sorghum varieties were the common farmers' variety, "Inoke" and an improved variety, Seredo. The nitrogen levels were 0 and 80 kg Nha^{-1}, applied at planting. The weeding levels were weeding once at two weeks after crop emergence and weeding twice at two weeks after crop emergence and the second four weeks later.

Experiment 2: The effect of interplanting/intercropping *C. agentia* and cowpea with sorghum: The sorghum variety used was Inoke, a local variety very susceptible to *Striga*. The size of the plots was as in the first experiment above. *C. argentia* and cowpeas (local variety, Ebelat) were interplanted with sorghum to compare their respective abilities to suppress *Striga* emergance and minimise the impact of the parasite on sorghum yields. This gave a total of three treatments; cowpea/sorghum intercrop, *C. argentia* planted in between the sorghum was planted at a spacing of 60 cm x 20 cm and cowpea and *C. argentia* planted in between the sorghum rows. Both were spaced at 60 cm between rows and 20 cm between plants giving a 50:50 sorghum: intercrop/interplant ratio. The experiment was weeded twice, at two weeks and then four weeks after crop emergence. The experimental design was a randomised complete block with five replications.

For all experiments, *Striga* counts were taken three times during the growing season, at two weeks interval starting five weeks after crop emergence. The counts were done by randomly throwing a 1 square meter quadrat four times in each plot and all emerged *Striga* plants within the quadrat counted.

The average was calculated and expressed as *Striga* number/m^2. Grain yield was obtained by harvesting an area of 2x2m per plot. Net income was determined by deducting the costs of hand weeding estimated at Ushs 71428 or USD 51ha^{-1} for one weeding and fertilizer (Ushs 156000 or USD 111ha^{-1}) from the gross monetary value of sorghum. The value was obtained as a product of the prevailing sorghum prices (Ushs 300 or USD 0.214kg^{-1} for farmers' variety and Ushs 1000 or USD 0.714kg^{-1} for Seredo) and grain yield. The data were subjected to analysis of variance (ANOVA) using Genstat 5 release 3.2 statistical software.

Research Results

Second rains, 1998 Effect of management practice on *Striga* emergence.

Results of this season indicated that all treatments with Seredo had low *Striga* emergence compared to those with the farmers' variety Inoke (Table, 1). The treatment, which had the lowest *Striga* emergence, was that involving a combination of Seredo, nitrogen fertilizer, *C. argentia* and two weedings. This was closely followed by a combination of Seredo, *C. argentia* and two weedings without nitrogen. The highest *Striga* emergence was recorded in the farmers' variety and farmer practice (broadcast and one weeding). There were no significant effects of management practice on grain yield and generally, the grain yields were much lower than expected. This was probably due to the severe drought which affected the crop towards the end of the season. However, economic analysis indicated that Seredo gave higher net income compared to the farmers' variety and that treating the farmers' variety with the proposed management option would give negative returns.

Table 1: The effect of management practice on *Striga* emergence during second rains of 1998

Management practice	Mean *Striga* emergence (plants m^{-2})
Farmers' variety + farmer management	11.5
Seredo + farmer management	4.1
Farmers' variety + nitrogen + *C. argentia* + 2 weedings	8.2
Seredo + nitrogen + 2 weedings	2.8
Seredo + nitrogen + *C. argentia* + 2 weedings	1.4
Seredo + *C. argentia* + 2 weedings	1.9
s.e.d	3.65

First rains, 1999

Experiment 1: Effect of management practice on *Striga* emergence.

Results of the first experiment in the first rains of 1999 also indicated that Seredo showed relatively low *Striga* counts compated to the local variety in all treatments (Table 2). The lowest *Striga* emergence was recorded in combination of nitrogen application and two weedings and nitrogen applied without weeding. The highest count was recorded in a combination of Nitrogen and one hand weeding. In the absence of fertilizer application, weeding twice had a slightly lower *Striga* count compared to weeding once for both varieties. Ransom and Odhiambo (1994) reported a significant fertility by weeding interaction on *Striga* emergence. This showed that hand weeding did control *Striga* to some extent but its effect were not significant if not integrated with other cultural practices. In this study, application of nitrogen alone without weeding led to the suppression of *Striga* emergence but this could largely be due to overgrowth of other weeds, which suppressed *Striga* as *Striga* is a week competitor. Application of nitrogen with only one weeding resulted into the highest emergence of *Striga*. A probable explanation of this is that a single weeding removes most of the early weeds reducing competition against *Striga*. The underground parasite always escapes this early weeding because it emerges later in the season. The interaction between nitrogen and one weeding seemed to lead to increased *Striga* emergence.

Table 2: The effect of various treatments on mean *Striga* emergence during first rains of 1999

Mean *Striga* emergence(plants m^{-2})			
Treatment	Farmers' variety	Seredo	Mean
N_0	20.9	13.4	17.1
N_1	17.2	7.7	12.4
W_1	49.3	27.1	38.2
W_2	40.2	23.0	31.6
N_1W_1	72.9	30.0	51.4
N_1W_2	27.1	7.8	17.4
Mean	37.9	18.2	
s.e.d[a]	16.74		
s.e.d[b]	9.66		

s.e.d[a] = treatment means N_o = no nitrogen W_1 = one weeding
s.e.d[b] = variety means N_1 = nitrogen applied W_2 = two weedings

Effect of management practice on crop yield and net income. The crop yield was affected by management practice in the first rains of 1999. Seredo yielded about 3.5 times more than the local variety in all treatment combinations. There was no difference in yield between one weeding and two weedings. A combination of nitrogen and two weedings, however, gave the highest grain yield in each compared to other treatments, in each of the varieties. Carson (1988) reported that the yield of the crop is rarely improved by hand weeding of *Striga* alone. While Ramson and Odhiambo, (1994) reported the positive impact of combining hand weeding and fertilizer application. The yields obtained however, are lower than the expected values for the varieties because of pests, diseases and low soil fertility on top of *Striga* infestation. Seredo gives increased net incomes in all the management options while the farmers' variety gives negative returns in most management options. The highest net income was realised in a combination of Seredo and one weeding and Seredo combined with nitrogen and two weedings. The farmers' variety only gives small positive returns when interplanted with *C. argentia* or treated under farmers' management. The difference is mainly due the relative market prices of the two varieties as seen above.

Experiment II

Effect of interplanting/intercropping on *Striga* emergence and sorghum yield.

Intercropping cowpea or interplanting *C. argentia* with sorghum lowered the number of *Striga* plants emerging compared to the sole sorghum (Table 3). The impacts of cowpea and *C. argentia* on *Striga* emergence were not significantly different. While their effects on *Striga* emergence were not different, cowpea and *C. argentia* affected sorghum yield differently (Table 4). *C. argentia* increased sorghum yield over the sole sorghum crop while cowpea reduced sorghum yield even more than when sorghum was planted alone. Results of sorghum growth parameters (not reported) show that cowpeas climbed the sorghum plants and reduced plant heights. This suggests that while cowpea reduces *Striga* emergence it has a high competitive effect on sorghum while *C. argentia* did not exert much competition on sorghum. The main differences would be in the growth habits.

Table 3: The effect of interplanting cowpea and *C. argentia* with the farmers' (susceptible) sorghum variety on *Striga* emergence

Treatment	*Striga* emergence(plants m^{-2})
Cowpea/Sorghum	8.6
C. argentia/Sorghum	13.5
Sorghum(sole)	24.6
s.e.d	6.69

Table 4a: Effect of *Striga* management option on sorghum yield and net income, Second rains 1998

Management option	Sorghum yield(kgha^{-1})	Income(USD)ha^{-1}
Farmers' variety + Farmer management	618	81
Seredo + Farmer management	738	476
Farmers' variety + fertilizer + *C. argentia* + 2 weedings	563	-93
Seredo + fertilizer + 2 weedings	713	296
Seredo + fertilizer + *C. argentia* + 2 weedings	650	251
Seredo + *C. argentia* + 2 weedings	525	273

Table 4b: Effect of *Striga* management option on sorghum yield and net income, First rains 1999

Experiment 1		
Farmers' variety without nitrogen	399	85
Farmers' variety with nitrogen	151	-79
Farmers' variety + 1 weeding	233	-1
Farmers' variety + 2 weedings	294	-39
Farmers' vareity + nitrogen + 1 weeding	369	-83
Farmers' variety + nitrogen + 2 weedings	597	-86
Seredo without nitrogen	1013	724
Seredo with nitrogen	1082	661
Seredo + 1 weeding	1288	869
Seredo + 2 weedings	1159	726
Seredo + nitrogen + 1 weeding	1042	582
Seredo + nitrogen + 2 weedings	1471	837
Experiment 2		
Sorghum + cowpea	8.6	-14
Sorghum + *C. argentia*	13.5	47
Sorghum (sole crop)	24.6	42

Impact

This study shows that an integrated management option consisting of a of tolerant sorghum variety, Seredo, modest fertilizer application, two hand weedings and interplanting with *C. argentia* can minimize the impact of *Striga* parasitism. Economic analysis indicates the use of fertilizer is economic only on the improved sorghum variety. *C. argentia* indeed influences *Striga* emergence and subsequent sorghum grain yield. It therefore has potential in the management of this weed. Sorghum is an important cereal grain, and the use of this management option should improve sorghum productivity and incomes.

Networking Activities

A. All the collaborating scientists in the project participated at the IPM CRSP country workshop from 26th - 29th August.

Publications and Presentations

A working paper entitled, Development of an integrated *Striga* management strategy for small-scale sorghum farmers in Uganda was presented at the first annual IPM CRSP national conference in Uganda (26th – 29th August) by J.R. Olupot. The same paper was presented at the second annual graduate student conference, at the Faculty of Agriculture, Makerere University, Uganda and the student was awarded a

certificate of merit ranked third best presenter in the conference. Prof. D.S.O. Osiru present some of the results in a paper to the 17th Biennial Weed Science Society conference in Harare, Zimbabwe this year.

Training output

A full-time MSc student, J.R.Olupot has successfully completed his first year of training and is left with one more year to complete course work and thesis.

Project Highlight

In 1999, IPM CRSP Uganda confirmed that *Celosia argentia* can suppress *Striga* in farmers' fields and the farmers of Kumi district have expressed interest to use it.

Acknowledgement

We thank the IPM CRSP for funding this research and the farmers of Kumi district who provided land and participated in carrying out the experiments.

DEVELOPING IPM SYSTEMS FOR TOMATO IN CENTRAL AND EASTERN UGANDA

Investigators: M.C. Akemo[1], S. Kyamanywa[2], G. Luther[3], C. Ssekyewa[1], J.M. Erbaugh,[4] H. Warren[3]

Abstract

Tomato is the most important vegetable crop in Uganda, being produced mainly in the peri-urban areas for the fresh market. Major diseases on tomatoes include Early and Late Blights (*Alternaria solani* and *Phytophthora infestans*), and Bacterial wilt (*Ralstonia solanacearum*). Major pests include (*Polyphagotaronemus latus*), thrips, aphids, mites (*Frankliniella sp*), and American bollworms (*Helicovepa armigera*). Control is by synthetic pesticides that are expensive, may not be readily accessible, and may not be used correctly and in the right concentrations. Bacterial wilt is soil-borne with no chemical control yet available.

To identify and test alternative disease and pest control options in order to reduce the amounts of synthetic pesticides currently being used on tomatoes, the IPM CRSP tomato program carried out the following activities:

a) a Participatory Assessment session to identify and rank major tomato constraints;

b) a surveillance of the occurrence and severity of tomato diseases and pests;

c) an on-station trial to examine alternative interventions to control late blight;

d) an on-farm trial to test tomato lines with resistance or tolerance to bacterial wilt.

At the PA on the 8 March 1999 the farmers' ranked tomato as their number one cash crop. The most important constraint was Late blight, followed by Bacterial wilt. Late blight and thrips were observed on three tomato crops in the first season of 1999, with thrip numbers increasing during dry spells. Preliminary results from the on-station trial show that cover crop mulch and reduced fungicide applications controlled late blight almost as well as 2 fungicide applications per week plus cover crop mulch. Low levels of wilting were observed with on-farm trials probably due to low levels of bacterial wilt inoculum.

Objectives

Research objectives for this reporting period were:

1. To identify and rank constraints encountered in tomato production.

2. To monitor incidences and levels of pest and disease infestations on tomatoes.

3. To reduce the use of pesticides on tomatoes.

4. To develop alternative interventions for controlling priority diseases and pests of tomatoes.

5. To develop these methods in collaboration with tomato growers in Namulonge, Busukuma sub-county.

IPM Constraints

Farmers depend on excessive use of pesticides to control tomato diseases and insect pests. Currently farmers are spraying pesticides twice a week throughout the tomato growing season. There is no need to find a way of reducing the pesticide application.

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Research Approach and Output

Research Methods

1. Participatory assessment session with tomato growing farmers:

This was held on the 8th March 1999 with an informal grouping of tomato farmers at Busukuma sub-county headquarters, Mpigi District. Eight (8) farmers participated in the exercise, heavy rain deterring additional potential participants. Farmers were first asked to list crops they grew, their utilization, and prioritization based on income generation. Specific constraints encountered in tomato production were then identified and ranked.

2. On-farm trial of bacterial wilt resistant tomato lines:

Three tomato lines found tolerant to bacterial wilt in on-station trials at KARI were planted on-farm at Namulonge on 5th May 1999, in a field in which the farmer said he had earlier lost a tomato crop to bacterial wilt. The tomato lines were MT55 and MT56 developed by a breeder at Makerere University, and Redlander from Australia. The control was the local tomato which is highly susceptible to bacterial wilt. The trial was laid out in a Randomized Complete Block Design, with four replications. Spacing was 45 cm between plants and 60 cm between rows. Plots were 1m apart. NPK was applied 2 weeks after transplanting, and the crop was weeded and mulched. Dithane M45 and Dursban were applied for fungal disease and insect pest control respectively. The trial was monitored regularly to assess the severity of bacterial wilt, blight, and pests. The farmers were also asked to observe the tomato lines as they grew in comparison to their local cultivar and indicate their preference and reasons.

3. On-station trials on alternative methods to control blight and aphids:

This on-station trial combined examining alternative methods of pest control and using cover crops in tomato production. The trial was laid out in a RCBD, with 4 replicates and 8 treatments. Four plots in each block were sown with the cover crop Siratro a month before transplanting the tomato crop. Nursery raised seedlings of MT55 were transplanted to all plots on 20th April 1999. The cover crop was cut down one month after transplanting tomatoes to allow it to accumulate more above ground biomass for mulch. NPK was applied to the plots without cover crops two weeks after transplanting. The final layout of treatments in each replicate was as follows:

1. 2 spray applications of DM 45 per week (farmers' practice)
2. Reduced spray program based on disease monitoring (at most once per week)
3. Pre-established cover crop mulch with no pesticide
4. Reduced spray program + cover crop mulch
5. 2 spray applications + cover crop mulch
6. Bakers yeast applications once a week + cover crop mulch
7. Bakers Yeast with no mulch
8. Control- no spray and no cover crop.

Data was taken on disease incidence and severity and occurrence of pests on the different treatments. Tomato fruit yield was also recorded.

4. Surveillance of tomato pests and diseases:

Diseases and pests on three tomato crops including the demonstration plot were monitored every 2 to 3 weeks to determine their incidence and severity.

Research Results

1. Participatory assessment session with tomato growing farmers:

Table 1. Cash and Food crops grown and rankings.

Crop		Cash Crop	Food Crop	Ranking in money earning
English (Scientific Name)	Local Name			
Tomato (*Lycopersicon esculentum*)	Nyanya	x	x	1
Cabbage (*Brassica oleraceae*)	Mboga	x	x	5
Green/sweet pepper (*Capsicum annum*)	Kamulali	x	x	7
Aubergine/eggplant (*Solanum melogena*)	Biringanya	x	x	12
Bitter tomato/garden egg(*Solanum gilo*)	Entula	x	x	13
Solanum ethiopicum	Nakati	x	x	2
Amaranthus spp	Bugga	x	x	8
Steaming bananas (*Musa* spp)	Matooke		x	14
Brewing bananas (*Musa* spp)	Musa	x		3
Cassava (*Manihot esculentum*)	Muwogo	x	x	11

Table 1. *continued*

Crop		Cash Crop	Food Crop	Ranking in money earning
Dry beans (*Phaseolus vulgaris*)	Bijanjalo	x	x	10
Maize (*Zea mais*)	Kasooli	x	x	4
Sweet potatoes (*Ipomoea batatas*)	Lumonde	x	x	6
Coffee/Robusta	Emwaanyi	x		9

The farmers ranked tomato, which they supply to one of the major markets in Kampala City, as their number one cash crop. The rejects are used for home consumption. Starting with the most serious constraint, general problems encountered in crop production were ranked as follows:

1. Availability of pesticides in terms of both price and proximity
2. i) Not enough markets for the produce
   ii) Transport to markets is expensive
3. Availability of land (none for sale, renting, or borrowing). This limits acreage for each crop, rotation intervals, and results in soil exhaustion.
4. i) Low yields
   ii) Pests and diseases
   iii) Poor soil fertility
   iv) Scarce labour for hire.

These constraints result in lower potential incomes from tomatoes and other cash crops. Specific constraints encountered in tomato production are presented in Table 2. The blights, especially *Phytophthora*, are very common and if left unchecked result in crop losses greater than 75%, as stems, leaves, and fruits are all affected. Blight is more prevalent during heavy rains, and is controlled using Dithane M45, a contact fungicide, which is washed off if it rains soon after spraying. This is why farmers spray more than once a week during the rainy season, resulting in high production costs.

Bacterial wilt has also become wide spread in tomato growing areas and can also kill up to 100% of the crop. The commonly grown commercial varieties including Moneymaker, Heinz, Roma, Marglobe, and local (Nganda) are susceptible to bacterial wilt. Since the disease is soil borne farmers in hard hit areas are demanding resistant varieties to replace the ones they are currently growing. However these varieties have to be acceptable in the market.

Table 2. Tomato production constraints and their ranking.

Problem	Local name	% of farmers who reported problem	Final ranking
Blight	Kubabuka	100	1
Wilting	Okuwotoka	100	2
Mixing pesticides	Okutabula eddagala	100	3
Blossom end rot	Okuvunda muntobo	80	4
Correct spraying methods	Enfuyira entuufu	60	5
Insect pests/e.g. boll worm	Obusaanyi, etc.	100	6
Crickets & cutworms	Akawuka akassala obuboga obuto- kasanyi	100	7
Flower abortion	Ebimuli bikunkumuka	80	8
Thrips	Obuwuka obudugavu nga butono	80	8
Stunting, leaf distortion, curling, crinkling, mosaic	Okugengewala	60	9
Expensive sprayers	Ebbomba tezigulika	80	10
Poor pricing	Katale kafu	100	11
Purely vegetative tomato growth	Temulisa	100	12

The mixing and safe use of pesticides was ranked as the third most important constraint. Farmers are confused by the large number and constantly changing names of pesticides on the market. Many cannot read the labels to get the correct concentrations to mix so they just use arbitrary measures like table and teaspoons. This results in under- or over-dosing of the pesticides. Many farmers also do not use protective clothing when applying pesticides. Insecticides which were being used by tomato farmers were Ambush, Sumithion, Dimethoate, Neurella-D, Sherga, Dursban, Salute and Safi-safi. The fungicides included: Dithane M45, Manacozeb, and Zancor. Farmers mentioned mixing cooking oil and omo (detergent) with fungicides. From the PA results, it was decided to focus on the constraints ranked first and second by the farmers.

2. On-farm trial of bacterial wilt resistant tomato lines:

Not much wilting was observed in the trial probably because of low levels of bacterial wilt inoculum in the soil. The severity of late blight was also kept low using DM 45 applied right from transplanting (Table 4). Thrips infested the crop lightly. The farmers' initial preference is for MT56 because of its heavier flowering and fruit setting. It has more trusses and fruits per truss than Redlander and the local tomato, though they also set big fruits. MT55 has small fruits of 30 to 50 g in weight, though it has a long shelf life. MT 56 also flowered and fruited earliest. The yield data is still being recorded by the farmer, but MT56 is so far giving the highest yields.

3. On-station trials on alternative methods to control blight and aphids:

Late blight (*Pseudomonas solanacearum*) was the only foliar disease observed on the tomato crop and its severity and progress of infection on the different treatments was scored on a percent scale every 2 weeks starting on 3rd May 1999. The unsprayed control was most severely affected by late blight followed by treatment 7 with bakers' yeast and no mulch. Treatments 6 (bakers' yeast + cover crop mulch) and 3 (only cover crop mulch) had similar disease severity and infection rate. The cover crop mulch might have provided protection from infection by spores spread by rain splash on soil. Treatments 2 and 1 with applications of DM 45 once and twice per week respectively but without cover crop mulch also had similar disease severity and infection rate, with 2 sprays having a slightly better disease control. The best disease control was obtained with 2 sprays of Dithane per week and cover crop mulch, followed by 1 application and cover crop mulch. Weed suppression was 30 to 40 % before killing the cover crop. One month after killing the mulch had broken down and some weeds had grown through.

Table 3 shows tomatoes in treatment 4, the reduced spray program and cover crop mulch yielding the highest, followed by those in treatment 2. 5, and 1. There was no significant difference in fruit weight per hectare between treatments 5, and 1, and between treatments 3, 7, and 8.

Table 3. Tomato fruit yield.

Treatment	Fruit weight (t ha^{-1})	Number of fruits (x 1000 ha^{-1})
1. 2 spray applications of DM 45 per week	29.6 c	1158 d
2. Reduced spray program based on disease monitoring	38.6 b	1968 b
3. Pre-established cover crop mulch with no pesticide	5.7 e	352 f
4. Reduced spray program + cover crop mulch	57.0 a	2244 a
5. 2 spray applications + cover crop mulch	32.9 c	1450 c
6. Bakers' yeast applications once a week + cover crop mulch	17.9 d	889 e
7. Bakers' Yeast with no mulch	7.0 e	411 f
8. Control-no spray and no cover crop	4.4 e	307 f
	^{a} = 0.05, lsd = 3.302 at 0.05	^{a} = 0.05, lsd = 227.05 at 0.05

Surveillance of tomato pests and diseases:

Table 4. Scoring of diseases and pests on three tomato crops.

Date	Demonstration	Farmer 1	Farmer 2
31/5/99	Thrips tabaci - 1-3 / plant		
10/6/99	Thrips < 3 < 7/ plant Blight – 0	Blight < 5 < 10% infection / plant Thrips < 5 < 10 per leaf	
21/6/99	Thrips - 7 < 10 per leaflet Bacterial wilt = plants wilting in one plot Blight < 1-2% per plant	3 month old tomatoes blight 5 < 15% infection thrips < 7 - 15 per leaflet	Young plants = Blight < 2 < 5% Thrips < 3 < 8 per leaf
9/7/99	Blight < 0 Thrips < 0 (Dimethoate applied)	Blight < 30 < 50 % Thrips < 10 < 30 / leaf	Blight < 5 < 25 % Thrips up 20 per leaf
30/7/99	Blight < 0 < 2% Thrips- 1 per leaf Farmer spraying 75gm of DM45	Old crop: Blight < 50 < 60 % Thrips < 0 -1 per leaf Young crop: Nymph thrips (Yellow) < 0 < 4 per leaf Aphids < 0 < 3 per leaf Blight < 2- 5%	Blight - 20 < 30 % Thrips up to < per leaf (Sherpa sprayed when available) Thrips leaf damage - 20 < 60 % per leaf
16/8/99	(1 month of harvesting) thrips - 3 < 7 per leaf leaf damage < 40 < 75 % blight < plants prunned, MT 55 and Redlander – 50%; Local 30 < 40%	Old crop: Blight < 50 < 75% Thrips < 0 < 2 per leaf	Blight < 30 < 50 % on old foliage; new leaves clean Thrips - 3 < 8 per leaf DM45 and Endadol sprayed twice / week.

Diseases and pests on three tomato crops including the demonstration plot were monitored to determine their incidence and severity (Table 4). Late blight and thrips were common on all three crops. Thrips became numerous during dry spells, and when not sprayed regularly. The second farmer only sprays against pests when he has money to spare for some pesticides even when thrip populations are high.

Impacts

For this particular season, the main disease observed on tomato crops was late blight, and thrips were the most prevalent pest building up populations quite rapidly during dry spells if not controlled. No conclusions can be drawn from one trial season, so the on-station and on-farm trials will be repeated two more times for reliable conclusions and recommendations to farmers.

Many farmers claim that certain pesticides are not effective. However some of the farmers in the group have admitted that they do not spray the recommended concentrations of pesticides or as frequently as recommended when a pest attacks a crop. This can result in the pesticide seeming to be ineffective in controlling the disease or pest and can result in resistance to a pesticide.

The farmers are eager to get bacterial wilt resistant varieties and many have already taken the seed from the on farm trial to plant in their own gardens.

GERMPLASM EVALUATION FOR TOLERENCE TO BACTERIAL WILT IN HIGHLANDS AND MID-ELEVATIONS OF UGANDA

Investigators: Hakiza J.J.[1], Kakuhenzire R.[1], Kanzikwera C.[1], Berga Lemaga[1], Adipala E.[2], Bhagsari A[3].

Abstract

Twelve elite potato entries and one susceptible check were evaluated in bacterial wilt-infested soil at three farm sites in Kabale and on one Variety Trial Centre in Kisoro, south western Uganda. The same genotypes were planted at Kalengyere Research Station to assess their levels of resistance to late blight. There was high wilt incidence, low plant survival, high tuber rottage and poor yield. The four best clones, with minimum wilting, low tuber rotting and relatively high yield, were 388575.9, 390018.3, 388575.5 and 390854.11. These entries, and 388575.5 displayed low levels of susceptibility to late blight. They will form part of future IPM trials in Uganda.

IPM Constraints

Bacterial wilt of potato caused by *Ralstonia salanacearum* (E.F. Smith) is one of the most devastating diseases of potatoes in the tropics. Early disease expression is usually a result of planting latently infected seed tubers or using heavily infested fields. However, potato plants which show wilt symptoms after tuberisation usually have only few rotten tubers. On the other hand, some tubers may look healthy superficially, but are latently infected. All these lead to low yields and financial losses. There is no cure for BW and attempts at soil fumigation are very expensive and uneconomical. The best option is to adopt Integrated Pest Management strategies that include clean seed, tolerant genotypes and cultural practices. Thus, our IPM CRSP trials for BW management started by first identifying superior clones with high levels of tolerance to BW. The promising clones will subsequently be evaluated with other components (cultural control) to develop IPM protocols for management of BW in south western Uganda. The other important disease of potatoes, especially in the highlands, is late blight (*Phytophthora infestans* de Bary). Thus, the BW tolerant clones have also to be evaluated for resistance to LB. This is being done in our IPM CRSP trials.

Research Methods, Results and Impact: Four trial sites were established in southwestern Uganda, in Kisoro and Kabale districts.Twelve potato genotypes, identified in earlier trials as showing some tolerance to BW, were grown in 1998. A highly susceptible check (Kabale) was included. The experiment was repeated at two sites in 1999A. Additionally, these genotypes were grown at a wilt-free site (Kalengyere), but with high levels of LB. The experimental layout in all cases was a randomized complete block design with three replications. There were four-row plots per experimental unit, with 15 tubers per row. The distance between rows was 70 cm while the potato hills within rows were spaced 30 cm apart. The experiments were kept weed-free and at the BW-infested sites, the crops were sprayed twice each season with Dithane M45 (Mancozeb 80% wp) to control LB.

Data were collected from the two middle rows of each plot. The number of wilting plants were counted weekly until 85 days after planting when most of the entries had shown tendency to senesce. The number of plants that survived till harvest were also recorded. The harvested tubers from each plot were grouped into unmarketable (rotten) and marketable tubers and weighed. The data were subjected to analysis of variance and LSD mean separation using the MSTATC statistical computer package.

Results and Discussion

Across the four sites, the clones with the least final wilt incidence were 390854.11, 388575.5, 388575.9, 388580.18A, 390018.3, 39005.11 and 390854.11 (Table 1). Across the four sites, the greatest rotting occurred in 388576.10, and the least in entries 390854.11, 388575.9, 388580.18A, and 388575.5. The four highest yielding clones were 388575.5, 388575.9, 390854.11 and 388718.8. It is important to note that three of these clones had minimum rotting tendency, and minimum number of wilted plants.

The experiment was repeated at two sites in first season of 1999, Rugarambiro and Rukore in Kabale district. The experiment was affected by unprecedented drought which resulted in poor crop emergence and poor growth. For this season, the five highest yielding clones at Rugarambiro were 388576.10, 390018.3, 388574.2B, 388575.9, and 388575.5. At Rukore, the best clones were 388576.10, 388574.2B, 388574.8, 388718.8 and 388574.6 (Table 2).

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Table 1. General performance of 14 BW tolerant potato genotypes across four farm sites in 1998A season in south western Uganda.

Genotype	Plant survival (%)	Final wilt incidence	Rotten tubers (%)	Yield (Mt/ha)	Rank sum position
390005.11	74.2	10.8	49.4	11.3	6
388575.9	81.4	5.0	3.6	16.1	1
388574.2B	61.2	12.0	43.5	8.8	12
388575.5	69.8	7.0	5.3	19.0	3
Kabale	71.3	9.0	58.9	10.7	8
390018.3	69.4	6.5	13.1	11.4	4
390854.11	72.5	4.0	0	13.6	2
388574.8	63.8	9.0	57.0	11.5	7
388574.6	71.1	7.3	11.9	10.7	5
388718.8	68.1	10.3	17.5	13.4	9
388580.18A	42.4	5.3	13.9	3.5	10
390006.13	62.2	10.8	14.4	9.0	11
388572.2	48.8	14.0	17.8	3.7	13
388576.10	55.6	22.0	0	7.2	14
Mean	65.13	9.5	25.53	10.71	

Table 2. Performance of Bacterial wilt tolerant clones at two sites in south western Uganda, 1999A

	Rugarambiro		Rukore	
Genotype	Plant survival (%)	Yield (T/ha)	Plant survival (%)	Yield (T/ha)
390005.11	44.0	1.8	81.1	4.4
388575.9	70.8	5.3	88.8	3.4
388574.2B	76.4	7.5	97.8	7.5
388575.5	65.3	5.1	77.8	3.2
Kabale	55.6	9.3	86.7	9.7
390018.3	72.2	9.5	73.3	5.0
390854.11	62.5	4.4	55.6	4.2
388574.8	48.6	3.0	91.1	6.8
388574.6	54.2	4.6	76.7	5.8
388718.8	54.2	4.0	75.6	6.1
388580.18A	48.6	4.4	76.7	5.7
390006.13	48.6	2.5	64.4	3.2
388576.10	80.6	11.0	74.4	7.9
Kisoro	52.8	2.6	43.3	3.2
Musitamya	50.0	2.7	73.3	3.2
Mean	59.0	5.2	75.8	5.3
$LSD_{0.05}$	24.8	4.2	24.7	3.2
CV(%)	25.1	48.4	19.4	36.1

Table 3. Performance of Bacterial wilt tolerant clones at Kalengyere in the second season of 1998B

Genotype	Tubers per plant	Mean tuber weight (g)	Yield (Mt/Ha)	LB: Final score (%)	LB: AUDPC General
388580.18A	5.2	48.5	10.8	22.5	323.6
390005.11	11.6	28.6	15.4	30.0	594.3
388574.8	7.4	48.6	17.0	11.8	184.3
388575.5	8.6	36.1	13.8	42.5	741.0
388574.6	8.6	41.9	15.0	21.8	342.4
388575.9	8.4	37.2	14.8	22.5	408.9
390018.3	7.0	41.9	13.5	23.8	338.5
388574.2B	8.2	53.9	20.7	35.0	616.4
Kabale	4.5	62.8	13.4	35.0	711.5
388576.10	7.1	29.8	10.1	9.3	161.9
388718.8	7.4	67.7	23.7	30.0	439.3
390854.11	5.2	53.1	13.1	12.5	252.1
390006.13	6.3	43.4	13.3	27.5	433.8
$LSD_{0.05}$	2.6	14.7	4.9	8.2	164.1
CV(%)	24.3	22.6	23.0	22.9	26.8

Considering all the sites and 3 seasons of study, clones 388575.9, 390018.3, 388575.5, 390018.3 and 388574.6 showed considerable levels of BW tolerance. These clones also exhibited low levels of LB (Table 3). The farmers especially liked 388575.5 and 388575.9. Thus, future evaluations will pay special attention to these two clones.

Impact

The participating farmers recognized that the different potato genotypes reacted to BW infection differently. They also found that some of the elite genotypes withstood BW better than the check varieties. Based on farmer evaluations, one of the test clones, 388575.5 displayed good culinary characteristics besides having high yield and tolerance to BW. The clone is now being multiplied for on-farm testing.

Networking

- Three of the experiment sites in Kabale were visited by a group of 100 farmers. The farmers were from different community based organization; Uganda National Seed Potato Producers Association, Africare's Food Security Initiative Project, Kabale Women's Organization for Rural Development, Nyamiyaga Technology Transfer Group and African Highlands Initiative.

Project Highlights

Two clones 388575.5 and 388575.9 were found to be highly tolerant to BW and were liked by the farmers.

ECONOMIC ASSESSMENT OF IPM CRSP ACTIVITIES IN UGANDA

Investigators: V. Kasenge[1], and D. B. Taylor[2]
Collaborating scientists: S. Kyamanywa[1] and G. Bigirwa[3]

Economics of Management of Beanfly and Root rot on Beans in Iganga District.

Abstract

The economic consequences of the various treatments compared to farmers' way practices of growing beans in management of bean fly and root rot were assessed using partial budget analysis. All treatments produced higher net returns than the controls.

Objective

To compare the economics of the various trials with the farmer's way of growing beans.

Methodology

Partial budgets were prepared using data from the biophysical trials. Data on differences in bean yields, farm input quantities and prices associated with the various on-farm trials were collected.

Results

Table 1 contains the partial budget analysis of the trials. Seed dressing with Endosulfan produced the highest added net return with a 213 percent over farmer practices. It was closely followed by seed dressing with Endosulfan and earthing up which realized a 181 percent increase in income over farmer practices. Earthing up during weeding produced a 32 percent increase in income while the maize/bean intercropping practice had the lowest increase in income at 5 percent above farmer practices.

[1] Makerere University
[2] Virginia Tech
[3] NAARI

Table 1: Partial budget of bean fly and root rot control practices on beans in the Iganga district, Uganda.

Bean Price (per kg)	Net returns above controls (farmer practices) in USD per ha			
	Earthing Up During Weeding	Seed Dressing with Endosulfan	Seed Dressing and Earthing Up	Maize/Bean Intercropping
0.4: farmgate average	143.9	974.5	832.8	24.1
0.6: National average	218.9	1,480.7	1,264.0	36.5
0.8: National average next quarter	293.9	1,986.9	1,695.2	48.9

Table 2 contains the partial budget analysis of the trials. Important links existed between biophysical indicators and economic indicators.

In biophysical terms, grain yields were higher for Longe-1maize than for the Local maize irrespective of cropping system. Grain yields were higher in the monoculture system than in intercropping with beans irrespective of maize variety.

In economic terms (Table 2) Longe-1 maize in monoculture gave the highest net cash benefit with an added return of USD 257 per ha compared to the Local maize monocrop and an added net return of USD 107 per ha compared to intercropping with beans. The local maize monocrop yielded the lowest added net benefit of about USD 10 per ha compared to its intercrop. Intercropped Longe-1 added USD $159 in net returns per ha compared to the local maize intercrop.

Table 2. Partial budget analysis of Long-1 maize and a local variety under monoculture and intercropping with beans in Iganga district, Uganda 1997-99

Change Parameters in USD per hectare	Longe-1		Local Maize		Bean
	monocrop	intercrop	monocrop	intercrop	monocrop
1. Credits					
Mean Grain Output/a	1198.40	1112.66	941.10	952.08	471.00
2. Debits					
Mean grain loss	36.08	27.56	50.76	41.46	
Farm Inputs/b					
Seed	20.00	49.70	5.00	34.70	45.00
Fertilizer	54.00	54.00	54.00	54.00	
3. Net cash benefit (1-2)	1088.32	981.40	831.34	821.92	426.00

Notes: /a 1 USD = Ushs 1450, Farmgate average price per kg: Maize 0.2, Beans 0.3
/b Input retail price per kg: Maize seed 0.8, Bean seed 0.9, DAP 0.6, UREA 0.4.

Potential Impacts

The adoption of Longe-1 maize variety in monoculture should be a high priority which could increase yields and ensure enough supply for both farm household food needs and cash income.

Networking

The findings were presented to biophysical co-principal investigators and discussed at the Uganda site IPM CRSP Workshop in Mbale during August 26-28, 1999.

Economic Impact Assessment of IPM CRSP Activities in Uganda: A GIS Application

Investigators: G. Norton[1], D. Taylor[1], and T. Debass[1]

Abstract

The aggregate economic impact of IPM technologies is assessed using partial budget analysis and economic surplus methods for Uganda. The Maize variety Longe-1 and Seed-Dressing for Beans are being evaluated. From preliminary results of the partial budget analysis, all treatments give higher net return than the farmers' practices.

Objectives

1. To determine the benefits of IPM CRSP activities in Uganda's Bean/Maize production system.
2. To access the potential spillover economic impacts of the IPM practices on a regional basis.

IPM Constraints

Examination of adoption *constraints* must be fully rendered prior to any economic analysis. Land, labor, capital, knowledge, and cropping system factors may facilitate or *constrain* adoption of IPM technologies. There are also technical, Socio-economic, institutional, and political constraints that need to be fully investigated before undertaking such an analysis.

Research Methods

An ex-ante economic (consumer-producer) surplus analysis is being employed to assess the aggregate benefits of IPM CRSP interventions on the economy of Uganda. Also, a Geographic Information System (GIS) is used to project the transferability of IPM CRSP strategies beyond the primary research sites using agro-ecological and socio-economic information to estimate adoption rates. Data on production, consumption, prices, price elasticities for demand and supply, and experiment costs are gathered and assessed to project aggregate benefits. Questionnaires were developed to acquire expert opinion on adoption rates. Agroecological and socio-economic data were collected to facilitate the spatial framework to examine adoption rate patterns.

The economic analysis will be completed in the next two months and will provide information on the benefits of IPM CRSP technologies on the aggregate economy of Uganda. The GIS analysis will give an insight on the spatial dimension of economic analysis and will complement the effort of the IPM CRSP to globalize its activities by providing a framework to develop a spatial analysis for IPM practices around the world.

Networking Activity

T. Debass spent three weeks in Uganda to gather data and related information for his thesis research.

Training Output

Thomas Debass is working on his M.S. thesis on this activity at Virginia Tech.

[1] Virginia Tech

Baseline II Follow-up Survey of Farmer Pest Management Practices and IPM Technology Adoption and Diffusion

Scientists: J.M. Erbaugh[1], D.Taylor[2], B. Bashasha[3] and P. Padde[4]
Collaborating Scientists: S. Kyamanywa[5], V. Odeke[6], E. Mwanja[7]

Abstract

Three years following the conduct of an initial baseline study at IPM CRSP research sites in Uganda a follow-up baseline survey was conducted with farmers at research sites in Iganga and Kumi Districts and with farmers in adjacent sub-counties to determine farmer pest management practices, socio-economic factors associated with the practices and adoption and diffusion of IPM technologies. Eight field enumerators, 4 women and 4 men, reviewed and revised the survey instrument in a two day training workshop held in Jinja, March 1999, prior to going to selected sub-counties to conduct interviews. Two hundred questionnaires were eventually collected from research sites and neighboring sub-counties. Data transformation continues, but preliminary descriptive information of survey respondents indicates a slightly younger group of farmers were interviewed, with smaller average farm sizes, but similar levels of education and acres in crops than farmers sampled in the original baseline survey. Whereas 70% of the respondents reported using pesticides on crops in the field in the first baseline survey, 63% reported using pesticides on crops in the follow-up survey. As in the original baseline survey, farmers were more likely to be using pesticides on cowpea (80%) and groundnuts (37% overall, 43% in Kumi).

Objectives

1) To broaden knowledge base of pest management practices used by Ugandan farmers; 2) to examine socio-economic factors associated with knowledge, awareness and practice of IPM and other pest management practices; and 3) to assess impacts of IPM CRSP activities in Uganda.

IPM Constraints

Failure to consider farmers' socio-economic conditions and associated knowledge and attitudes pertaining to crop production and pest management has constrained successful development and adaptation of IPM technologies to meet the specific needs of resource poor farmers. Baseline information can also contribute to research prioritization and to measuring project progress and impacts.

Research Methods

Research Methods and Results

A survey instrument originally designed by Drs. Erbaugh , Taylor and Kyamanywa, was reviewed by field enumerators during a review and training workshop held in Jinja, Uganda, March, 1999. Field enumerators were chosen from District extension staffs and IPM CRSP supported graduate students. Four women and 4 men were selected and instructed to complete 25 questionnaires each. Female enumerators were to interview women farmers who were members of households but not necessarily heads of households. Male enumerators were to interview members randomly selected from farmer NGO groups. Sampling frames were derived from lists of farmers from NGOs in sub-counties where the IPM CRSP had conducted research activities and from adjacent sub-counties with new NGOs who had not been exposed directly to IPM CRSP activities. Additional supervision and logistical support for the interviewing process was provided by experienced survey administrators from Makerere University and the Ministry of Agriculture.

Preliminary Results

Two hundred questionnaires were eventually completed and delivered to the United States by the end of May. Raw data entry has only recently been completed and thus only descriptive information about the survey population is currently available. Completion of higher order analyses will be completed by the end of the year. Preliminary characteristics (see Table 1) of those interviewed indicates that 100 farmers were interviewed in each district including 50 each in two counties per district and 25 each in four sub-counties in each of the two counties per district. In the total sample, 53% of the respondents were female and 47% were male.

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[2] Agricultural Economist, Virginia Tech, USA
[3] Agricultural Economist, Makerere University, Uganda
[4] Agricultural Extension, Ministry of Agriculture & Animal Industries, Uganda
[5] Entomologist, Makerere University, Uganda
[6] Agricultural Extension Kumi District, Ministry of Agriculture & Animal Industries, Uganda
[7] Agricultural Extension Iganga District, Ministry of Agriculture & Animal Industries, Uganda

Table 1: Sample Characteristics

District	County	Sub-county	Male	Female
Iganga	Bunya	Imanyiro	25	
		Baitambogwe	12	13
	Kigulu	Bulamagi	13	12
		Nakalama		25
Total Iganga			**50**	**50**
Kumi	Kumi	Kumi	25	
		Atutur		25
	Bukedea	Malera	20	5
		Bukedea		25
Total Kumi			**45**	**55**
Sample Total			**95**	**105**

Comparing socio-demographic characteristics (see Table 2) of the sampled group of farmers in the follow-up baseline with the original baseline conducted in 1996, reveals roughly similar characteristics. However, follow-up baseline respondents were slightly younger, averaging 40 years of age compared to 42 years of age in the original baseline; were living in slightly smaller households that averaged 8.7 members per household compared to 9.5 in the original baseline; and the respondents to the follow-up baseline had smaller average farm sizes. The average number of years of education was roughly similar between the two surveys with the average and modal group equaling a primary education. Although farm sizes were larger in the original baseline survey, the number of acres reported to be in crops was nearly similar between the two surveys.

Table 2: Socio-demographic Profile of Sampled Farmers in Iganga and Kumi Districts, Uganda, 1999 and 1996.

	Iganga	Kumi	Sample Totals 1999	Sample Totals 1996
Average Age	37.0	42.7	40.0	42.0
Years of Education	6.9	6.6	6.8	6.3
Household Size	7.3	10.0	8.7	9.5
Farm Size (acres)	4.8	13.4	9.1	17.1
Crop acreage	3.0	8.4	5.7	5.9

In the original baseline survey 70% of the respondents reported using some pesticides on field crops whereas in the follow-up baseline 63% reported using some pesticides in the field (see Table 3). As in the original baseline survey, farmers were more likely to be using pesticides with the production of cowpea (80% of all farmers growing this crop) and groundnuts (37% of the farmers growing this crop). In general, farmers in Kumi were more likely to report some use of chemical pesticides than farmers in Iganga. Use of pesticides with maize was minimal in both surveys.

Table 3: Farmer Use of Pesticides by Priority Crop

	Total Farmers Growing	Pesticide Use by Crop		Sample Total Using Pesticides
	200 farmers	Iganga	Kumi	
Reporting Pesticide Use		44	82	126 (63)
Crop Name				
Maize	100	3(3)		3 (3)
Beans	93	16 (17)		16 (17)
Gnuts	171	21	42	63(37)
Sorghum	92	13 (14)		13 (14)
Cowpea	92	74 (80)		74 (80)
Tomato	27	12	9	21 (77)
Value in ( ) percentage of farmers using pesticides.				

Preliminary results explored in Table 4 mirror those from the original baseline survey. Pesticide use is more common in Kumi than in Iganga District. Household decision making regarding use of pesticides was more likely to be done by male household members, however, joint decision making was common, as was female decision making, probably in households where women are the primary agricultural decision makers. Men were more likely to purchase and apply pesticides. Pesticide application in particular appears to be perceived as a male domain. However, this information will need to be cross-checked by gender of the survey respondent to form a clearer picture of pesticide decision making.

Table 4: Pesticide Use Information

	Iganga	Kumi
Sample Size	100	100
Using pesticides	44	82
1. Family member who makes decision		
No ans.	56	18
Male	22	33
Female	12	24
Both	10	25
2. Who purchases pesticides		
Not using	56	18
Male	35	55
Female	2	18
Both	7	9
3. Who applies pesticides		
Not using	56	18
Adult male	35	41
Boys	6	22
Female/girls	6	3
Both	3	1
Hired	3	15

Impact

At this stage in the process, the primary impact of the survey has been to heighten awareness of IPM and IPMCRSP activities including technological recommendations with participating farmer NGO groups and expand and broaden awareness of these same features among NGO groups that had not formerly participated but who were included in the survey sampling frame.

Networking Activities

Workshops Planned or Participated In: Four workshops were planned and participated in this year in Uganda. The first was a one day, mid-year Annual Meeting held in Jinja, Uganda, December 8, 1998; The second was a two day Workplan Development Conference held in Mbale, Uganda, March 5-6, 1999; The third was a two day Field Enumerator Training Workshop held in Jinja, Uganda, March 8-9; and the fourth was the two-day workshop on presentation of research results, held in Mbale, Uganda, August 26-28, 1999.

Research Investigator Exchanges: 1) Arrangements were made to receive, transport and work with Drs. Kyamanywa and Bigirwa when they traveled to Ohio and then to Purdue for the Annual Meetings in May 1999; 2) Was instrumental in facilitating the secondary collection activities of Mr. T. Debass while in Uganda. Mr. Debass is a graduate student in Agricultural Economics from Virginia Tech; 3) Helped plan and coordinate visit to Uganda by External Evaluation Committee member, Dr. Ramaswamy.

Project Highlight

A follow-up baseline questionnaire to obtain information on pests, pest management practices and socio-economic factors associated with knowledge, awareness and practice of IPM was administered to 200 farmers in Iganga and Kumi Districts in Uganda. Preliminary data analyses indicate that 63% of the respondents are using pesticides on field crops. Pesticide usage is more common in Kumi than in Iganga district. Among the IPM CRSP focal crops of maize, beans, groundnuts, sorghum, and cowpea, the most commonly sprayed crops are cowpea and groundnuts. In both districts, men are more likely than women to purchase and apply pesticides.

Publications

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Presentations

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The Role of a Farmer Implemented Pest Monitoring Program in the Implementation of On-Farm Maize Pest Management Research

Investigators: Willson, H. R.[1], S. Kyamanywa[2] and M. T. Kauma[2]

Abstract

Following stakeholder meetings to establish interest of Ugandan institutions in participatory integrated pest management research, participatory assessments were conducted with four farmer groups in two Ugandan District to identify research priorities on a number of crops. This study focuses on results obtained on maize in the District of Iganga. In the participatory assessments, farmers initially identified stalk borers and termites as entomological pests causing production constraints in maize. A farmer implemented crop monitoring program was established which documented six growing seasons of stalk borer and termite infestation levels at the farm level. Successful implementation of the crop monitoring program depended on a combination of grower participation, active extension agent supervision, and organization by research scientists. One year after initiation of the farmer crop monitoring program, on-farm research trials were initiated by university and research station scientists with the cooperation of farmers having experience in crop monitoring. Low level infestations of stalk borer demonstrated in the farmer implemented program were substantiated by observations in replicated on-farm trials sampled university graduate student. On-farm studies by research scientists generated information on yield losses and stalk borer species, namely *Chilo partellus and Busseolus fusca* causing the stalk borer complex infestations. Subsequent direction of research activities have been based in part on the results of farmer monitoring efforts and results of on-farm studies by university and research station scientists.

Objectives

This report focuses on the results of three years of farmer monitoring of maize crops in Iganga District with specific attention on the stalk borer complex on maize and how the pest monitoring project related to subsequent on-farm research trials. The basic issues of this study are that (1) data collected by farmers in a well structured program can provide information relevant to pest management programs, and (2) farmers participating in crop monitoring programs provide a source of cooperators for on-farm trials conducted by research institutions.

IPM Constraints

Effective implementation of on-farm pest management research requires cooperation among all participants

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including farmers, research specialists and extension workers, who often fulfill a liaison role between farmers and researchers. Effective maintenance of research plots requires the cooperation of farmers who understand the research objectives and manage plots in a manner that facilitates data collection. In this study, farmer cooperators are introduced to research principles by participating in crop monitoring programs.

Research Methods

In December of 1994, the Integrated Pest Management Collaborative Research Support Program (IPM CRSP) was initiated in Uganda with a series of stakeholder meetings between representatives of agricultural research and development institutions of Uganda and Ohio State University representatives of the USAID supported IPM CRSP. In July of 1996, participatory assessments were conducted with two farmer groups in Iganga District to identify grower priorities on pest problems of various crops and evaluate grower interest in participating in on-farm pest management research.

Prior to the first growing season in 1996, small groups of growers were selected from each of the farmer associations of Iganga District to implement a crop monitoring program focused on periodic sampling of pest complexes associated with a limited number of crops, namely maize, beans and groundnuts. In 1997, after one year of farmer implementation in the crop pest monitoring project, on-farm research trials were initiated by pest management scientists of Makerere University (MU) and research stations of the National Agricultural Research Organization (NARO) in cooperation with the farmer groups participating in the IPM CRSP crop monitoring project.

The participatory assessment in Iganga District was conducted from July 20 to 22, 1995. Approximately 20 farmers in Baitambogwe sub-county and 30 farmers in Bulamagi sub-county participated in focus group sessions offering their opinions on the relative importance of crop and pest problems regarded as constraining factors to maize, bean and groundnut production. In regard to specific pest problems, hand votes were generally taken to provide a relative ranking of the importance of various pests. Following each group session, interviews were conducted with various farmers to obtain specific information on the relative size of farm operations. In the case of the Baitambogwe farmer group, most of the farmers were women. In the case of the Bulamagi group, most of the farmers were men.

In the spring of 1996, organization of farmer IPM groups were initiated with meetings of interested farmers from the Baitambogwe and Bulamagi farmer associations. Approximately five farmers were selected from each farmer association and a local IPM coordinator was selected. Each farmer was requested to monitor two or three sites maize, bean and/or groundnut production. Field instruction in sampling procedures and field data sheets were provided to each participant. Periodic supervision on scouting methodology and record keeping was to be provided by the local extension specialist linked to the District office of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). The future success of the program depended primarily on the periodic cooperation of the group IPM coordinator and the local extension agent plus occasional visits from the research scientists of MU or a NARO research station. In general, field sites were sampled three to five times during a growing season. In the case of maize, ten plants from four locations in a field were sampled during each inspection and levels of infestation recorded for each pest symptom targeted. In addition, stand counts and crop development stages were recorded. At the end of each growing season, the local extension collected the field records and submitted them to the MU IPM CRSP program coordinator for processing. Farmers were compensated for their efforts in the program. Travel expenses of the local extension personnel and research specialists from MU and NARO were covered by the IPM CRSP program.

In the spring of 1997, on-farm field trials were initiated by scientists from MU and NARO. Farmers who had demonstrated reliable reporting of crop monitoring data were selected to be managers of the trial sites providing agronomic assistance from planting to harvest. Field data on the replicated plot trials were collected on a bi-weekly schedule by either graduate students from UM or NARO technicians. In the case of maize, two research projects were conducted in the Iganga District with two plot sites in each sub-county. The primary maize project focused on comparison of a new MSV variety (Longe I) compared to local maize varieties grown under mono-crop and inter-crop (with beans) cultural conditions. The emphasis of this study was on the maize disease complex and stalk borer incidence and injury. Data reported in this paper includes only averages of stalk borer infestation and yield losses that can be related to the observations of the farmer crop monitoring program. The second maize research project focused on biological control to evaluate the release and establishment of *Cotesia flavipes*, a hymenopterous parasite of the exotic spotted stem borer, *Chilo partellus*. Since the farmer monitoring effort had established a baseline of stalk borer activity, the area was selected as a parasite release site by research collaborators from the International Center for Insect Physiology and Ecology (ICIPE).

Results

The participatory assessment in Iganga identified the pest problems and production constraints of four crops grown by the Iganga farmers, namely maize, beans, groundnuts and bananas. The ranking of pest problems perceived as production constraints Mammalian pests identified as key production constraints included monkeys, birds, and mole rats.

The results of three years or six growing seasons of maize crop pest monitoring by Iganga farmers is presented in Table 1. Foliar infestations by stalk borer averaged 14.9% of stands monitored. Stalk and ear infestation levels average 9.2% and 4.9% respectively. Considering that the visual stalk borer infestation levels recorded by farmers represented a stalk borer complex of four species and individual site infestations never exceeded 50%, the severity of stalk borer infestations may be regarded as relatively low. Termite injury or stand loss averaged 16.1% of stand with the most severe levels of injury during the 1st rains - especially during seasons of dry weather. Root rat injury was relatively low, except during the 1st rainy season of 1997. Maize streak virus symptoms were found on an average of 13.3% of stand ranging from a low of 8.3% in the 2nd rainy season of 1998 to a high of 35.3% in the 2nd rainy season of 1997.

Table 1. Infestations of pests and diseases on maize observed by growers of Iganga District.

Year	Rainy Season	No. Sites Monitored	Average Stand Infestations Observed (% of Stand)					
			Stalk Borer			Termite Loss	Root Rot	Maize Streak
			Foliar	Stalk	Ear			
1966	1st	5	24.5	15.6	7.5	39.4	0.0	11.5
	2nd	5	13.1	4.7	3.1	12.5	0.6	20.0
1997	1st	5	16.1	9.6	6.0	16.0	6.4	13.9
	2nd	3	12.0	10.0	5.5	0.8	0.2	36.2
1998	1st	3	11.0	8.2	3.2	19.8	0.0	14.5
	2nd	10	12.8	7.3	3.8	7.8	0.0	8.3
3 Year Average of 1st Rains:			17.2	11.1	5.6	25.1	2.1	13.3
3 Year Average of 2nd Rains:			12.6	7.3	4.1	7.0	1.2	21.5
Average of All 6 Seasons:			14.9	9.2	4.9	16.1	0.3	17.4

Three seasons of stalk borer infestation data collected from on-farm plot trials by a MU entomologist that may be compared to the observations of farmers are presented in Table 2. Although the foliar infestation levels in the replicated on-farm trials are consistently higher than that of the farmers' observations, the levels may be regarded as equivalent in respect to economic impact. The difference in average foliar infestation levels observed by the farmers and the scientists may be due to the difference in sites monitored or to the fact that a trained entomology graduate student may inspect plants more intensively. Yield analysis of the on-farm trials established that stalk borer infested plants exhibiting foliar infestation had a yield loss of 16.9% compared to non-infested plants. Adjusting the yield loss for the proportion of stand infested results in a stand loss averaging 3% for the trials and a 2% loss for the field sites monitored by farmers.

The on-farm trial study documented that the primary species causing stalk borer injury were the spotted stem borer, *Chilo partellus*, and the maize stalk borer, *Busseola fusca*. *B. fusca* was the dominant species in the 2nd rains of 1997. *C. partellus* was the dominant species in both the 1st and 2nd rains of 1998. Specific identification of species causing stalk borer injury was not established in the farmers' observations since destructive sampling was not conducted and specimens were seldom collected for taxonomic identification.

Table 2. Observations of foliar stalk borer injury by growers compared to results of on-farm replicated trials conducted by Makerere University and NARO scientists on nearby farms in Iganga District.

Year	Rainy Season	Grower Observations		Makerere / NARO Trial Results			
		No. Sites Monitored	% Foliar Stand Inj.	No. Sites Sampled	% Foliar Stand Inj.	Est. % Yield Loss	
						Inf. Plant	Stand
1997	2nd	3	12.0	4	19.8	13.6	2.7
1998	1st	3	11.0	4	13.6	15.9	2.2
1998	2nd	10	12.8	4	19.5	21.1	4.1
Average of 3 Seasons			11.9		17.6	16.9	3.0

Discussion

Stalk borer infestations reported by growers were equivalent to that observed in on-farm trials considering that grower observations were based periodic visual observations of maize stands and sampling results of on-farm trials were taken by a graduate student in entomology conducting a rather intensive sampling of four replications of four variety/cultural treatments at four locations. Yield loss assessments derived from on on-farm trials demonstrated that the prevailing yield loss due to stalk borers on a total stand basis was only 3%. If the same criteria is applied to the level of foliar stand injury observed by farmers, the prevailing yield loss on a total stand basis would be 2%. In summary, both the grower monitoring program and the on-farm trials demonstrated a very low level of stalk borer infestation loss, which represents the combined impact of two primary stalk borer pests and two secondary stalk borer pests.

Given the low levels of stalk borer infestations observed, the need for any treatment of total stand with a pesticide cannot be justified. However, it should be recognized that the pesticide treatment of stalk borer in this area is performed on a selective plant by plant basis where only plants exhibiting symptoms of infestation are treated with a granular pesticide formulation such a 2% beta-cyfluthrin marketed under the trade name of Bulldock.

Farmers observations of pest activity on maize demonstrated that termites were a more significant problem than stalk borers, since the infestations levels reported by growers for termites generally represent premature stalk breakage at the base of plants which often represents a loss in yield equivalent to the percent of infestation reported. Support of entomological research on maize in Uganda by the IPM CRSP program is currently being shifted from stalk borers to termites.

The only disease initially targeted in the grower monitoring program was maize streak virus. Since only 17.4% of the stand exhibited MSV symptoms, the impact on yield was likely moderate. However, subsequent observations in the on-farm trials by NARO demonstrated that the primary disease problems in the region were Gray leaf spot and Northern leaf blight.

Impact

The data presented from farmer monitoring of maize crop pests demonstrated that results of farmer implemented monitoring programs can generate reliable data on prevailing pest infestations if an effective system of farmer training and supervision is implemented. Similar results have been generated on beans, groundnuts, sorghum, millet and cowpeas within the Uganda IPM CRSP program, although data on the other crops were not as complete or consistent as that generated from the program on maize in the Iganga District.

The most significant result of the grower implemented monitoring program has been the provision of grower cooperators for on-farm trials subsequently conducted by university and experiment station scientists. It should be recognized that growers participating in the process of collection crop monitoring data become familiar with the importance of sampling procedures, record keeping, and develop an awareness of the systematic process required in field plot trials.

Networking Activities

During the June-1999 tour of the Uganda IPM CRSP program, H. Willson toured and reviewed the field status of nine projects including: (1) maize-bean inter-crop trials in Iganga, (2) biological control of stalk borer, (3) bean trials in Iganga, (4) groundnut trials in Iganga and Kumi, (5) cowpea trials in Kumi, (6) striga trials in Kumi, (7) post-harvest trials on beans and cowpeas, (8) tomato IPM project near Numalonge, and (9) termites on maize (new project).

Technical assistance was provided to the USAID IDEA program by providing a review of a Quick Reference Guide for Crop Chemicals currently under development for use in pesticide management training programs in Uganda. In addition, a review was provided to USAID personnel on an

Agriculture Sector pesticide Procedure Guide related to USAID program compliance with USEPA regulations and the need for development of Initial Environmental Evaluations (IEE) and/or Environmental Assessments (EA).

Project Highlights

- Stalk borer infestations reported by growers were equivalent to that recorded by university scientists demonstrating that farmers can collect reliable data in support of an IPM program.

- Yield loss assessments derived from on on-farm trials demonstrated that the average yield loss due to stalk borers on a total stand basis ranged from 2 to 4%. Such a low level of loss due to a pest problem is not readily observed in the field and unlikely to stimulate grower actions to apply control measures.

- Farmers observations of pest activity on maize demonstrated that termites were a more significant problem than stalk borers. Support of entomological research on maize in Uganda by the IPM CRSP program is currently being shifted from stalk borers to termites.

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ERITREA

The reports given below cover research programs carried out in Eritrea by DARHRD in collaboration with the IPM CRSP both in 1997 and 1998.

Monitoring, Survey, and Assessment of Insect and Disease Incidence and Severity on Farmers' Fields

Investigators: Asmelash Wolday[1], Biniam Weldeab[1], Goitom Gobozl[1]
Collaborators: Brhane Gebrekidan[2], Herman Warren[2], Hal Willson[3]

Objective

To develop an integrated pest management (IPM) strategy based on the information gathered on the program of global 2000 farmers' fields.

Research Methods

This activity was planned to be implemented on the program of Global 2000 farmers' fields both in the highland and the western lowland zones. Five maize fields in the highlands and five sorghum fields in the western lowlands were selected for observation and evaluation. It was anticipated that the information gathered this year on the global 2000 farmers' fields would be used to devise appropriate IPM tactics for the next year.

Progress to Date

The farming practices followed by the farmers in the program of Global 2000 did not allow us to gather information on insect and disease incidence and severity. The farmers did not use row planting and used chemicals to control insects and diseases. Thus the required data to be taken was not obtained for both years (1997 and 1998). In both years we took the first record but we could not continue to take the rest of the records and other data as the farmers used chemicals to control insects and diseases.

Striga Experiments: Integrated *Striga* Management (ISM) Trial and Evaluation of Sorghum Varieties for *Striga* Resistance

Investigators: Asmelash Wolday[1], Biniam Weldeab[1], Goitom Gobozi[1]
Collaborator: Brhane Gebrekidan[2]

The trial was carried out both in 1997 and 1998 in the western lowland (Shambuko), but the 1997 trial failed because of the drought. The trial intended to be carried out in the highland (Mendefera) was not carried out because rain started late and the planting dates passed. The results given below for 1998 are from the western lowland (Shambuko).

Abstract

***Striga* infestation was considerably reduced when sorghum received integrated *Striga* management (inter-cropped with soybean, applied nitrogen fertilizer and hand weeded twice) as compared to the check plot. The application of the ISM practice reduced the *Striga* weed population by 95 % and increased grain yield of sorghum by 86 % with an additional legume yield of 117kg/ha. The ISM practice improved sorghum production both by reducing *Striga* count and increasing sorghum grain yield.**

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[2] Virginia Tech
[3] Ohio State University

Objective

To develop appropriate and meaningful control of parasitic weed *Striga hermonthica* for small scale farmers through multiple control measures used together.

Research Methods

Striga sick plots were identified in five farmers' fields in the western lowlands, around Shambuko. The five farmers' plots were considered as replications. The variety used was local-Bazenai with 15 kg/ha seeding rate. Twenty two rows of 20m length each were used for each treatment. Each farmer's plots were prepared in an area of $1000m^2$ which was divided into two equal half plots. One half plot was managed as a control while the second half received Integrated *Striga* management (ISM). Data recorded included date of planting, plant height, stand counts of sorghum plant and *Striga*, and grain yield (q/ha).

The ISM plot was planted in rows and was also inter-cropped with one row of soybean often every two rows of sorghum, received Nitrogen fertilizer (50% applied basal and 50% at the second weeding stage), and was hand weeded two times (early and late season). On the other hand, the control plot was sown by broadcasting and received neither weeding nor fertilizer.

Results and Discussions

The trial showed significant difference among the treatments and *Striga* infestation level. *Striga* infestation was considerably reduced when sorghum received integerated management (inter-cropped with soybean,applied nitrogen fertilizer and hand weeded twice) as compared to the check plot (Table 1). The application of appropriate *Striga* management practice reduced the *Striga* weed population by 95 % and increased grain yield of sorghum by 86%, with an additional legume yield of 117kg/ha. This integrated management practice improved sorghum production both by depressing *Striga* count and increasing sorghum grain yield.

Table 1. Effect of combined treatments on *Striga* infestation and sorghum grain yield, Shambuko, 1998

Treatments	Plant height	*Striga* count/m^2	Yield (kg/ha)	
			Sorghum	Soybean
Farmer's Practice	235	58	1368	----
Integrated *Striga* Management (ISM)	238	3	2540	117
$LSD_{0.05}$	18.0	35.0		
SE	4.0	7.8		
CV%	18.97	53.3		

Evaluation of Introduced Sorghum Varieties for *Striga* Resistance

The trial was carried out both in 1997 and 1998 in the western lowland (Shambuko), but the 1997 trial failed because of the drought. The trial intended to be carried out in 1997 in the highland (Mendefera) was not carried out because rain started late and the planting dates were missed. The results given below are for 1998 carried out in the western lowland (Shambuko) and in the highland Mendefera).

Abstract

In the trial of screening high-land sorghum cultivars for their resistance against *Striga* all the varieties were infested with the parasitic weed. Although no yield data could be obtained, *Striga* counts were recorded. Entry IS-29415 supported the lowest *Striga* emergence compared to the other varieties.

In the trial of screening low-land sorghum cultivars for their resistance against *Striga*, the *Striga* count during the early growth stage of sorghum was very few in number, but the number of *Striga* increased greatly during late season when the crop was already well established. Varieties with entry numbers 8579 and 8568 were with no *Striga* at all and Varieties with entry numbers 8557 and 8580 were with very few number of *Striga*. Variety with entry number 8552, 8556, 8566, 8577 and 8555 sustained fewer *Striga* and as the same time gave

good yield with 39.2, 33.2, 29.8, 29.7 and 29.4 q/ha, respectively.

In the trial of screening selected cultivars of sorghum for their resistance to *Striga*, although the varieties were expected to show high degree of resistance because of their reported genetic potential, all the varieties were seriously infested with the weed. No yield data were obtained from the trial.

Objectives

To evaluate highland, lowland and selected sorghum cultivars with enhanced level of resistance to *Striga* under Eritrean conditions.

Research Methods

(1) Highland cultivars

Eight treatments of which 6 were varieties received from ICRISAT, selected on the basis of agronomic characteristics, with two local varieties were tested. The experimental design was Randomized Complete Block Design (RCBD) with four replications. Four rows of 5m length were used for all the treatments. The experiment was carried out on farmers' plots in Ma`edo around Mendefera. *Striga* count were recorded for each plot.

(2) Lowland cultivars

Twenty six varieties of which 24 were received from INTSORMIL/Purdue University (International *Striga* Resistant Sorghum Nursery) along with two checks (8575 and Pato) were planted. The trial was carried out on five farmers' fields around Shambuko. The experimental design at each farmer's field was RCBD with four replications. Three rows of 5 m length were used for each treatment (variety) in each replication. Plant height, panicle size, sorghum stand count, *Striga* count and yields of the treatments were recorded.

(3) Selected lowland cultivars.

Eight special sorghum varieties selected for their resistance to *Striga* were received from INTSORMIL/Purdue University (International *Striga* Resistant Nursery). A local check Bazenai (8556) was also included in the trial. The experimental design was RCBD with four replications. Three rows of 5m length were used for each treatment. The experiment was carried out at the Shambuko Research Center. Data recorded included plant height, sorghum as well as *Striga* stand count per plot.

Results and Discussions

In the highland trial all the varieties were infested with the parasitic weed and no yield data were obtained. IS-29415 sustained relatively fewer *Striga* than the other entries (Table 2). In general in this trial, *Striga* count during the early growth stage of sorghum was very few in number. Greater number of *Striga* was observed during late season.

Table 2. Screening highland sorghum cultivars for their resistance to *Striga*, Mendefera, 1998

No	Treatments	Stand count	*Striga* count/plot	
			1st count	2nd count
1	IS-29376	44	6	32
2	IS-29415	32	0	17
3	IS-25557	34	0	33
4	AMAL	41	8	40
5	IS-11272	39	12	38
6	IS-25546	40	0	36
7	KODEN	46	9	41
8	NYNDO	33	11	45
$LSD_{0.05}$				20.5
SE				71
CV%				13.9

In the lowland *Striga* resistant sorghum nursery, the varieties with entry numbers 8579 and 8568 did not have any *Striga* at all and varieties with entry numbers 8557 and 8580 supported *Striga*. Entry numbers 8552, 8556, 8566, 8577 and 8555 had relatively few *Striga plants* and at the same time gave good yield with 39.2, 33.2, 29.8, 29.7 and 29.4 q/ha, respectively (Table 3). The main advantages of these cultivars is that they can give reasonable yields under heavy *Striga* infestation.

The trial of the eight special selected *Striga* resistant cultivars showed that all the varieties were seriously infested with the weed (Table 4) and no grain yields were obtained because the entire trial was damaged by animals. Entry number 8552 had the lowest *Striga* count.

Table 3. Screening lowland sorghum cultivars for their resistance to *Striga*, Shambuko, 1998

No	Treatment	Plant height (cm)	Panicle size (cm)	Stand count	*Striga* count/plot		Yield (Q/ha)
					1st count	2nd count	
1	8551	133	26.2	38	3	40	22.7
2	8552	150	28.8	59	2	28	39.2
3	8553	143	30.0	37	3	13	23.7
4	8554	148	32.5	29	1	15	24.8
5	8555	137	30.5	54	0	18	29.4

Table 3. *continued*

No	Treatment	Plant height (cm)	Panicle size (cm)	Stand count	*Striga* count/plot		Yield (Q/ha)
					1st count	2nd count	
6	8556(control)	130	29.8	56	0	12	33.2
7	8557	134	29.0	33	1	4	15.2
8	8558	100	27.8	43	10	65	19.0
9	8559	138	30.0	55	10	75	25.3
10	8560	127	19.5	46	32	66	15.6
11	8563	138	29.5	40	9	169	26.0
12	8564	129	28.2	41	26	196	23.3
13	8565	132	29.8	49	25	181	25.8
14	8566	136	29.2	48	3	36	29.8
15	8568	138	23.0	57	0	0	13.8
16	8571	111	28.0	40	4	36	18.4
17	8572	117	25.7	39	1	22	24.1
18	8573	134	34.5	41	0	12	26.4
19	8574	128	23.8	34	8	43	17.7
20	8575	267	30.8	67	15	148	35.4
21	8576	129	27.8	52	12	84	26.1
22	8577	150	26.5	44	2	120	29.7
23	8578	153	24.8	42	1	21	20.4
24	8579	108	25.2	38	0	0	21.4
25	8580	111	25.5	27	0	5	12.3
26	PATO	223	22.0	25	10	12	22.2
$LSD_{0.05}$				12.1			
SE				6.1			
CV %				35.9			

Table 4. Screening selected cultivars of sorghum for their resistance against *Striga*

No	Treatment	Sorghum stand count/plot	*Striga* count/plot	
			1st count	2nd count
1	8551	56	7	155
2	8552	79	14	126
3	8553	32	17	185
4	8554	38	7	299
5	8555	52	25	206
6	8556(Local-Bazenai)	91	6	251
7	8557	52	24	347
8	8558	48	2	314
9	8559	75	16	299
$LSD_{0.05}$		129.9		
SE		106.15		
CV%		53.59		

Assessment of Advanced Sorghum Varieties for Disease and Insect Resistance

Investigators: Asmelash Wolday[1], Biniam Weldeab[1], Goitom Gobozi[1]
Collaborators: Hal Willson[2] and Herman Warren[3]

The trial was planted both in 1997 and 1998 in the western lowland (Shambuko), and in the highlands (Mendefera), but the trial of the western lowland in 1997 failed because of the drought and that of the 1998 was destroyed by animals. The results

[1] DARHRD
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[3] Virginia Tech

from the 1997 highland (Mendefera) trial are presented below. The highlands trial of 1998 also failed because of the heavy hail of August 8, 1998.

Abstract

The variety IS-25557 had relatively high stalk borer infestation (7.25%), however it gave the highest yield with 16 q/ha, followed by the variety IS 29376 with 15 q/ha and scored the least stalk (3.75%) borer infestation. The local variety Amal had 5.5% stalk borer infestation and gave the lowest yield of about 3 q/ha.

Objectives

To evaluate sorghum varieties with enhanced level of resistance toward sorghum pests and diseases.

Research Methods

This assessment was done at Halhale Research Center. Six advanced varieties which have been evaluated and selected previously for their agronomic performances and one local check were used. The varieties were tested for their resistance to sorghum pests, particularly to stalk borers. The Experimental design was RCBD with four replications.

Results and Discussions

The trial showed significant difference among the treatments for grain yield but not for stalk borer infestation. The variety IS-25557 gave the highest yield with 16 q/ha, followed by variety IS 29376 with 15 q/ha. Amal the local variety gave the lowest yield of about 3 q/ha (Table 5).

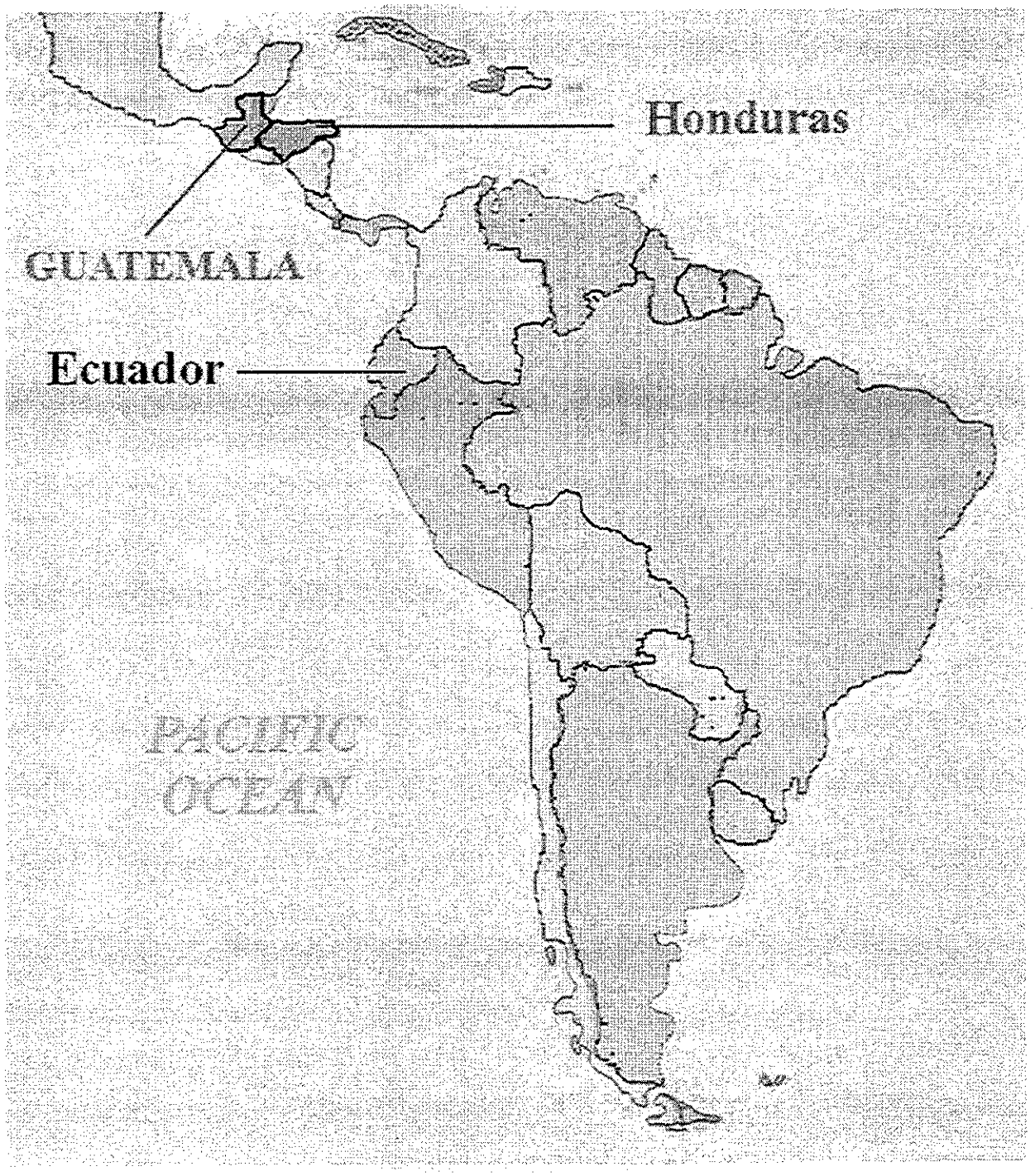
Table 5. Sorghum mean yield (q/ha) and stalk borer attack in %

No.	Varieties	Stalk borer attack in %	Mean yield q/ha
1.	Amal (control)	5.50	3.3
2.	IS 11272	6.75	11.8
3.	IS 25546	6.25	8.4
4.	IS 29376	3.75	15.4
5.	IS 25557	7.25	15.8
6.	NYUNDU	8.75	10.1
7.	IS 25547	10.50	13.0
$LSD_{0.05}$	NS	3.6	
SE	6.80	1.7	
CV%	69.00	43.7	

The following additional studies were planned but not implemented because the necessary materials and research methods were not available:

Study and Identification of races of fungi: planned to study and identify the major fungal diseases of sorghum in Eritrea with a special emphasis on the races of leaf blight and rust.

Monitoring seasonal activity of adult stem borer populations utilizing pheromone traps: planned to monitor the activities of adult stem borer populations, using pheromone traps, both in the highland and the lowland zones.



LATIN AMERICA

Annual Report Overview for IPM CRSP Central America Site, Year Six

Authors: Glenn H. Sullivan[1], Guillermo Sánchez[2], Stephen C. Weller[3], and C. Richard Edwards[3]

Description

The Central American Site operates through a site committee structure, with Guatemala as the prime site. Dr. Guillermo Sánchez, Head of the Department of Agricultural Sciences and Forestry at the Universidad of del Valle, serves as the regional site coordinator for Central America. The Regional Site Committee is comprised of Dr. Sánchez, Ing. Luis Calderón (ICTA), Juan Enrique Leal (AGRILAB), Luis Alvarez (ARF/AGEXPRONT), Rafael Solorzano (ALTERTEC), Eddy Diaz/Victor Salguero (MAGA), Luis Caniz (APHIS-IS), Dr. Linda Asturias (ESTUDIO 1360), and Maria Mercedes Doyle (ZAMORANO). The U.S. researchers that collaborate with the regional site committee and provide research support, technical support, and program coordination include: Drs. Glenn H. Sullivan, Stephen C. Weller, C. Richard Edwards, and Ray Martyn (Purdue University) and Dr. Sarah Hamilton (Virginia Tech). The overall Central American site activities in Year Six were funded through U.S. IPM CRSP under subcontract with Virginia Tech, and grant funds generated from the Government of Guatemala (GOG), FONAPAZ, and ARF/AGEXPRONT.

ZAMORANO (Honduras) was the principal regional collaborating institution outside Guatemala. In Year Six, however, substantive discussions were carried forward with Nicaragua and El Salvador with the purpose of establishing MOU's in these countries during Year Seven.

APHIS and ARF/AGEXPRONT continued to provide strong collaborations in the development of IPM / ICM strategies for reducing pesticide use and improving the performances for achieving safer food supplies in the NTAE sector. APHIS-IS continued to provide collaborative leadership in the development of preinspection programs in Guatemala. ICTA has collaborated in testing and revising IPM CRSP production strategies for improved pest management in snow peas (leaf miner), tomatoes (white fly), and broccoli (*Plutella xylostella*). ESTUDIO 1360, in collaboration with Dr. Sarah Hamilton (Virginia Tech) contributed substantively to research activities that evaluated the socioeconomic impacts of NTAE production at the community and household levels.

Research collaborations with FONAPAZ were strengthened in Year Six. FONAPAZ proceeded to revise their domestic development programs in Guatemala commensurate with IPM CRSP program priorities, including community level transfers of IPM CRSP developed production strategies and protocols. FONAPAZ grants to the IPM CRSP researchers at Univ. del Valle provided funds for community level research transfer activities, including field demonstrations.

Preliminary research agendas and budgets for the Central America Site are established during the annual Technical Committee Meetings. These broad research agendas are then presented to the Site Committee for review, discussion, and prioritization of specific research activities for the year. The Site Committee meets monthly to discuss research progress and make consensus decisions on any revisions. Each collaborator and/or collaborating institution has the opportunity throughout the year to request revisions in previously approved research agendas and budgets. Such revisions require Site Committee consensus.

IPM Constraints

Institutional Policies

Public and private sector policies significantly influence NTAE development in Central America, including the implementation of performance-proven IPM / ICM practices and certified preinspection programs. In Guatemala, the private sector has led the initiative for policy revision. AGEXPRONT has reorganized their overall committee structure in a serious effort to develop more proactive policies that will enhance performances in the NTAE sector. Science-based production and preinspection policies that lead to reduced pesticide usage and decreased product rejections at U.S. ports-of-entry are now a major focus of AGEXPRONT's policy revision initiatives. Similarly, private sector firms like Tierra Fria and Frutesa have established aggressive proactive policy revisions in their operating performances in a serious effort to enhance their competitive position in the NTAE sector.

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[2] Regional Site Coordinator, Universidad del Valle, Guatemala City, Guatemala..
[3] Co-Principal Investigator, Purdue University, West Lafayette, Indiana, USA.

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On the other hand, government initiatives to revise policies commensurate with the needs of a more competitive marketplace in the NTAE sector have been slow to develop, and currently represent a serious impediment to Guatemala's future performance capacity in international and/or regional markets for NTAE crops. The research and technology transfers of performance-proven IPM / ICM production and post-harvest practices advanced by the IPM CRSP have been frustrated by the lack of timely and response-effective policy initiatives at the central government level.

Technology Transfers

The timely implementation of performance-proven IPM CRSP production and post-harvest handling strategies continue to be a constraint. Again, the lack of timely and response-effective support from government is an important factor delaying these transfers. ICTA has not yet been given an administrative mandate and/or funding to provide the GOG leadership effectuating such technology transfers, and no other GOG entity, other than FONAPAZ, is positioned to assume such a leadership role. As a result, too many small independent NTAE producers still rely heavily on agrochemical sales agents and unregistered pesticides for their disease and insect pest control information. This constraint will gradually be overcome as more IPM CRSP approved pest management information is transferred through regional workshops, seminars, and field demonstrations, and as the private sector struggles to overcome the gaps left by the government's slow response. However, the private sector alone cannot provide the resources needed to reverse Guatemala's gradual decline in competitiveness in the international marketplace. Recent IPM CRSP market competitiveness assessments indicate that Guatemala is now the 15th most competitive external supplier of vegetables for export to the USA, a decline from the 5th most competitive position in 1992.

Research Capacity

A primary constraint to IPM program adoption in Central America in past years has centered on the research capacity within the collaborating institutions and among the individual collaborators. Many of the collaborating institutions / collaborators simply have lacked the scientific capacity to bring science-based solutions to current pest management problems. While we have made significant progress in resolving this constraint over the last two years, much remains to be done in Guatemala and Honduras. Research is now more focused relative to our overall IPM CRSP objectives and missions, and is presented in a more scientific manner. Dr. G. Sánchez, the IPM CRSP Site Coordinator and plant pathologist trained in the United States, is well founded in science-based research and has been extremely successful in helping raise the level of scientific approach to current research activities among collaborators. Sánchez' leadership in this important area, combined with U. del Valle, Purdue University, and Virginia Tech collaborations, and with AGEXPRONT's restructuring and science-based focus, have combined to help enhance the scientific rigor of IPM CRSP research in Guatemala.

Institution Building

The Government of Guatemala has strongly supported the IPM CRSP's overall objectives for strengthening scientific capacity and market-focused planning in the NTAE sector. Institutional linkages with the Ministry's of Finance and Agriculture, FONAPAZ, and ICTA have been important factors in moving the IMP CRSP research and development agenda forward in Central America.

In addition, institutional collaborations with APHIS-IS, FAS, and AGEXPRONT have been critically important in helping bring additional program funding and focus to the IPM CRSP. APHIS-IS has been instrumental in helping move the preinspection program forward in the NTAE sector. FAS has teamed with the GOG (Ministry's of Finance and Agriculture) to provide additional funding for the IPM CRSP Guatemala workplan activities. AGEXPRONT has been instrumental in providing additional research funds and in the transfers of performance-proven IPM CRSP pest management strategies.

The leadership role that was established between Purdue University and U. del Valle and Dr. G. Sánchez has helped strengthen the scientific research capacity of collaborating institutions in Guatemala, as well as, that of collaborating researchers and student training programs. The U. del Valle has an excellent reputation in the science areas, and has the human resources to play an ever increasing role in the institutional strengthening objectives of IPM CRSP. In recognition of the role that Dr. Sánchez and U. del Valle has played in the IPM CRSP, Purdue University awarded Dr. Sánchez an Adjunct Professorship in Year Six. In this appointment, Dr. Sánchez has full rights given to Full Professors at Purdue University with respect to serving on graduate student and research committees, electronic access to the Purdue University system, publication rights, etc.

Efforts continued in Year Six to strengthen institutional collaborations with Zamorano and FHIS (Honduras). However, progress has been slow with the departure of Drs. Zeiss and Hruska, and the impact of Hurricane Mitch. These efforts will continue in Year Seven through collaborations with Dr. Maria Mercedes Doyle at Zamorano and Dr. Dale Krigsvold at FHIA.

IPM CRSP in Central America continues to place high priority on strengthening the institutional capacity of collaborators and collaborating institutions. IPM CRSP scientists in the United States have collaborated with individuals to strengthen their capacity in research and technology transfer.

Student Training

A total of three students received training through the IPM CRSP in Year Six.

Phillip Lamport, a native Guatemalan, completed his Master of Science Degree under the direction of Dr. Stephen Weller and C. Richard Edwards at Purdue University. His thesis title was "Development of IPM Techniques for the Control of Pea Leaf Miner *Liriomyza huidobrensis* (Blanchard) on Snow Peas, *Pisum sativum* L.." His research led to a new and extremely effective trap crop system, using faba beans as a border planting to reduce leaf miner damage in snow pea. The result was a significant reduction in the use of pesticide applications and higher marketable yields.

Jim Julian, a U.S. citizen, finished his Master's Degree in marketing under the direction of Dr. Glenn H. Sullivan at Purdue University. His thesis titled "An Assessment of the Value and Importance of Quality Assurance Policies and Procedures to the Guatemalan Snow Pea Trade" has been instrumental in helping move the public and private sectors towards finalization of a formal preinspection program, as the findings clearly quantified the benefits of quality assurance to enhancement of market performance in NTAE crops.

Carlos Mayen, a native Guatemalan and undergraduate student in his senior year at Universidad del Valle, spent the 1999 summer term at Purdue University working on IPM field research with Drs. Stephen Weller and C. Richard Edwards. Carlos will return to Purdue in July 2000 to pursue a Master of Science Degree under the direction of Dr. Weller.

Victor Hernandez, a native Guatemalan, completed his Ing. Agronomy thesis at Universidad Rafael Landívar titled "Intercropping Impacts on Control of Leaf Miner in Snow Peas". This research was conducted under the direction of Dr. Sánchez.

Sergio Torres, native Guatemalan, achieved partial fulfillment of his research for his Ing. Agronomy degree at San Carlos University testing the resistance of various snow pea cultivars to leaf miner infestation. This research was conducted in collaboration with ICTA under the direction of Ing. Luis Calderón.

Margarita Palmieri and Laura Vergara, both of Guatemala, completed an eight week training session at the University of Georgia under the direction of Dr. Wayne Parrot and assistance from Dr. Sánchez at Universidad del Valle in molecular biology techniques. This research will be instrumental in furthering the IPM CRSP work for the detection and evaluation of papaya ringspot potyvirus. This research training is being used in the tissue culture labs at Universidad del Valle in an effort to help solve the devastating effects of ringspot damage in papaya orchards throughout Central America. This research was partially funded by the Guatemalan National Science and Technology Council.

Brenda Tevalán, a native Guatemala, and a member of the Estudio 1360 staff directed by Dr. Linda Asturias received her licenciatura degree in Anthropology from the Universidad del Valle with a thesis titled "La división del trabajo por género en la producción agrícola de Santa María Cauqué durante la segunda mitad del siglo XX." This research focused on the socioeconomic dynamics of NTAE crop production at the small family farm level.

The human resource development initiatives in Central America focus on five areas: (1) greater student training at U.S. institutions and/or in collaboration with U.S. scientists, (2) NGO training and technology transfer through national and regional workshops, (3) capstone research (thesis) training in collaboration with ZAMORANO and the U. del Valle, (4) continued strengthening of the research capacity of host country collaborators, and (5) research training that emphasizes less reliance on pesticides and improved food safety/quality to achieve expanded market opportunities in the NTAE sector.

Networking

Workshops have been developed at the regional, district, and community levels. This activity has been expanded in Year Six with funding from FONAPAZ. The regional workshops have focused on technology transfers to NGO's and independent private sector technicians, while district and community workshops and IPM demonstration research have focused on small NTAE producers in collaboration with ICTA. All workshops and demonstration research have been supplemented with published research materials and user manuals that present performance proven IPM pest management strategies.

Collaborations with APHIS-IS in the development and testing of pilot preinspection programs have helped further expand the IPM CRSP networking activities in Year Six. Private sector grower-shippers and shippers of NTAE crops that are participating in the IPM CRSP led initiative became important "conduits" for technology transfers, potentially reaching nearly 9,500 small farm producers, field technicians, and community leaders throughout Guatemala in our Year's Five and Six workplan activities.

Initial programs collaborations were explored with UTZ SAMAJ in Tecpán, Chimaltenango, Guatemala to develop an IPM / ICM technology transfer program for small NTAE producers throughout the central Highlands. UTZ SAMAJ recently received a grant to achieve the transfer of IPM / ICM technology through community level program collaborations, and IPM CRSP was contacted to help achieve the overall program objectives, as the IPM CRSP

already has established collaborations in over 56 communities throughout the region.

The IPM CRSP strengthened regional collaborations with AGRITRADE and AGEXPRONT through assistance in the development of the 1999 Regional AGRITRADE Conference. This important conference includes public and private sector participants from throughout the region (Guatemala, El Salvador, Nicaragua, Honduras, and Costa Rica). The IPM CRSP portion of AGRITRADE program focuses on "Food Safety and Implications for Market Development in the NTAE Sector". Drs. Sullivan, Sánchez, and Weller are the lead IPM CRSP participant in the 1999 AGRITRADE Conference. Participation in this program has led to further discussion on IPM CRSP regionalization with Nicaragua and El Salvador.

Finally, the IPM CRSP held a series of discussion with the Ministry of Agriculture in Guatemala (MAGA) seeking to strengthen program collaborations through greater participation in the development of research priorities and workplan activities. These discussion were still in process at the end of Year Six. It is likely that these discussions will generate a positive result early in Year Seven of the IPM CRSP, after the new GOG administration assumes office.

Research Accomplishments

1. The premier accomplishment in Year Six centers on further development and formalization of the preinspection program for snow peas in Guatemala. Guatemala's competitive position in the NTAE sector has suffered since 1995 due to sanitary and phytosanitary violations detected at U.S. ports-of-entry. In Guatemala and throughout the region, the need for a program that controls the product's quality at the point-of-origin is accepted by a progressive group of snow pea growers and exporters. AGEXPRONT has been instrumental in helping focus the private sector attention on preinspection. It is through this group that a voluntary pre-inspection pilot program was established in the 1998-1999 growing seasons and further finalized for the 1999-2000 seasons. After two years of field trials the IPM CRSP and its collaborators clearly demonstrated that high quality snow peas meeting all sanitary and phytosanitary regulations could be produced with the technology currently available when properly implemented and precisely managed. These results have been the basis for the field and post-harvest handling protocols to be followed in the pre-inspection program. Under the leadership of the IPM CRSP, the pre-inspection program was tested in the 1998-99 growing seasons with the participation of several key collaborators. Seven major NTAE packers/exporters agreed to participate in this effort, their combined output accounting for approximately 30%-40% of the country's total snow pea exports. Other key players include APHIS-IS, the Ministry of Agriculture through the Directorate of Plant Health, the Institute of Agricultural Science and Technology (ICTA), ARF-AGEXPRONT, and the Foreign Agricultural Service's Office of Agricultural Affairs in Guatemala, each participating in specific aspects of the program. Success in the 1998-99 pilot testing phase led to program expansion for 1999-2000, and serves as the focus for most of the IPM CRSP component research activities in Year Six and Seven.

   Future economically sustainable expansion in the Central American NTAE sector will substantially depend upon the industry's capacity to address increasingly important aforementioned non-economic constraints to interregional trade. An assessment of U.S. trade data suggests that there is a correlation between the lack of compliance with these non-economic constrains and a decline in Guatemala's competitive position in the U.S. vegetable market. In 1992, Guatemala was ranked 5th among all countries supplying fresh vegetables to the United States and 8th among countries supplying fresh fruit, other than bananas, to the United States. But in 1997, Guatemala was ranked only 12th among fresh vegetable suppliers. The NTAE sector is very competitive, and the more successful competitors seem to have adopted a more "market-driven" focus. Our research suggests that given its relative economic competitiveness, Guatemala could be the 5th or 6th largest supplier of fresh vegetables to the United States with full implementation of a certified preinspection program. The IPM CRSP is playing a pivotal role in helping reestablish regional competitiveness in the NTAE sector.

2. The technology transfers associated with these activities (preinspection) significantly impacted NTAE crop producers by helping reduce pesticide use to acceptable and sustainable levels. Snow pea producers participating in the IPM CRSP integrated pest management / integrated crop management programs reduced pesticide applications from 13 to 4 in each snow pea cropping cycle, while increasing product quality and marketable yields to 12,600 lbs. per menzana (approximately 18,000 lbs. per hectare). This level of performance translates to about $2916 per acre in gross revenue, or about $895 per acre net return to management and family labor. This level of performance is approximately 35% above the average, helping assure economic and socioeconomic sustainability at the small farm household level.

Overall, IPM CRSP sponsored research documentation and training at twelve regionally dispersed community sites, comparing performance-proven IPM / ICM practices to traditional snow pea production practices, resulted in 25 to 50 percent higher average marketable yields with 75 percent fewer pesticide applications for IPM CRSP developed management strategies.

More importantly, performance-proven IPM / ICM strategies for tomatoes have allowed the reintroduction of tomato production into regions that were no longer being cultivated because of severe white fly – geminivirus problems. The implementation of IPM CRSP developed strategies for control of white flies in tomatoes has enabled several regions in Eastern Guatemala (Sanarate, San Agustin Acasaguastlán and Retana Valley) to reestablish high value fresh market tomato production. Research in tomato has shown that use of the IPM CRSP developed 22 point program for control of white fly and its associated gemni-virus can reduce the number of needed insecticide sprays from 30 to 12, and greatly improve grower profits.

3. The significance of the aforementioned IPM CRSP research accomplishments in Central America were highlighted in the inaugural issue of *Sustainable Development International: Strategies and Technologies for Local and Global Agenda 21 Implementation* (an entity created by 174 heads of state at the United Nation's Rio Summit in 1992). The paper titled "Sustainable Development in Central America's Non-Traditional Export Crops Sector Through Adoption of Integrated Pest Management Practices: Guatemala Case Study" was published and is summarized as follows: Non-traditional crops for export (NTAE's) have played an increasingly important role in Central America's economic development since 1983. This relatively new market-driven development opportunity has represented the fastest expanding sector of the agricultural industries in Central America, with an average annual growth rate of 16 percent between 1983 and 1997. However, future development of economically sustainable expansion in NTAE crops in Central America will be substantially influenced by the region's capacity to meet more demanding food safety standards in the United States and Europe. Market access in these countries is increasingly being determined by sanitary and phytosanitary standards, and not solely by economic competitiveness at the production level. Case studies in Guatemala found that chemical overuse was the primary factor contributing to high detentions and rejection rates for NTAE shipments at ports-of-entry in the United States. It was found that producers who adopted performance-proven integrated pest management practices had significantly fewer sanitary and phytosanitary compliance problems. Further, these producers achieved higher marketable yields at lower production costs, resulting in greater economic and socioeconomic sustainability.

4. The Central American IPM CRSP was recognized in Year Six by the Association for International Agriculture and Rural Development (AIARD), Washington, D.C. as one of three exemplary examples of international development that benefits both the United States and foreign host countries.

5. Two graduate students completed their Master's of Science degrees under the IPM CRSP in Year Six, both with thesis research that contributed significantly to the IPM CRSP mission objectives in Central America.

Phillip Lamport, a native Guatemalan, completed his Master of Science Degree under the direction of Dr. Stephen Weller and C. Richard Edwards at Purdue University. His thesis title was "Development of IPM Techniques for the Control of Pea Leaf Miner *Liriomyza huidobrensis* (Blanchard) on snow peas, *Pisum sativum* L.." His research led to a new and extremely effective trap crop system, using faba beans as a border planting to reduce leaf miner damage in snow pea. The result was a significant reduction in the use of pesticide applications and higher marketable yields.

Jim Julian, a U.S. citizen, finished his Master's Degree in marketing under the direction of Dr. Glenn H. Sullivan at Purdue University. His thesis titled "An Assessment of the Value and Importance of Quality Assurance Policies and Procedures to the Guatemalan Snow Pea Trade" has been instrumental in helping move the public and private sectors towards institutionalization of a formal preinspection program, as the findings clearly quantified the benefits of quality assurance to the enhancement of market performance in NTAE crops.

6. ICM research was elevated in Year Six IPM CRSP activities. ICM (integrated crop management) focuses on the combining of integrated pest management, intercropping, and strip-cropping techniques to achieve a holistic production management strategy that significantly reduces pesticide use, increases marketable product yields and quality, and achieves greater economic, environmental, and socioeconomic sustainability at the small producer and community levels. The integration of these techniques were found to increase marketable yields in snow peas by an

average of 25 percent, while reducing pesticide use to only 3 to 4 applications per cropping cycle. The full significance of this research will be determined in Year Seven, but preliminary results are extremely encouraging.

7. The institutionalization of IPM CRSP performance-proven production strategies in snow pea, broccoli, tomatoes, and sugar snaps realized a quantum leap forward in Year Six. The "foundation" research in the development of preinspection protocols, combined with the aforementioned ICM research, captured the attention of private sector entities, resulting in widespread adoption of IPM CRSP pest management strategies in Guatemala. Led by AGEXPRONT and FONAPAZ, it is estimated that over 50 percent of Guatemala's current commercial snow pea production in 1999/2000 will be managed under IPM CRSP developed pest management strategies. This conversion to more sustainable production strategies will help assure the transfer to other NTAE crops, and provide the basis for the revision and institutionalization of GOG policies that are sorely needed to support this new production paradigm throughout the region.

8. Research focusing on the use of entomopathogenic fungi and entomophagous nematodes for control of white grub (*Coleoptera:Scarabeidae*) in broccoli was advanced in Year Six through collaborations with ICTA. Research also continued on parasitoids for the control of leaf miner in snow pea. The parasitoid research on white grub control was inconclusive, but the potential for ectoparasitoid *Diglyphus* in the control of leaf miner was found to be quite promising. Parasitoids have a potentially promising role to play in a fully integrated IPM strategy. Concurrent research has found that once sustainable pest management strategies are implemented for at least three cropping cycles in snow peas, the natural parasitoid populations begin to reestablish. Therefore, the role of a massive parasitoid breeding program may prove not to be economically justifiable. But, this research clearly has helped IPM CRSP researchers understand the role natural enemies play in a balanced and sustainable production regime.

9. Socioeconomic research findings completed in Year Six enabled collaborators to establish baseline models for measuring NTAE/IPM adoption impacts at the small farmer household and community levels. These research findings will be used to develop and initiate a comprehensive quantitative assessment of socioeconomic and economic impacts from NTAE cropping regimes in Year Seven. This research will be led by Drs. Hamilton (Virginia Tech) and Sullivan (Purdue University) in collaborations with Dr. Linda Asturias and Brenda Tevalán at ESTUDIO 1360.

Economic and Socioeconomic Impact Assessment of Non-Traditional Crop Production Strategies in Small Farm Households in Guatemala

Investigator(s): Dr. Linda Asturias de Barrios[1], Licda. Brenda Tevalán[1], Flor Mencos[1], Mónica Berger[1], Hugo Alfaro[1], Cecilia Skinner-Klée[1], Dr. Glenn H. Sullivan[2].

Collaborating Scientists: Dr. Sarah Hamilton[3], Dr. Guillermo Sánchez[4], Ing. Jorge Luis Sandoval[4], Ing. Luis Calderón[5], Ing. Alberto Chamorro[6], Dr. Liliana Goldin[7]

Abstract

Year VI work was affected by three facts: (1) The completion of the regional socioeconomic baseline survey allowed the social researchers to produce abundant and complementary quantitative data. (2) The modification of the workplan by Dr. Glenn Sullivan, Dr. Sarah Hamilton, Dr. Guillermo Sánchez and Dr. Asturias at the end of January prioritized the elaboration of a detailed final report on the regional survey, incorporated a new survey of perception of social and economic well-being pre- and post adoption of NTAE and reduced the research profile of the assessment of institutional policies and the description of product rejection through the commercialization chain. (3) The cancellation of contracts of Estudio 1360 and other Guatemalan collaborators with CATIE/ICTA due to problems to access PL 480 funds provoked the abortion of several research activities scheduled for the last two quarters. Thus a multi-method study among ICM adopting and non-adopting households, a case study on institutional policies and product rejection in a leading cooperative and the new survey were either interrupted or cancelled. In spite of this serious financial limitation, accomplishments included the final report of the regional socioeconomic baseline survey, the completion of a paper on economic ideology and perceptions of socioeconomic change that will be published on an anthropological journal and the successful defense of a thesis on gender division of labor in agricultural production. Because these three main deliverables will soon be published on printed or electronic means and due to space limitations, only a few selected tables are included here.

San Mateo Milpas Altas was chosen as the third and last community to be included in the regional survey. One of the selection criteria was the fact that most NTAE producers are members of a leading cooperative, for most NTAE farmers in previously surveyed communities (Xeabaj, Xenimajuyú) are independent producers. Intensive ethnographic fieldwork and a household survey were conducted in San Mateo during the first half of year VI, especially from December to February. Data were analyzed. Estudio 1360 and Dr. Sarah Hamilton finished the final report of the regional socioeconomic baseline survey. This report has sections on the communities, socioeconomic indicators, agricultural base, agricultural production, profile of NTAE producers, IPM and intrahousehold resource allocation. Estudio 1360 and Dr. Liliana Goldin analyzed survey data on economic ideology by using community, schooling, NTAE production, wealth and other variables.

Due to topic sensitivity, the social research team was advised to not conduct research on institutional policies on pest management among agroexport companies. Therefore, a decision was made to concentrate on a case study of a leading NTAE cooperative. Documentary and social research took place at the cooperative as well as on associated producing communities.

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[4] Universidad del Valle, Guatemala City, Guatemala.
[5] Institute of Agricultural Science and Technology (ICTA), Guatemala.
[6] Soluciones Analíticas, Guatemala.
[7] University at Albany, State University of New York (consultant).

Having Dr. Asturias as her advisor, Brenda Tevalán submitted her thesis, which presents a comparison of agricultural production in Santa María Cauqué during two periods divided by the introduction of NTAEs in the late 1970s. This comparison includes occupation, land tenure, land use, agricultural calendars, and gender division of labor in commercial crops, both domestic and NTAE. In addition, Cecilia Skinner-Klée presented a thesis proposal on intrahousehold allocation of land, labor and income in NTAE-producing cooperative households to Universidad del Valle de Guatemala. Her research proposal was envisioned as an opportunity to examine gender and NTAE cooperative issues in development.

Objectives

The following objectives are included in the Year Six Workplan for the Latin American site. To identify them in the Workplan, see the numbers inside the parentheses.

- Regional survey/analyses/assessment of the socioeconomic impact of the production of NTAE crops including IPM CRSP transferred integrated crop management practices (I.1, c, 1).
- Descriptive analyses of the farmers' perception on pests, chemical pesticides, and pest management in NTAE crops, including ICM farmers' perceptions on quality control during production and commercialization of produce (I.1, c, 1, i).
- Comparative analyses of the socioeconomic situations of farmers using different agricultural strategies including and excluding NTAE crops, both within and among selected communities of the major NTAE-crop producing areas (I.1, c, 1, ii).
- Comparative analyses of the socioeconomic changes perceived by farmers growing NTAE crops in communities with differing time-involvement in this type of agricultural activity (I.1, c, 1, iii).
- Economic assessment of benefits derived from performance proven IPM practices in the production/marketing chain (I.1, c, 1, iv).

Assessment of institutional policies (I.1, c, 2)

- Analysis of the institutional policies on pest management of two of the agro-export organizations participating in the pre-inspection pilot study (I.1, c, 2, i).
- Comparative analyses of institutional policies on pest management year-five versus year six results (I.1, c, 2, ii).
- Description of farmers', intermediaries' and agro-export-organization employees' perceptions on quality control in the production and commercialization chain of the pre-inspection pilot study on snow peas (I.1, c, 3, i).
- Comparative analyses of product rejection in the production and commercialization chain: year-five versus year-six results (I.1, c, 3, ii).

IPM Constraints

Use of pesticides and IPM practices in both NTAEs and internally marketed crops were addressed in the research conducted in San Mateo. The regional survey questionnaire included a section with more than 20 questions on IPM practices on both types of crops. In addition, in the section on gender division of labor in agricultural production, items about buying and applying pesticides were asked. Results on these topics constitute a fundamental comparative baseline for the IPM CRSP.

Research Methods

Fieldwork in San Mateo Milpas Altas included several methods and techniques. Qualitative information was gathered through participant observation, systematic observation, as well as formal and informal interviewing with farmers, their families, community members, middlepersons and agricultural technicians. Some of the interviews were taped and later transcribed. Some of this information was used to adapt the regional survey questionnaire to San Mateo setting. The questionnaire comprised sections on: household composition, participation in local groups, socioeconomic data of household members, housing and services, land tenure, agricultural production and commercialization, IPM practices, gender division of agricultural labor, household income strategy, and economic ideology. A pilot application of the adapted questionnaire was carried out in the community. A sample of 105 households (29.7%) was randomly chosen. The survey was conducted during the last week of January and was monitored by Dr. Hamilton. Appointments were made in advance to interview household heads at their most convenient place and schedule. Filled questionnaires were revised, and yield and other agricultural measures were standardized. The previously used SPSS data entry was modified in order to fed in San Mateo data. Analyses were conducted to comply to the outline of the final report. In addition, qualitative information gathered in San Mateo during year VI, as well as ethnographic information collected in Xenimajuyú and Xeabaj during year V, were reviewed, organized and summarized in order to integrate them into this report. In addition, Dr. Goldin and Dr. Asturias de Barrios conducted statistical analyses of survey data on economic ideology and perceptions. Methodological details are included in the paper cited below. During the third quarter of year VI, information on institutional policies on pest management, as well as on rejection of snow peas in the commercialization chain, were gathered at a major cooperative of NTAE producers and in San Mateo. Methods included study of institutional documents and structured interviews.

Research Results

The following socioeconomic indicators characterize the three communities included in the regional survey. Between 60 and 70% of the households are integrated by a nuclear family. As part of the development cycle of the household, virilocality creates extended families. Xeabaj and Xenimajuyu have a high percentage of bilingualism, a relatively low percentage of female Kaqchikel monolingualism and an even lower percentage of Spanish monolinguals. Kaqchikel has been displaced in San Mateo, where Spanish monolingualism is highly prevalent among self-identified indigenous population. Illiteracy (16% in the three communities) shows uneven female: male rates ranging from 4: 1 in San Mateo to 2:1 in Xeabaj. Measured in mean numbers of years, schooling level varies from 2.6 (SD 2.5) in Xenimajuyu to 3.0 (SD 2.32) in San Mateo. Agriculture as primary male occupation is higher in Xenimajuyú and Xeabaj (83.2%) than in San Mateo (68%). Taking into account men's under-reporting of spouses' work, female agricultural involvement is higher in San Mateo (41%) than in Xenimajuyu (28%) and Xeabaj (11%). Water home service is available in 61% households in Xenimajuyu, 81% in San Mateo and 91% in Xeabaj. Most homes (92%) in the three villages have electric access. Bicycles are found in 2 out of each 5 homes, but only 1 out 10 households own a car.

Table 1 shows household land tenure by community and agricultural strategy, which is conceptualized as the selection of one or more types of crops differentiated by their economic destination (self-consumption, domestic market, NTAEs). Table 2 demonstrates that while land inheritance follows an uneven gender pattern disfavoring women, purchasing land within marriage tends to result from joining income generated by both spouses.

Table 1. Household land tenure by agricultural strategy and community (hectares)

Agricultural Strategy	Xenimajuyu				Xeabaj				San Mateo Milpas Altas			
	Households	Owned Land	Rented in Land	Owned and rented in Land	Households	Owned Land	Rented in Land	Owned and rented in land	Households	Owned land	Rented in Land	Owned and rented in land
	f	X	X	X	*f*	X	X	X	*f*	X	X	X
SC+IC+NTAE	17	0.54±0.54	0.49±0.65	1.03±0.80	18	1.16±0.62	0.21±0.26	1.37±0.57	22	1.01±0.81	0.24±0.28	1.25±0.76
SC+IC	20	0.76±1.35	0.21±0.35	0.97±1.33	3	0.73±0.44	0.15±0.26	0.88±0.40	12	0.56±0.64	0.05±0.09	0.62±0.64
IC+ NTAE	1	0.17	0.45	0.62	1	0.00	0.23	0.23	2	0.28±0.08	0.56±0.00	0.85±0.08
SC+NTAE	12	0.25±0.36	0.36±0.27	0.61±0.50	17	1.34±2.85	0.17±0.27	1.51± 2.80	20	0.66±0.46	0.15±0.22	0.81±0.43
SC	30[a]	0.25±0.30	0.17±0.26	0.43±0.34	12	0.74±0.57	0.13±0.25	0.87±0.49	33	0.25±0.33	0.04±0.09	0.29±0.31
IC	2	0.10±0.10	0.00	0.10±0.10	--	--	--	--	--	--	--	--
Do not plant	4	0.00	0.00	0.00	3	0.00	0.00	0.00	12[b]	0.06±0.09	0.00	0.06±0.09
NTAE	--	--	--	--	--	--	--	--	3	0.34±0.49	0.04±0.06	0.38±0.47
Total	86	0.41±0.75	0.26±0.40	0.67±0.83	54	1.02±1.67	0.17±0.25	1.18±1.64	104	0.51±0.60	0.11±0.20	0.62±0.63

SC = Self-consumption; IC = internally commercialized or internal market products; NTAE = Non traditional agricultural exports.
a and b: One case didn't report land tenure.

Table 2. Land held by gender and community (in cuerdas)

	Community											
	Xenimajuyu (n=86)				Xeabaj (n=54)				San Mateo Milpas Altas (n=104)			
	Purchase		Inheritance		Purchase		Inheritance		Purchase		Inheritance	
	f	χ	*f*	χ	*f*	χ	*f*	χ	*f*	χ	*f*	χ
Male	14	5.91±8.32	31	2.63±1.64	8	5.94±3.34	33	8.77±14.99	5	6.40±3.05	61	3.70±3.55
Female	1	6.5	17	3.32±6.45	0	—	8	1.87±1.62	0	—	16	1.55±1.37
Both	20	4.29±3.16			18	7.44±6.41			23	8.09±6.78		
Total	34	5.15±5.80	41	3.37±4.33	26	6.98±5.62	34	8.96±14.77	28	7.79±6.27	69	3.63±3.45

Some analyses were conducted before San Mateo data were registered into the data basis. In order to understand the nature of the association between land access and NTAE production, Gamma and Analysis of Variance tests were done to determine if there are thresholds in land access that correlate with planting NTAEs or with the amount of land planted to non-traditional. When the sample of those who control land is ranked into 4 groups representing households with (1) less than .5 hectares, (2) .5 - .99 hectare; (3) 1 - 2.49 hectares; and (4) more than 2.5 hectares, results show that although the number of households planting NTAEs increases significantly along with greater access to land (Table 3; Gamma test), the amounts planted to NTAEs differ significantly only between those with the smallest and largest amounts of land (results not reported here). Table 3 presents results of Analysis of Variance tests for a subsample including only those 66 households planting NTAEs in Xenimajuyu and Xeabaj. Amounts planted by

NTAE producers do not differ significantly among those who control fewer than 2.5 hectares. The range for these producers varies from .06 hectares to .68 hectares; most producers plant only .11 hectares, with half of those in the third tier planting between .2 and .6 hectares. Even among those in the top tier, only one producer plants more than one hectare. No one in the sample corresponding to both communities plants more than one half of household land to NTAEs, and most plant less than one fourth of their land to NTAEs.

Table 3. Nontraditional Agricultural Export Production as a Factor of the Amount of Land Controlled by Households in Xenimajuyú and Xeabaj

	Amount of Land Controlled by Households, in Hectares				*Sample*
	.03 - .49 (N = 50)	.5 - .99 (N = 43)	1 - 2.49 (N = 29)	2.5 - 32.6 (N = 12)	(N = 134)
Percentage planting NTAEs	30%	61%	55%	75%	49%
Gamma = .416; p = .001					
ONEWAY ANALYSIS OF VARIANCE					
Households planting NTAEs	N = 15	N = 26	N = 16	N = 9	N = 66
Mean no. of hectares in NTAEs	.14	.14	.29	1.0	.29
Standard Deviation	.07	.05	.20	1.4	.59
Minimum	.06	.06	.08	.23	.06
Maximum	.39	.23	.68	4.74	4.74
F = 7.005; p = .007					
[1] mean differences among groups are significant at <.01	* Group 4	* Group 4	*Group 4	* Groups 1, 2, 3	
Homogeneous subsets using harmonic mean group size of 14.35	Subset 1	Subset 1	Subset 1	Subset 2	

[1]Caution should be used in interpreting significance levels for groups of these sizes. For procedure using harmonic means, type 1 error levels are not guaranteed.

Source: IPM-CRSP /Estudio 1360 surveys in Xenimajuyú and Xeabaj conducted in 1998

These data show that in Xenimajuyu and Xeabaj most households with less than .5 hectare are either unable to produce NTAEs or have decided that it is not in their best interest to invest their land, labor, and cash in NTAEs. Even for those with more land, production of NTAEs is clearly only one part of a diversified portfolio of household agricultural activities.

Women's work in NTAE production is important to their households in Xenimajuyú and Xeabaj. As only 18 women provided information regarding the gender division of labor in household agriculture, reported patterns are those given by male respondents. Given the tendency of both genders to somewhat underestimate the work of their spouses, and to under-report the participation of women in work that is considered masculine (such as hoe cultivation), it is remarkable that 92% of male NTAE producers reported that their wives work in the harvest; 77%, that the women work in planting, and 20-22%, in the application of fertilizer and in hoe cultivation. Considering all tasks, women do field work in 94% of producing households. It is perhaps even more remarkable that in these households, where men regard themselves as the primary producers of agricultural crops, three-fourths of men also reported that decisions regarding land use are taken jointly with their wives. This pattern may reflect the fact that 44% of men also reported that both spouses provide money for agricultural inputs. In around one-fourth of households, men reported that decisions regarding selection of pesticides and fertilizers are also taken jointly with their wives. This proportion rises to around one-third among the women who answered these questions.

As nearly all women in NTAE producing households work in this production, it is important to test whether women tend to substitute labor in family NTAE production for their own independent income-producing activities as the extensiveness of household NTAE production increases. The effects of snow pea and broccoli production by their households on women's independent income sources are neutral in the case of women's commerce and positive in the case of women's income from animal sales. Table 4 shows that neither the number of income sources a woman has nor the likelihood that a woman will have nonagricultural commercial income is affected by her household's increasing production of snow peas and broccoli. Women are somewhat more likely to have income derived from animal sales in households that produce larger amounts of these crops. Table 5 presents similar findings, using Analysis of Variance tests. It should be noted that only one household plants more than one hectare in NTAEs, and 80% plant less than one-fourth hectare. The fact that households with larger amounts of land planted to NTAEs tend to have

more land at their disposal, indicating that these are relatively well off families, is also relevant. Women from these households may be better able to invest in animal production. In any case, women do not appear to be foregoing independent income-earning activities in order to work in family NTAE production.

Table 4. Household Production of Nontraditional Export Crops and Income Earning by Female Household Heads

Zero-Order Correlations			
	Number of Woman's Income Sources[1]	Woman's Commerce [2]	Woman's Animal Sales[3]
Area planted to snow peas and/or broccoli	r = .039	r = -.085	r = .171
	p = .646	p = .319	p = .043
	n = 141	n = 141	n = 141

[1] 57% of female heads are the primary producers of one or more sources of income for their households
[2] 32% of female heads have nonagricultural commercial incomes
[3] 33% of female heads have incomes from animal sales
[4] 47% of households have land planted to snow peas and/or broccoli (mean = 2.6c; sd =5.2c)

Source: 1998 Household Surveys, Xenimajuyú and Xeabaj, IPM CRSP/ Estudio 1360

Based on survey data dealing with economic ideology, people's perceptions of a changing regional economy were examined by conducting a series of statistical analysis. Some of the results are as follows: Almost two thirds of the household heads perceive the economic situation as being better since the introduction on NTAEs. Heads with more land would likely to invest in irrigation, savings or agricultural inputs, whereas those with less land would buy land, a house, a business, or a car. Education, wealth, occupation, position in the economy, religion and ethnicity predict attitudes towards economic opportunities available in the region. NTAE producers tend to be younger and to have a higher level of education. They are also doing better economically than others. Users of intermediaries tend to be less wealthy than those who commercialize their crops through cooperatives or agroexporters. Among NTEA producers, the main predictors of an improved position in the economy are commercialization through a cooperative (as opposed to use of intermediaries); ethnicity, amount of land owned and an overall increased sense of community solidarity.

The adoption of NTAE and the involvement of young people in factory work since the 1980s have been affecting Santa María Cauque's economy. Based on census or surveys conducted in 1963, 1967, 1971 and 1994 by INCAP or ASIES, changes in agricultural production in Santa María Cauqué were demonstrated in Tevalán's thesis. In 1963, 86% of men and 3% of women were engaged in agriculture. Thirty years later, male involvement had decreased to 73% while women's participation had augmented to 72%. In the same period the proportion of land planted with vegetables ascended from 16% to 33%, whereas that devoted to corn, a staple, descended from 59% to 46%. Due to the adoption of labor-intensive NTAEs, such as snow peas, female labor, especially family one, was demanded in the fields. Gender division of labor was re-structured. While in the 1960s women's agricultural labor was limited to harvest and post-harvest, in the 1990s they are contributing labor during most phases of the cycle, from planting to crop maintaining to harvest and post-harvest. With a few exceptions, they do not prepare the soil, neither do they perform tasks demanding too much strength or use of tools perceived as male. This gender division of labor responds to a gender ideology within which: (1) the man is strong and the woman weak, (2) women are suited to tasks demanding patience or kneeling, and (3) men are more suited to perform activities needing reading skills. As women devote more time and work to agricultural production, they have to modify their household labor by re-allocating responsibilities to older daughters, by reducing their sleep period, or by using other adjusting strategies.

Table 5. Income Sources of Female Household Heads by Level of Household NTAE Production *Mean Differences Analysis of Variance Test*

Land planted to snow peas and/or broccoli	N	Woman has nonagricultural commercial enterprise	Woman has income from animal sales
0 c	75	35%	25% *
.06 - .21 hectares	37	32%	32%
.23 - 4.74 hectares	29	24%	55% *
		F = .529 sig = .590	F = 4.370 sig = .014

* Mean difference is significant at the .05 level, Tukey's honestly significant difference test. Harmonic mean of the group sizes is used; type I error levels are not guaranteed.
For discussion of appropriateness of analysis-of-variance tests with ordinal dependent variables, see Bernard (1988: 411); Pagano (1990: 26), and Gaito (1980).

Source: 1998 Household Surveys, Xenimajuyú and Xeabaj, IPM CRSP, Estudio 1360

Table 6. Production of Agricultural Income vs. Management of Income by Gender, as reported by Male Household Heads

Source of Income	Male Household Head	Female Household Head	Both Household Heads	Total Number of Households reporting
Production sales in bulk, Primary producer	90%	5%	5%	39
Production sales in bulk, Primary manager of income	30%	10%	60%	40
Production sales in smaller amts., retail, Primary producer	78%	12%	10%	68
Production retail, Primary manager of income	26%	19%	54%	68

Source: 1998 Household Surveys, Xenimajuyú and Xeabaj, IPM CRSP, Estudio 1360.

Table 7. Integrated Pest Management Use in NTAEs, by Community (Percentages)

	Xenimajuyu (n=30)	Xeabaj (n=36)	San Mateo Milpas Altas (n=47)
Uses rotation	93.3	88.9	83.0
Uses natural controls	23.3	16.7	6.4
Counts pests before fumigation	26.7	22.2	25.5
Consults technician before fumigation	66.7	58.3	66.0
Changes pesticide to prevent toleration	90.0	88.9	78.7
Uses sticky or color traps	66.7	47.2	31.9
Uses protection equipment	70.0	97.2	91.5
Consults if pesticides are registered	83.3	94.4	100.0
Keeps registry of pesticide application	40.0	55.6	29.8
Has received capacitation	56.7	61.1	87.2

Networking Activities

Dr. Hamilton came to Guatemala in January to join Estudio 1360 team during the application of the regional survey in San Mateo. As a Peace Corps voluntary was working in agriculture in this community, an exchange of information took place between him and Estudio 1360. In addition, two members of Estudio 1360 attended a workshop on the use of *metilbromuro* in agriculture. Delivered by Spaniard consultants, this activity was organized by ICTA

Publications and Presentations

Asturias de Barrios, Linda, Brenda Tevalán and Sarah Hamilton. IPM CRSP Socioeconomic Baseline Survey in the Central Highlands of Guatemala. To be submitted to the IPM CRSP Working Papers.

Hamilton, Sarah, Linda Asturias, and Brenda Tevalan. *Intrahousehold Resource Control and Agricultural Commoditization in Guatemala and Ecuador.* Paper presented at the Society for Applied Anthropology Annual Meetings in Tucson, April 20-24, 1999.

Tevalán, Brenda (1999). *La división del trabajo por género en la producción agrícola de Santa María Cauqué durante la segunda mitad del siglo XX.* Universidad del Valle de Guatemala. *Licenciatura* thesis.

Goldin, Liliana and Linda Asturias de Barrios. Economic Ideology and Non-Traditional Agricultural Exports in the Central Highlands of Guatemala. Paper to be submitted to Culture and Agriculture.

Training Output

Three students from del Valle University, who are also members of Estudio 1360, were trained in ethnographic fieldwork methods and household surveying in San Mateo. During her stay in Guatemala in late January and early February, Dr. Hamilton provided research orientation and taught some statistical analyses to Estudio 1360 members. On August Brenda Tevalán was awarded her licenciatura degree in Anthropology after defending her thesis.

Project Highlight

- Of particular interest to IPM CRSP programmers will be the finding that between 22% and 40% of women in Xenimajuyú and Xeabaj, by their husbands' accounts, share responsibility for provision of agricultural inputs and decision-making regarding selection of pesticides, an expensive input. Clearly, women in these communities should be included in program activities that will enable them to propose fully informed pest management choices and to be effective agents of IPM.
- Among NTAE producers, the main predictors of an improved position in the economy are commercialization through a cooperative (as opposed to use of intermediaries), ethnicity, amount of land owned and an overall increased sense of community solidarity. Therefore, although IPM positively impacts yields and prices, commercialization of NTAEs produced by small farmers should not be overlooked.

An Assessment of the Value and Importance of Quality Assurance Polices and Procedures to the Guatemalan Snow Pea Trade

Investigators: James W. Julian[1], Guillermo E. Sánchez[2], and Glenn H. Sullivan[3]

Abstract

This paper presents an assessment of the potential impact, at the exporter level, of implementing industry-wide uniform production and post-harvest practices that are consistent with U.S. Good Agricultural Practice guidelines. Some exporters indicated paying an averaging of $0.74 per kg of snow peas that were 60 to 80% export grade on the open market. However, others paid an average of $0.77 and $0.84 per kg for snow peas that were 85 to 95% export grade. Despite the appearance of the open market being the low cost source for snow peas, our research indicates the opposite is true. The open market was the most expensive source for export quality snow peas. That, combined with the lack of record keeping and other quality safeguards suggests that exporters who obtained snow peas primarily from the open market were at a competitive disadvantage.

Objective

To quantify the value of uniform production and post-harvest practices that are consistent with U.S. Good Manufacturing Practice and Good Agricultural Practice guidelines and APHIS pre-inspection protocols.

IPM Constrains

Snow pea exports to the U.S. have had difficulty meeting U.S. import standards. This has been primarily due the volume of snow pea exchanged on the open market. Open market snow peas have no trace-back ability and have no production records to certify that they were produce in a manner acceptable to the U.S. market. Implementation of IPM production methods and pre-inspection programs lower costs and reduce the risk of rejection by the U.S. market and increase NTAE market sustainability.

Research Method

This research had two components: 1) a survey to assess current exporter performance and market structure and, 2) a model was developed to assess the economic impact of improving snow pea quality in the open market, the least regulated snow pea supply channel.

The Survey. A questionnaire was designed and a survey of snow pea exporters was conducted in order to assess the current condition of the snow pea market. The questionnaire consisted of five baseline questions targeting exporter performance characteristics: 1) the total volume of snow peas exported, 2) source and paid by the snow pea exporter 3) destination of the snow peas and price obtained by the exporters, 4) the services that exporters provided during the production and post-harvest handling of the snow peas, and 5) what percentage of the total snow pea volume obtained by the exporters were exported.

In order to obtain the best possible responses to the questions the interviews were conducted by IPM CRSP collaborators in Guatemala who were know to the respondents. AGEXPRONT, the Guatemalan NTAE guild, officially listed 37 snow pea exporters. After screening for duplications and respondent qualifications, only 24 actual export companies were found to have shipped snow peas during the 1997/98 dry season. All 24 exporters were contacted for the survey, and of those, 10 responded positively. The respondents were visited and interviewed. They also provided answers to follow-up questions clarifying their initial response. All responses were assumed to be best estimates of the respondent's organization's performance during the 1997/98 dry season.

Modeling the System. A model was developed to estimate snow pea exporter performance. The snow pea exporter survey provided baseline snow pea procurement data. And therefore provided a benchmark to evaluate the impact of changes in snow pea quality that are assumed to be associated with improved production and post-harvest handling practices. To assess the value of implementing uniform production and post-harvest handling practices in

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the snow pea industry, snow pea export net operational returns were modeled.

The model assigned the average grower-shipper and contract producer supply channel cull percentage to the volume of snow peas obtained from the open market supply channel. It was assumed that snow peas cull percentages were related to the production and post-harvest handling practices of a given snow pea supply channel. The grow-shipper and contract producer supply channels have production and post-harvest handling practices that result in a lower cull percentage. Therefore it is assumed the implementation of uniform production and post-harvest handling practices in the snow pea industry would result in a uniform snow pea cull percentage.

Once the survey data were compiled, three equations were developed to perform exporter cost and revenue modeling. Equation one determined the total payment for an exporter's snow peas. Equation two determined the quantity of snow peas to be obtained to achieve current export levels, taking into consideration the percentage of snow peas culled by the exporters. Finally, equation three determined the cost-of-goods-sold (COGS) per kg of snow peas exported. These equations were used to assess individual exporter snow pea costs as well as the aggregate snow pea costs associated with a snow pea supply channel (i.e. grower-shipper, contract producer, or open market).

Equations.

Equation 1. $$P_{tot} = (Q_{cgs})(P_{cgs}) + (Q_{om})(P_{om})$$

Equation 2. $$Q_e = (Q_{om})(C_{om}) + (Q_{cgs})(C_{cgs})$$

Equation 3. $$COGS = \frac{P_{tot}}{Q_e}$$

P_{tot} - Total price paid for all snow peas obtained.
Q_{cgs} - Quantity of snow peas obtained from contracted producers or grower/shippers.
Q_{om} - Quantity of snow peas obtained from the open market.
P_{cgs} - Price paid to per kg of snow peas contracted producers or grower/shipper.
P_{om} - Price paid per kg of snow peas on the open market.
Q_e - Quantity of exported snow peas.
C_{cgs} - Cull ratio for snow peas obtained from contracted producers or grower/shipper.
C_{om} - Cull ratio for snow peas obtained from the open market.
COGS - The cost of goods sold per kg of exported snow peas.

Research Results

Snow Pea Exporter Survey. The survey results comprise the responses of the 10 exporters that were active during the 1997/98 dry season. It was estimated that these 10 exporters represented over 90% of all snow peas exported from Guatemala during that period. The export volume for the participating exporters ranged from 1,136 kg to 2 million kg of snow peas shipped during this period. The total volume of all snow peas exported by the survey respondents was about 8 million kg, including fresh and frozen snow peas. The export volume data compiled by snow pea supply source indicates that 2.0 million kg came from grower-shipper supply channels, 1.5 million kg came from contract producer supply channels, and 4.5 million kg came from the open market supply channels (Table 1).

Table 1. Estimated volume of snow pea exports from Guatemala, in kg, during the 1997/98 dry season by participating exporters, listed by snow pea supply channel.

Snow pea supply channel	Volume (kg)	Percent of total
Grower-Shipper	2,040,000	25.4
Contract Production	1,506,590	18.8
Open Market	4,472,818	55.8
Total	8,019,408	

Exporters indicated the proportion of snow peas that were not export grade and therefore culled during the packing process ranged from 5 to 15% of the snow peas received from grower-shipper and contract producer supply channels, with 10% being the mid-point value. The proportion of snow peas culled that were obtained through open market supply channels ranged from to 20 to 40%, with 25% being the mid-point value.

Given the proportion of snow peas culled, it was estimated that 9.91 million kg of snow peas were delivered to packing houses during the 1997/98 dry season. Of the total volume of snow peas obtained, it was estimated that 2.67 million kg came from grower-shipper supply channels, 1.67 million kg came from contract producer supply channels, and 5.97 million kg came from open market supply channels (Table 2).

Table 2. Estimated volume of snow peas obtained by participating exporters during the 1997/98 dry season, in kg, listed by snow pea supply channel.

Snow pea supply channel	Obtained	Percent of total
Grower-Shipper	2,266,667	23
Contract Production	1,673,989	17
Open Market	5,973,806	60
Total	9,914,462	

Respondents to the survey indicated that the prices paid for snow peas varied with snow pea source. Snow pea exporters paid between \$0.70 and \$0.91 per kg of snow peas from grower-shipper supply channels, between \$0.60 and \$0.90 per kg from contract producer supply channels, and between \$0.60 and \$0.83 per kg from open market supply channels (Table 3). It should be noted that exporters indicated they paid between \$0.75 and \$0.83 per kg for snow peas from "middlemen," or freelance brokers. Brokers are speculators in the market that purchase snow peas from producers on the open market, with the intent of selling them to exporters at a higher price. However, the exporters did not indicate the volume of snow peas supplied by brokers so no mid-point price was determined.

Table 3. Estimated price paid per kg of snow peas during the 1997/98 dry season by Guatemalan snow pea exporters. Snow pea prices are listed by snow pea supply channel in dollars per kg.

Snow pea supply channel	Producer prices per kg	Weighted mid-point
Grower-Shipper	$0.70 - $0.91	$0.77
Contract Producer	$0.60 - $0.90	$0.82
Open Market	$0.60 - $0.82	$0.74
Broker	$0.75 - $0.83	na

Table 4. Estimated price received by participating exporters from the U.S. and E.U. markets for fresh and the frozen snow peas by during the 1997/98 dry season, in dollars per kg.

	Price received	Mean
Fresh		
U.S.	$2.60 - $3.09	$2.82
E.U.	$3.00 - $7.19	$4.11
Frozen		
U.S.	$1.23 - $1.25	$1.23

The prices received for exported snow peas varied with target market and snow pea form. Fresh snow peas exported to the United States received between $2.60 and $3.09 per kg, while the E.U. fresh market paid between $3.00 and $7.16 per kg of snow peas. The price received for frozen peas on the U.S market was estimated to be between $1.23 and $1.25 per kg (Table 4).

The survey also asked what production, post-harvest handling, and marketing services each exporter provided. All respondents indicated they provided grading, packing, and cooling services. However, some also provided chemical analysis, crop management assistance, crop variety recommendations, record keeping assistance, and technical assistance (Table 5).

Table 5. Production and marketing services performed by exporters. Also indicated is the exporter's share of total snow pea exports, if the exporter was on automatic detention[1], and the percentage of their snows obtained from each snow pea supply channel.

Snow pea exporter	1	2	3	4	5	6	7	8	9	10
Share of total exports	5%	4%	4%	23%	11%	14%	<1%	14%	25%	<1%
Automatic Detention	♦	♦	♦			♦	♦			
Snow pea supply channel										
Grower-shipper	-	-	-	85%	-	-	-	27%	10%	-
Contract producer	60%	50%	20%	-	20%	-	100%	-	40%	100%
Open market	40%	50%	80%	15%	80%	100%	-	73%	50%	-
Services[2]										
Chemical analysis				♦			♦	♦	♦	♦
Production guidelines			♦	♦			♦		♦	♦
Variety recommendations			♦	♦			♦		♦	♦
Record requirement				♦			♦		♦	♦
Technical assistance				♦						

[1] Snow pea exporters whose shipments were automatically detained for inspection at U.S. ports-of-entry as of 7-21-97.
[2] All exporters provide grading, packing, and cooling services.

The survey results indicate that the value of snow pea exports, in gross sales, was approximately $23.9 million (f.o.b. at the port-of-destination). Individually, exporter's gross sales ranged from $1,420 to $6.1 million. It was determined that exporters, as a whole, had net returns of about $16.4 million after cost of goods sold. Individually, their net operating performances ranged from $966 to $1.9 million. Exporter performance complied by snow pea supply channel indicated that snow peas from the grower-shipper supply channel had the highest margin of return. Snow peas from the contract producer supply channel had the lowest cost of goods sold. While, open market snow peas had both the highest per unit costs and the lowest margin of return on cost of goods sold (Table 6).

Table 6. Estimated exporter performance under observed conditions and projected exporter performance under target performance conditions during the 1997/98 dry season, f.o.b. port-of-destination in dollars. Indicated are the gross sales by snow pea supply channel, cost of goods sold (COGS), net sales after COGS, and per unit snow pea costs.

	Observed Condition Performance			
Snow pea supply channel	Gross sales	COGS	Net Return	Per unit Cost
Grower-Shipper	7,432,960	1,753,333	5,679,627	0.86
Contract Production	5,246,476	1,367,278	3,879,198	0.80
Open Market	11,302,677	4,438,048	6,864,629	1.00
Total	23,982,114	7,547,660	16,434,454	0.93
	Target Condition Performance			
Snow pea supply channel	Gross sales	COGS	Net Return	Per unit Cost
Grower-Shipper	7,432,960	1,753,333	5,679,627	0.86
Contract Production	5,246,476	1,367,278	3,879,198	0.80
Open Market	11,302,677	3,905,078	7,397,600	0.87
Total	23,982,114	7,014,689	16,967,425	0.86

Results from the snow pea cost model indicate that reducing the open market cull percentage to the 10 percent target level reduced the total volume of snow peas obtained from the open market supply channel by 1,004,008 kg from 5,973,806 to 4,969,798 kg (Table 7). The volume reduction to the individual exporter ranged from 28,929 to 285,714 kg.

Table 7. Volume of snow peas needed from snow pea sources in kg in order to obtain the 1997/98 dry season export volume under observed exporter cull percentages and at target cull levels.

Snow pea supply channel	Observed cull rates (kg)		Target cull rates (kg)		Reduction (kg)	
Grower-shipper	2,266,667	23%	2,266,667	25%	-	-
Contract production	1,673,989	17%	1,673,989	19%	-	-
Open Market	5,973,806	60%	4,969,798	56%	1,004,008	17%
Total	9,914,461		8,910,453		1,004,008	

The model also indicated that the COGS decreased as a result of reducing open market supply channel cull percentages to the 10 percent target level. The observed open market supply channel COGS ranged from $0.88 to $1.09 per kg of snow peas exported for participating exporters. After adjusting for the target cull percentage, the open market supply channel COGS ranged from $0.86 to $0.94 per kg of snow peas exported. Cull percentages complied by snow pea source show that the COGS from the open market supply channel decrease from $1.00 per kg to $0.87 resulting in a net reduction of about $500,000 (Table 6). The average COGS was a weighted average of an exporter's snow pea acquisition costs after adjusting for snow peas that were culled.

Impacts

Exporters use a combination of supply channels to acquire their snow peas for export. The surveyed exporters indicated that they initially paid more for snow peas from grower-shipper and contract producer supply channels than they paid for snow peas obtained from open market supply channels. However, the final price point for export quality snow peas from open market supply channels was actually higher due to a high percentage of those snow pea that were below export grade. The findings from this study suggest that if open market supply channels implement the same production and post-harvest handling practices as the grower-shipper and contract producer supply channels, practices that are consistent with U.S. Good Agricultural Practice guidelines, the volume of snow peas culled would be reduced and the cost per unit of snow peas exported would decrease. It is also likely that the adoption of these practices would play an important role in maintaining and increasing access to North American markets by preventing future FDA detentions and events such as the snow pea-leaf miner crisis. In turn, this change would increase net operating profit for exporters and increase economic sustainability at all levels. Therefore, this research concludes that snow pea producers and exporters would benefit from an industry-wide implementation of uniform production and post-harvest handling practices that consistent with U.S. Good Agricultural Practice guidelines.

Networking Activities

USDA/APHIS – Collaboration to establish pre-inspection protocols to facilitate access to U.S. markets.

Universidad Del Valle – Collaboration in research protocol development, snow pea exporter survey, and assistance in surveying snow pea exporters.

GEXPRONT – Development of snow pea exporter collaborator linkages to facilitate snow pea exporter survey and research.

Publications and Presentations

Julian, J.W. 1999. An Assessment of the Value and importance of the Quality Assurance Policies and Procedures to the Guatemalan Snow pea Trade. M.S. Thesis. Department of Horticulture and Landscape Architecture, Purdue University, West Lafayette, IN.

Project Highlight

Open market snow peas are the most expensive and most risky sources of snow peas for Guatemalan exporters. Implementation of IPM and pre-inspection programs would reduce the costs and risks associated with exporting snow pea.

Institutionalization of an IPM CRSP Quality Control Process in the Production and Export of Snow Peas (*Pisum sativum* L.) in Guatemala

Investigators: Jorge Luis Sandoval[1], Guillermo E. Sánchez[1], Luis Caniz[2], Glenn H. Sullivan[3], Stephen Weller[3], C. Richard Edwards[3]

Abstract

The overall objective of this project was to implement a quality control program in snow pea production and handling, targeted to reduce the number of USDA interceptions at ports-of-entry due to pest infestations and unacceptable pesticide residues in Guatemalan fresh produce exports. Specific production and post-harvest guidelines were developed and will be implemented by growers and exporters alike. Trained inspectors from participating export companies, will be in charge of monitoring and supervising the production and packing technology. These inspectors received during 1998-99 adequate training through IPM and ICM courses and field days. Between August 1999 and April 2000, a production quality control program will be implemented on approximately 350 ha, representing 25% of the national projected snow pea volume to be exported during the 1999-2000 season. In order to implement the guidelines appropriately, over 30 training sessions and extension field days have taken place, organized by IPM CRSP and AGEXPRONT (guild of non-traditional products exporters), in which 110 field technicians and 525 growers have received technology transfer on the Integrated Crop Management guidelines for snow peas.

Objectives

The overall objective of this project was to implement a quality control program in snow peas, targeted to reduce the number of USDA interceptions due to pest infestations and unacceptable pesticide residues. The specific objectives were to:

1. Reduce the level of unacceptable pesticides residues in the export product.
2. Prevent future pest outbreaks such as the 1995 leaf miner crisis.
3. Demonstrate to the Guatemalan snow pea industry the advantages of a quality control program that will ensure the country's future competitiveness by exporting snow peas that are safe to consumers and have been grown in an environmentally friendly farming system.

IPM Constraints

The future sustainability and competitiveness of Guatemala as a non-traditional crop exporter may depend on the implementation of sound control programs that ensure the quality of the export product. Presently, Guatemala is the

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country in Central America with the highest number of interceptions at the port of entry to US markets, due mostly to pesticide residue contamination and some exotic pests detection, such as the 1995 leaf miner (*Liriomyza huidobrensis)* crisis. If corrective measures are not taken, such as a quality control program for agricultural exports at the point of origin, the country's future as a fresh produce exporter may be in jeopardy.

Research Methods

Specific production and post-harvest Integrated Crop Management (ICM) guidelines have been developed and implemented by growers and exporters alike. Trained inspectors from participating export companies, will be in charge of monitoring and supervising the production and packing technology. These inspectors will have previously received adequate training through IPM and ICM courses and field days.

Research Results

Between August 1999 and April 2000, a production quality control program will be implemented on approximately 350 ha (Table 1), representing 25% of the total projected snow pea volume to be exported during the 1999-2000 season. Four major players in the snow pea export industry, all on a voluntary basis, have incorporated the IPM CRSP-generated Integrated Crop Management (ICM) guidelines for snow peas into their production protocols. As Table 1 shows, some companies have part of their acreage grown under very close supervision by the IPM CRSP technicians while some acreage is under their complete control. The 100% implementation means that the company has hired IPM CRSP trained field technicians and that planning and execution has followed the guidelines in detail. It also means that IPM CRSP field technicians visit the fields at least once a week. Fifty percent implementation means that field technicians from the respective company have participated in IPM CRSP extension and training activities and have followed IPM CRSP guidelines for the planning and execution of production activities. However, visits from IPM CRSP field researchers are not programmed.

Table 1. Distribution of snow pea acreage to be grown under the IPM CRSP-generated Integrated Crop Management (ICM) production guidelines during the 1999-2000 season.

Export Company	Number of Hectares	% Implementation[2]
Company A[1]	28	100
Company A	42	50
Company B	98	100
Company B	42	50
Company C	14	100
Company C	56	50
Company D	70	100

[1] For privacy reasons, companies are not named. [2]% Implementation refers to the degree of involvement the IPM CRSP has in the implementation of the ICM plan. 100% means that IPM CRSP technicians have been completely involved in the planning and design of the production protocols, complemented with weekly visits. 50% involvement means that IPM CRSP technicians have been involved in the training of technicians working for the respective company and have participated in the planning and design of the company's production guidelines.

The ICM production guidelines include recommendations for most of the agricultural practices implemented during snow pea production, from land preparation to harvest procedures, as follows: 1) crop debris elimination, 2) soil testing, 3) land preparation, 4) soilborne pest sampling (if needed), 5) soil decontamination, fertilization and planting procedures, 6) insect pest and disease scouting, 7) trap crops, 8) weed management, 9) fixed sticky traps, 10) movable sticky trap ("torito"), 11) biorational pesticides, 12) foliar fertilization, 13) trellising and plant support, 14) chemical pesticide sprays, based on EPA-labeling and target pest thresholds, and 15) harvest and field post-harvest practices.

As Table 2 shows, there have been a number of extension and training activities directed to field technicians and growers during 1998-99. The majority of active export companies were represented during both field days and training activities. A large number of growers also benefited from activities directed specifically to their sector. News of these activities was spread among growers, even to the western highlands of Guatemala. In April 1999, a group of 25 growers arrived unexpectedly at the field plots in Xeabaj and were hosted by Mr. Augusto Girón, the main IPM CRSP collaborator in the region. The group of growers, from Huehuetenango (nearly 100 miles away), expressed that they had heard of the interesting technology being applied by the IPM CRSP. They expressly made that trip to learn about the technology and transfer it to their own agricultural activities in the western Highlands.

Table 2. Training and extension activities conducted by IPM CRSP and AGEXPRONT for the transfer of ICM production guidelines to export company field technicians and producers.

Activity	Number of participants	Number of meetings
National leaf miner committee Meetings	9-20/meeting	20
Fields days with field technicians	110	8
Field days with growers	250	13
Training activities to growers	275	10
Transportable yellow sticky traps "torito"	175 distributed	
"torito" fact sheet distribution	1,000 fact sheets	

Impacts

The main impact of this study will be the establishment of an effective quality control program for snow peas that will guarantee 1) the quality of the product to the final consumer, and 2) the sustainability of the snow pea industry in Guatemala. In addition, it is expected that in the next 2-3 years the majority of Guatemalan snow pea exporters will implement the IPM CRSP-generated ICM production guidelines.

Networking activities

This project is intimately linked with other activities at the site, including research in non-chemical approaches to manage snow pea pests. Results from this research will be incorporated into the pre-inspection program. Local and US IPM CRSP collaborators, including ICTA, ARF, Purdue and Del Valle Universities are conducting the aforementioned research.

Project Highlight

IPM CRSP-generated guidelines for the Integrated Crop Management of snow peas have been implemented on 350 ha in Guatemala, representing nearly 5 million lb, or approximately 25% of the expected 1999-2000 snow pea exports.

Detection of Papaya Ringspot Potyvirus in Guatemalan Papaya Orchards

Investigators: Margarita Palmieri[1], Laura Vergara[1], Guillermo E. Sánchez[1], Glenn H. Sullivan[2], Stephen Weller[2], Wayne Parrott[3], Michael Deom[3]

Abstract

Hawaiian-type papayas represent a potentially profitable export crop for Guatemala. A main threat to papaya production in Guatemala is the infection by papaya ringspot potyvirus (PRSV) which when present can cause total loss of production as infected fruits are unmarketable. The objective of this study was to visit the different papaya growing regions of Guatemala to determine the presence of PRSV in the country and quantify its incidence. A series of field trips were taken throughout Guatemala, including the south coast, the eastern dry tropics and the northeastern coast. Papaya orchards of both the native "criollo" and Hawaiian type were visited and leaf samples collected, for a total of 234 and 198 samples of local and Type-type papayas, respectively. In the northeast, 12.2% of criolla samples were PRSV+ while 9% of type-type papayas were infected. In the eastern dry tropics of Guatemala, 50% and 34.4% of the samples were positive in criolla and type papayas, respectively. In the south coast, 34% of criolla samples were PRSV+ in contrast to 40% of

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the type-type papayas. When the total number of samples where pooled into either positive or negative, 34% (146) of the samples were positive for PRSV infection, while 286 (66%) were negative. The results obtained in this study show that PRSV is common virus in papaya orchards in Guatemala and that appropriate IPM measures must be taken to ensure that successful papaya orchards are established, especially if they are intended for the export market.

Objectives

The objective of this study was to survey the different papaya growing regions of Guatemala to determine the present level of papaya ringspot potyvirus in the country.

IPM Constraints

Papayas represent a major potential export crop for Guatemala, especially the export of Type-type "Solo" papayas, of great demand in the United States. One of the main threats for papaya production in Guatemala is the infection of papaya plants by the papaya ringspot potyvirus (PRSV) which drastically reduces productivity and may even threaten 100% of the output, as fruits are rendered unmarketable.

Research Methods

A series of field sampling trips were taken to the different papaya growing regions of Guatemala, including the south coast, the eastern dry tropics and the northeastern coast (Figure 1). Papaya orchards of the native "criollo" type were visited and leaf samples (3-4 leaves from the apical shoot) collected. Similar samples were taken from experimental plots of Type, Solo-type papayas belonging to the National papaya growers association and managed by the Guild of non-traditional products exporters (AGEXPRONT). A total of 234 samples of local papayas and 198 samples of type were collected from the different regions in the country.

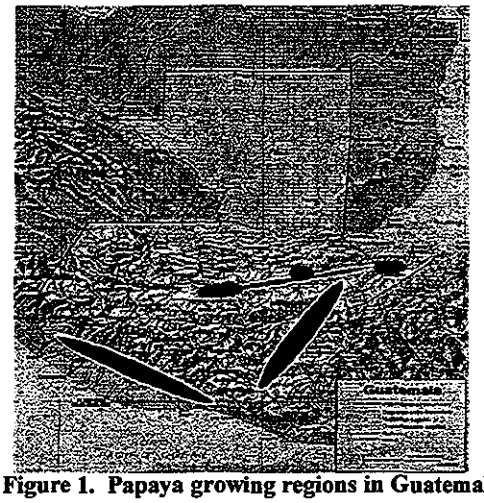

Figure 1. Papaya growing regions in Guatemala, where leaf samples for Papaya Ringspot Virus were collected.

Field samples were placed in labeled plastic bags and transported to the laboratory in ice chests. Once in the laboratory at Universidad del Valle, samples were classified and placed in a cold room overnight. The next morning samples were shredded and placed in silica gel for dehydration in the cold room (2-3°C). Once dehydrated samples were stored until analyzed. PRSV detection was done by the enzyme linked immunosorbent assay-direct sandwich ELISA, according to the protocol provided by AGDIA (Elkhart, IN).

Research Results

PRSV positive samples were detected in all the growing regions of Guatemala, although the virus was more prevalent in the southern and eastern parts of the country. These are the regions where the majority of papaya orchards are found. Figure 2 shows the percentage of positive samples found in both "criollo" and Hawaiian papayas in the different regions of the country.

The highest incidence of PRSV were found in eastern and southern Guatemala, while samples from the northeast showed smaller rates of PRSV-positive samples. In the northeast, 12.2% of criolla samples were PRSV-positive

(Figure 2A) while 9% of Hawaiian-type papayas were infected. In the eastern dry tropics of Guatemala, 50% and 34.4% of the samples were positive in criolla and Hawaiian papayas, respectively (Figure 2 C & D). The incidence rates found in the eastern region are the highest of all zones, but these results are not surprising, given the arid and hot conditions typical of the area which may favor the spread of the disease through its aphid vector. In the south coast, characterized by hot and humid conditions, 34% of criolla samples were positive for PRSV in contrast to 40% of the Hawaiian-type papayas (Figure 2 E & F). No positive samples were detected in the central region, although very few orchards exist in this area. Only one orchard (Enca campo) and one nursery (Enca semillero) were sampled in the central region, both sites located at the National Agricultural School (ENCA), located south of Guatemala City. When the total number of samples where pooled into either positive or negative, 34% (146) of the samples were positive for PRSV infection, while 286 (66%) were negative.

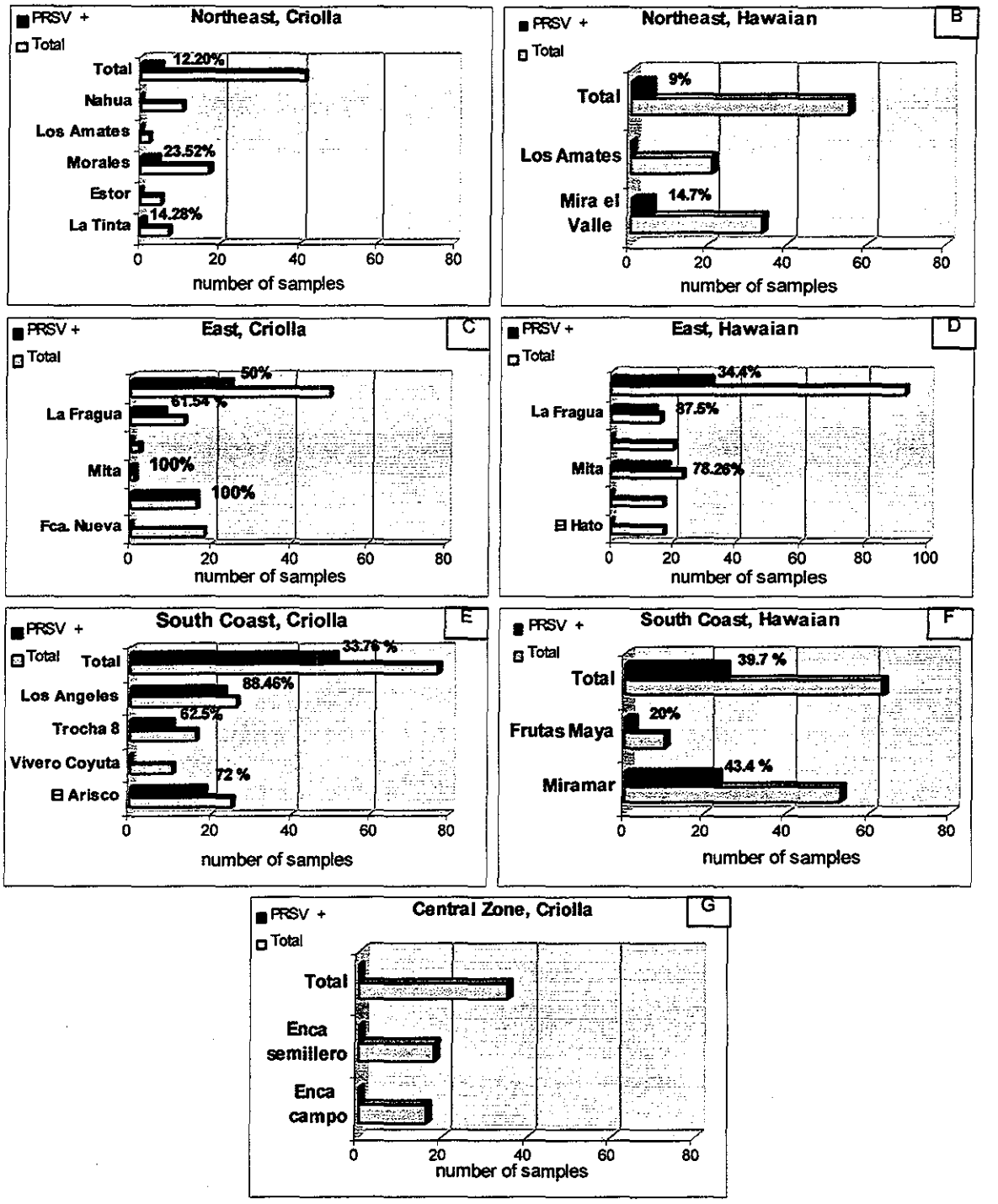

Figure 2. Results of ELISA tests for papaya ringspot potyvirus in native (criolla) and Hawaiian-type papaya orchards, according to the region of origin.

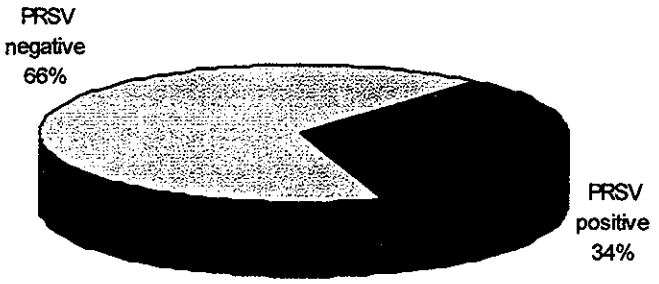

Figure 3. Total percentage of positive and negative papaya ringspot virus (PRSV) samples. Numbers were obtained from a total of 432 samples, 198 Hawaiian-type and 234 native (criolla) samples.

The results obtained in this study represent clear evidence that PRSV is a common virus in papaya orchards in Guatemala and that appropriate IPM measures must be taken to ensure that successful papaya orchards are established, especially if they are intended for the export market.

These results represent the initial component of a larger, more comprehensive study in which papaya, both the native and Hawaiian type, will be genetically transformed to incorporate coat protein-mediated resistance, via *Agrobacterium tumefaciens*.

Impacts

Papaya ringspot potyvirus has not been officially detected in Guatemala, as it does not appear in the listings of the International Regional Organization of Plant Health (OIRSA). As is the case in many developing countries, the presence of important plant diseases has not been detected. Growers, even though they may be familiar with the symptoms, do not know how to deal with such diseases and incur in severe losses. The detection and quantification of important plant diseases such as PRSV represents the first step in the development and implementation of appropriate IPM programs for many non-traditional agricultural export crops, including papayas.

Networking activities

This research was partially financed by the National Science and Technology Council, as part of a papaya genetic transformation study, pursuing to incorporate coat protein-mediated resistance into native and Hawaiian type papayas. AGEXPRONT and the National Papaya growers association (ANAPAPAYA) are both actively participating in this effort, by allowing researchers access to papaya orchards for data collection.

Training Output

Margarita Palmieri, senior virologist at UVG and Laura Vergara, laboratory technician, participated in a 8 week training session at the University of Georgia, at the laboratories of Drs. Michael Deom and Wayne Parrott. In addition, Carlos Mayen, a junior undergraduate in the agronomy department at UVG, participated in a 10 week internship at Purdue University under the guidance of Dr. Stephen Weller, Dr. Glenn Sullivan and Dr. Richard Edwards.

Project Highlight

Papaya ringspot potyvirus has been detected in Guatemala, where it is commonly found in the most important growing regions of the country. This knowledge will be crucial for the development of appropriate IPM programs for the production and export of Hawaiian-type papayas.

Development of IPM Techniques for the Control of Leaf Miners on Snow Peas

Investigators: P. Phillip Lamport[1], Stephen C. Weller[1], C. Richard Edwards[1], Guillermo E. Sanchez[2]
Collaborators: Glenn S. Sullivan[1], Jorge L. Sandoval[2]

Abstract

Snow peas have become an important non-traditional agricultural export (NTAE) crop in Guatemala in recent years and have allowed many growers who were previously subsistence farmers to become involved in export agriculture. The pea leaf miner *Liriomyza huidobrensis* (Blanchard) has become an important pest of snow peas, *Pisum sativum* L. in Guatemala. The cosmetic damage to pods caused by the leaf miner larvae is of great concern to growers and exporters. Such damage is often unnoticeable until the product has reached the U.S. port of entry. This pest has created additional concern because it is believed that it has developed resistance to the insecticides that are labeled for its control. The objective of this research was to investigate IPM techniques which would reduce leaf miner populations in snow pea fields. Two IPM techniques, the use of faba beans, *Vicia faba* L. as a trap crop and the use of neem, *Azadirachta indica* (Meliaceae) as a botanical insecticide were investigated. Results of choice and no choice laboratory experiments indicate that faba beans are a preferred host for leaf miner oviposition over snow peas, as higher number of eggs and greater larval emergence were observed on faba beans both in the presence and in the absence of snow peas. Field experiments with faba beans as a trap crop in snow pea production fields during the rainy season resulted in a reduction in leaf miner populations. The number of leaf miner adults caught in sticky traps was similar in the fields with or without the trap crop for a majority of the sampling dates, yet snow pea foliage from the trap crop plots consistently had lower number of emerging larvae than foliage without a trap crop. In a laboratory study, neem applied to the faba bean foliage was found to be an effective disrupter of the leaf miner life cycle. Experiments to test the effectiveness of treating leaf miner infested snow peas and faba bean foliage with neem showed that applications to faba beans before and after oviposition had no effect on pupation, but reduced adult eclosion by 80% compared control treatments (No Neem). Neem applied to infested snow pea foliage did not interrupt the leaf miner life cycle. Results strongly indicate that using faba beans as a trap crop and the neem as a botanical insecticide can be effective IPM strategies for reducing in reducing leaf miner populations in snow peas fields.

Objectives

(1) To determine if is an oviposition preference by adult leaf miners exits between snow peas and faba beans.
(2) To determine the effect of a Neem based insecticide on the leaf miner life cycle.
(3) To determine the effect of using faba beans as a barrier trap crop in reducing leaf miner population levels within snow pea fields.

IPM Constraints

Control of leaf miners by total chemical means is a common practice in snow pea production. Alternative approaches must be tested and shown to have promise before growers are willing to accept such practices.

Research Methods

Laboratory experiments were conducted from September 1998 to April, 1999 at Purdue University, West Lafayette, IN. 'Oregon Sugar Pod II' snow pea and faba bean plants were grown under greenhouse conditions for use in these tests.

Species choice experiments

No choice experiment. Four faba bean or four snow pea plants were placed in plexiglass containment cages, using three cages of each species per replication. The experiment was replicated three times. Leaf miner adults (5 males and 5 females) were placed in each cage, allowed to mate, removed after 3 days, and the number of eggs laid on each plant were counted and recorded. Plants were then transferred to an enclosed greenhouse and maintained until the first 3rd instar mine was visible, then foliage from each plant was cut at the stem, weighed and larvae were allowed

[1] Purdue University, West Lafayette, Indiana, USA.
[2] Universidad del Valle, Guatemala City, Guatemala.

to emerge and pupate. The number of emerging pupae were counted after 5 to 6 days.

Choice experiment. Plants of the same species were positioned diagonally to each other, using 2 plants for each species within the same cage. There were 3 cages per replication and the experiment was replicated 3 times. The infestation and data measurement procedure was the same as for the no choice experiment.

Effect of neem on *L. huidobrensis*. Three different timings for foliar application of Azatin EC (3% azadirachtin, produced by Agridyne Technologies Inc.) plus a control treatment were used: 1) 2 d before leaf miner infestation, 2)1 hr before leaf miner infestation and 3) immediately after leaf miner infestation. Treatment 1 was used to evaluate azadirachtin as a systemic, as well as an antifeedant, treatment 2 tested the systemic and antifeedant effects prior to any of the compound being translocated within the plant, and treatment 3 tested the systemic effects of azadirachtin on larvae and pupae. Target plant foliage was thoroughly sprayed at the recommended rate of 10 PPM azadirachtin with dilutions of Azatin EC made immediately before use while control plants were not sprayed. Each experiment consisted of spraying each plant species (faba beans and snow peas) with the three treatments plus a control and was repeated once. The first experiment with snow peas had seven replications and the second experiment had nine replications. Each experiment with faba beans had 8 replications.

Fifteen and ten recently hatched leaf miner adults of each sex were introduced into the plexiglass cages with snow peas and faba beans respectively, and allowed to mate and oviposit on plants for 3 days prior to their removal. Each cage contained four plants, one plant for each treatment, arranged at random. After adult leaf miners were removed from the cages and the number of eggs on each plant counted, plants were transferred to a greenhouse for six days until the first 3rd instar mine was visible. Foliage from each plant was cut at the stem, weighed, and prepupae were allowed to emerge and pupate. After 5 days the number of pupae were counted. Pupae were transferred to mesh-capped plastic vials and the number of adults emerging was counted after 7 to 10 days.

Faba beans as a barrier trap crop. A field experiment was conducted during the rainy growing season for snow peas, from May through September of 1999 at Xeabaj, Chimaltenango, Guatemala. Plots were managed according to standard agricultural practices without the use of any insecticides or herbicides. Faba beans were planted on May 15 and snow peas on June 1st. The experiment consisted of two treatments; faba beans as a barrier trap crop around snow peas and a control of snow peas only and each treatment was replicated three times. Plots consisted of eleven- 10 m rows with a within row spacing of 3 cm and 110 cm between rows. Plots were positioned 6 m from each other. In the trap crop treatment, three rows of faba beans were planted at a spacing of 35 cm between rows. Sampling for levels of leaf miner infestation was conducted 20, 30, 40, 50, 60, 70, and 80 days after planting at 8 different locations within the barrier crop treatment and at 13 locations within the snow pea treatment. Sampling involved cutting the upper 50 cm of the stem of each plant and placement each into a plastic bag. When plants were shorter than 50 cm, the whole plant was cut at ground level and placed in the plastic bags. The number of emerging pupae was counted 6 days after the plant was cut.

Yellow sticky traps (10 X 10cm) were placed at five locations inside the snow pea fields. The traps were placed in the plots on the day before tissue sampling. The number of adults caught on both sides of the trap crop were counted on the day the foliage was sampled (24 h after the traps placement in the field).

Research Results

Species choice experiments

No choice experiment There was a significant difference ($P<0.01$) between the number of eggs laid on faba beans (2.06 / g of FW, and the number laid on snow peas, (0.20/g of FW) (Table 1). Number of emerging pupae from faba bean foliage (0.43/g FW) was also significant when compared to those emerging from snow pea foliage (0.04/g of FW).

Choice experiment. There was a significant difference ($P<0.01$) between the number of eggs laid on faba beans (5.41/g of FW) and the eggs laid on snow peas (0.12/g of FW) (Table 1). Number of emerging pupae from faba bean foliage (2.14/g of FW) was also significant when compared to those emerging from snow pea foliage (0.25 /g of FW).

Table 1.[1] Number of eggs and pupae per gram of fresh weight of tissue per species in no choice and choice experiment[2]

	No choice experiment		Choice experiment	
Treatment	Eggs/g FW	Pupae/g FW	Eggs/g FW	Pupae/g FW
Faba bean	2.06**	0.43**	5.41**	2.14**
Snow pea	0.20	0.04	0.12	0.25

[1]Data presented are means for three separate experiments.
[2] Data were analyzed using a square root transformation. Data presented for the untransformed values.
**Significant difference at $P<0.01$ found between means.

Female leaf miners prefer faba beans as a host for oviposition, over snow peas. The results suggested to us that faba beans would be a good candidate to test as a trap crop for leaf miners in snow pea fields.

Effect of neem on *L. huidobrensis* development. Azadirachtin applied at various times to foliage of faba beans and snow peas resulted in no significant difference in % pupation among the four treatments for either species (Table 2). The % adult eclosion in faba beans was significantly higher in the control treatment (60.6) than in treatments 1 (25.9), 2 (35.0), and 3 (12.1), while % of adults in treatment 3 (12.1) was significantly lower than for treatments 1 and 2. There was no significant difference in the % of adult eclosion for any of the four treatments on snow peas.

Table 2.[1] Effect of neem treatments on leaf miner infested faba beans

	Faba beans		Snow peas	
Treatment	Pupation[2] (%)	Adult eclosion[5] (%)	Pupation[2] (%)	Adult eclosion[5] (%)
1) 2 d before	21.9	25.9b	22.3	49.6
2) 1 hr before	23.8	35.0b	38.8	48.9
3) Immediately after	15.9	12.1c	47.7	50.6
4) Control	26.5	60.6a	38.0	60.1
	ns		ns	ns

[1] Eggs were measured in total number of eggs per g of fresh weight.
[2] Pupation is expressed as a percentage of the number of eggs.
[3] Eclosion is expressed as a percentage of the number of pupae.
[4,5]Values in the same column followed by the same letter are not significantly different at the P=0.05 level (Tukey's studentized range test).
ns No significant difference was found between means

Foliar application of azadirachtin to faba beans resulted in reduced leaf miner adult eclosion, but had no effect on pupation. All three application times of azadirachtin to faba beans were effective in reducing adult eclosion, but the best (12% eclosion) was an application immediately after leaf miner infestation. Therefore, the best time to apply azadirachtin is after eggs laying but before they hatch (eggs hatch 2 to 3 days after oviposition). This timing would maximize the amount of active azadiracthin ingredient ingested by larvae and minimize the amount degraded on the foliage by the environment.

Neem application of to snow pea foliage had no effect on leaf miner development. This different effect could be a due to differences in the physiology of the 2 types of beans such as a lower level of translocation and/or absorption of the active ingredient in snow peas. Further research into the movement of neem in plants is needed to determine why the effects on leaf miner development were different for the two plant species used in this experiment.

Faba beans have potential as a trap crop for integration into an IPM system for leaf miner population management in snow pea production fields. Neem could be included in this system where applications made to the infested trap crop faba beans would reduce subsequent leaf miner population pressure and prevent high levels of infestation on the snow pea crop. The use of neem in this manner would eliminate the need to remove the trap crop so as to reduce the inoculum source, and allow trap crop effectiveness through the growing season and over repeated leaf miner generations.

Faba beans as barrier trap crop. The number of larvae emerging per snow pea plant was significantly (P=0.05) higher in monoculture control treatments than in the trap crop treatment (Figure 2) for tissue sampled at 20, 30, 40, and 60 days after crop planting (larvae were significantly different at P=0.10 level for days 50 and 70 after planting). There were no significant differences in the number of larvae emerging from snow pea plants in either treatment 80 days after planting.

Leaf miner larvae population in all snow pea treatments increased during the first three sampling dates but decreased after day 40. This reduction in leaf miner population could be a result of the effect of rain in reducing leaf miner populations. Leaf miner populations in the Guatemalan highlands usually reach their lowest population levels during the months of July through September, during the rainy season and higher rainfall during this experiment could account for lower population levels in the latter stage of the experiment. It is likely that heavy rains have a detrimental effect on adult longevity as leaf miners are very small and delicate. Nonetheless, the leaf miner population within the faba beans trap crop remained high throughout the growing period and only declined after day 60. Table 3 illustrates the number of larvae emerging from faba beans over the growing season.

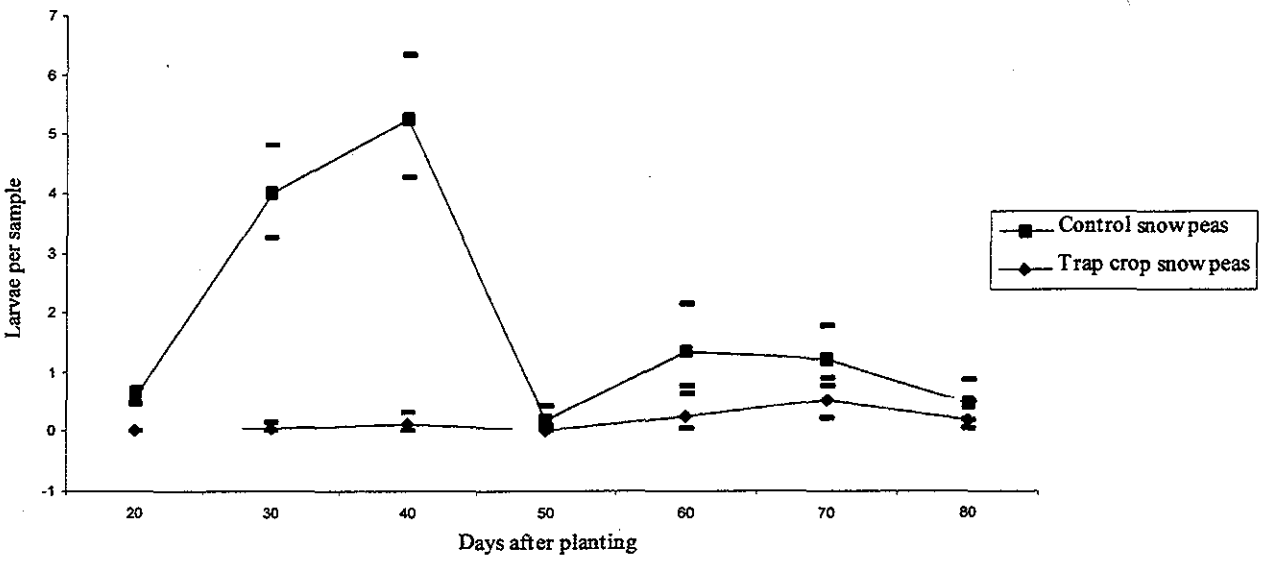

Figure 1. Changes in larval density over time[1]

[1]Data presented are the reverse transformed means of the treatments and their respective LSI for each treatment.

Table 3. Number of larvae per plant sample emerging from faba beans

Day	Number of larvae per sample
20	2.0
30	6.0
40	10.4
50	6.4
60	9.4
70	4.5
80	1.9

The number of adults caught on sticky traps in the trap crop treatment compared to the control treatment was significantly different only on days 30 (at the P=0.05 level) and 40 (significant at the P= 0.1 level) after planting (Figure 2). After 40 days, the number of adults trapped decreased as did the number of pupae (Figure 1) and probably is explained by the deleterious effect rainfall had on leaf miner flight and egg laying activity. Although, there was no difference in the number of adults caught at the majority of the sampling dates for either treatment, the number of larvae emerging from tissue was always higher on snow peas grown without a trap crop from day 30 to day 70. Even when the number of leaf miner adults in the trap crop treatment were higher (days 30 and 40), the number of larvae emerging from snow pea foliage was lower for snow peas grown with the trap crop. These data suggest that the effect elicited by faba beans on leaf miners is not primarily as a barrier which prevents their entrance into the snow pea plot, but rather as an attractant of female adults within each plot. The field results and laboratory choice experiments both strongly support this attractant concept.

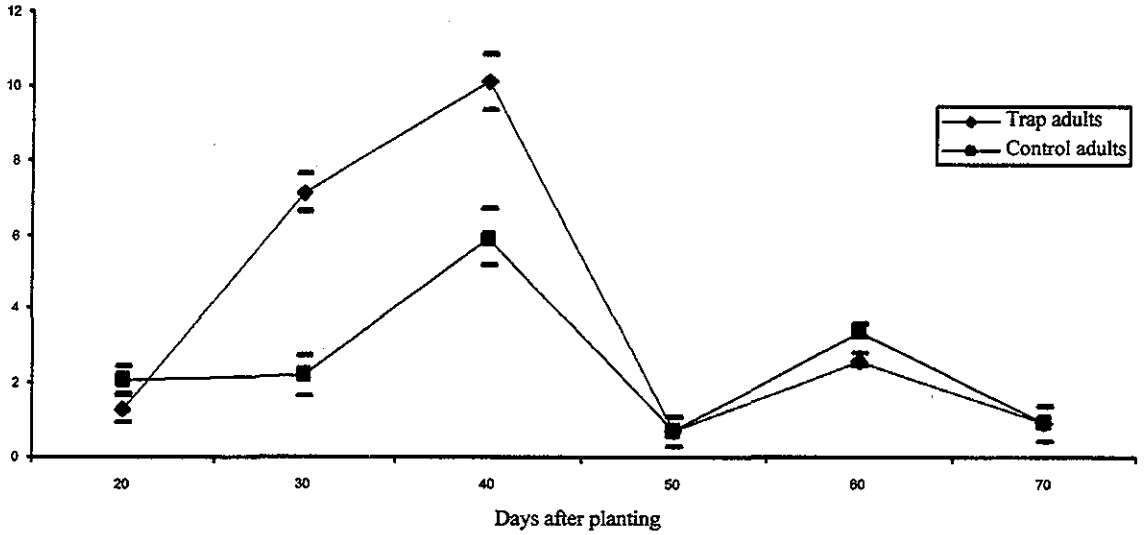

Figure 2. Change in the adult population over time[1]
[1]Data presented are for the means of each treatment and their respective LSI.

To use the trap crop technique during the dry season when leaf miner pressure is much greater, insecticide applications to the trap crop such as those conducted in the above experiments may be needed. Future experiments during the dry season will be necessary (and are planned) to confirm the effectiveness of a faba bean trap crop on leaf miner numbers and damage within a snow pea field. Research to determine the best position for the trap crop within the field will be helpful in refining and gaining the maximum benefit from the trap crop and obtaining the greatest acceptance of this IPM tactic by farmers. An added advantage of faba beans use as a trap crop is that the beans are consumed locally. Growers could harvest and market faba beans to avoid losing field productivity devoted to the trap crop. Use of the trap crop surrounding small snow pea plots is likely to work in Guatemalan since production fields rarely exceed one third of an acre. Applying the trap crop technique to larger fields would require more investigation relating to its positioning and quantity.

Networking Activities

Experiments collaboration between involved scientists from Purdue University, Universidad del Valle, Guatemalan farmer cooperators, GEXPRONT, Snow Pea Committee and has created much useful discussions among these groups.

Publications and Presentations

Master of Science Thesis "Development of IPM Techniques for the Control of Leaf miners on Snow Peas." P. Phillip Lamport, Purdue University, December 1999, Major Professors: S. C. Weller and C. R. Edwards.

Thesis seminar –" Development of IPM Techniques for the Control of Leaf miners on Snow Peas." Purdue University. Presented by P. Phillip Lamport September 24, 1999.

AGRITRADE presentation Guatemala City, Guatemala. December 1999, by S. C. Weller.

Development of IPM Techniques for the Control of Leaf miners on Snow Peas. Journal of Economic Entomology. Currently under internal review, for submission to J. Econ. Entm..

Training Output

Master of Science, P. Phillip Lamport, Purdue University, December, 1999.
Thesis title: Development of IPM Techniques for the Control of Leaf miners on Snow Peas.
Major Professors: Stephen C. Weller and C. Richard Edwards.

Project Highlight

Faba beans have been shown to be a preferred host for leaf miner oviposition compared to snow pea. Further, faba beans have been shown to have potential as a season long effective trap crop to reduce leaf miner infestations in snow peas culture. An effective combination of a faba bean trap crop and timed neem applications can increase the longevity of the trap crop effectiveness and reduce adult leaf miner eclosion. These IPM techniques are currently being incorporated into snow pea production in Guatemala.

Evaluation of Entomopathogenic Fungi and Entomophagous Nematodes for the Control of White Grub (Coleoptera: Scarabaeidae) in Broccoli Fields in Guatemala

Investigators: Humberto Carranza[1], Danilo Dardón[1], Luis Calderón[1], Stephen Weller[2]

Abstract

Entomopathogenic fungi and entomophagous nematodes were evaluated to determine which isolates and/or commercial bio-control products are effective white grub control agents in broccoli. The test site was established in Aldea Xecohíl, Santa Apolonia, Chimaltenango, during August through November of 1998. The tested isolates were Met-92, *Metarhizium* (rice), Terabeaveria, *Diplogasteritus*, Imidacloprid (Confidor) as a chemical control and a no treatment control. A completely randomized design was used in the experiment. The parameters measured were: 1) white grub's initial population, 2) number of damaged broccoli plants at 15, 30, 45 and 60 days after the isolates were applied, and 3) marketable and non-marketable yield. Results indicate that none of the biocontrol agents was effective in white grub management. While the commercial chemical product Imidacloprid (Confidor) was effective for control of white grub populations. The use of imidacloprid for white grub control in broccoli is recommended.

Objectives

Carranza and Orellana (1997) determined that on a national level, the genus *Phyllophaga* spp. and *Anómala* spp. cause serious damage yield reduction of broccoli. Damage is estimated at 25 % yield reduction with a great deal of these losses found in small farmer fields where the infestations are widespread throughout the small field. At the present, white grub management is by use of chemicals insecticides, although their effectiveness is being reduced, probably due to resistance developed by the pest.

Deuteromycetos, *Beauveria* and *Metarhizium* are the most widely used fungi for the control of soil born insects. All these organisms are widely disseminated in nature and can behave as facultative pathogens capable of growing saprophitically. There is much interest in their potential as control agents for white grub control in vegetable crops such as broccoli.

Carranza and Orellana (IPM CRSP annual report, year five) in a previous study, evaluated at a field level, several entomopathogenic fungi isolates for white grub control in broccoli. They determined that the chemical control Imidacropid was superior to both fungi isolates and nematodes, which did not perform any better than the control plot, probably due to their high white grub species specificity and the fact that they require specific environmental conditions for best effect. Since new isolates have become available it was deemed appropriate to evaluate in the field several different fungal and nematodes isolates compared to chemical products, with the potential to have new alternatives for white grub control in broccoli. The primary objective is to determine if commercial bio-control products and laboratory-reared isolates of entomopathogenic fungi and entomophagous nematodes are efficient for control of white grub in broccoli.

Research Methods

The experiment was conducted in Aldea Xecohíl, Santa Apolonia, Chimaltenango from August to November 1998.

Experimental treatments

1 *Met 92* (Fungus)
2 *Metarhizium (*Fungus cultured in rice*)*
3 *Terabeaveria*
4 *Diplogasteritus* (Nematode)
5 Chemical control (Imidacloprid) Confidor
6 Check plot

Experimental Design. Broccoli fields with heave infestations of white grub were selected for these experiments. A previous sampling of the field was made to ensure there was an adequate white grub population and to determine the larval distribution in the soil. This information was necessary for an appropriate experimental design. A completely randomized design was the most appropriate due to the non-uniform spatial distribution of the insect.

Initial white grub population. Before the application of the experimental treatments, a sampling was carried out

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in each of the experimental units and 3 cubes of 0.3x0.3x0.2 m. were collected. The mean number of larvae/sample was taken, determining that *Phyllophaga* and *Phillophaga menetriesi* were the main species present in the soil.

Data collection:

1. Samplings of white grub populations were conducted following the same procedure mentioned above at 15, 30, 45 and 60 days after the treatments were applied.
2. Incidence of white grub damage (Number of damaged plants/total number of plants) was determined at 15, 30, 45 and 60 days after the application of the evaluated products. For the purposes of this study, only white grub-inflicted plant loss was considered.
3. Gross broccoli yield (kg/ha)

Data Analysis. ANOVA for percentage of damaged plants (transformed to the square root of x + 0.5) at 15, 30, 45 and 60 days after the application of the treatments and Duncan's multiple mean comparison test were made. In addition a test for homogeneity by Bartlet's variance was done, to determine if the variances were homogeneous in order to make a combined analysis of the tests, and to detect differences in the effectiveness of the different products under evaluations.

ANOVA was not done for the commercial and non-commercial yield, because only plants in the Imidacloprid treatment yielded any harvestable flower heads. All plants in the other treatments were damaged.

Experimental management. The management of the broccoli fields was based on the Integrated Pest Management Manual in Broccoli generated by the Project MIP ICTA-CATIE-ARF (Morales, 1995).

Research Results

In the randomized sampling prior to the application of the white grub control agents (to ensure that the pest was present in high numbers), it was determined that the average was of 6.82 larvae/volume sampled Sixty percent of the larvae were *P. obsoleta*, 20 % *P. menetriesi*, 10 % a *P. valeriana* and 10 % *P. zunilensis*, which are similar to the results obtained in this site's prior study This indicates that the species are shown in a similar proportion in the department of Chimaltenango and that the sampled volume indicates that in the study site the pest existed in higher quantities.

The ANOVA (Table 1 and 2) indicated that significant differences exist between treatments at 15, 30, 45 and 60 after the application of the products. Imidacloprid showed the lowest amount of damage by white grub, with a minimum of 0% damage at 15 days after the application of the product to 3.6% at 60 days after its application. In contrast, the other treatments had a high percentage of damaged plants at the different reading dates. These results corroborate those obtained by Carranza and Orellana in 1997, but are different from the evaluation of Shannon (1994) and Velásquez who showed *Beauveria* and *Metarhizium* entomophatogenic fungi isolates and the entomophagous nematode of Diplogasteridae family are effective scarabeidos biocontrol agents. Our results indicate that Confidor is a consistent white grub controlling agent.

Table 1. Summary of individual and combined ANOVA done on the percentage of damaged plants, by white grub, at 15, 30, 45 and 60 days after the application in broccoli (transformed data). Chimaltenango, 1998.

Damage (%)	15 DAA	30DAA	45DAA	60DAA	COMBINADO
Readings					*
Treatments	**	**	**	**	**
Readings. X Treatment					NS
C.V.	11.52	6.05	5.47	4.55	7.23

Source: Project ICTA IPM-CRSP; DAA Days after the application of products
NS No significative; * Significative at 5 % of probability; ** Significative at 1 % of probability
CV Coefficient of variance

Table 2. Duncan test of the combined analysis for the % damaged broccoli plants by white grub by readings and treatments, Chimaltenango, 1998.

Readings	% damage plants	Duncan 0.05 %
60DAA	70.54	A
45DAA	67.15	AB
30DAA	63.50	B
15DAA	54.00	C
Treatments	% damage plants	Duncan 0.05 %
Met. in rice	88.08	A
Diplogasteritus	87.97	A
Check plot (control zero)	86.81	A
Met. 92	86.45	A
Terabeaveria	85.17	A
Confidor	1.22	B

Source: ICTA IPM-CRSP; DAA: Days after the application of products

Commercial and Non-Commercial Yield (kg/ha)
The ANOVA was not performed for this variable because of the 6 commercial products tested only plants in the Confidor treatment yielded marketable broccoli. In the other treatments, the yield was zero. The mean yield for Confidor in the 4 repetitions was 17015.39 kg/ha. which is an acceptable commercial yield (Table 3).

Table 3. Average yield (kg/ha) of the evaluated commercial products. Chimaltenango, 1998.

Product	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Mean
Met-92	0	0	0	0	0
Met. in rice	0	0	0	0	0
Terabeaveria	0	0	0	0	0
Diplogasteritus	0	0	0	0	0
Confidor	18037.52	17496.39	17466.33	15061.33	17015.39
Control zero	0	0	0	0	0

Source: ICTA IPM-CRSP

Impacts

None of the Metarhizium and Beauveria entomophatogenous fungi isolates or the *Diplogasteritus* entomophagous nematode were efficient for white grub larvae control. The chemical product Imidacloprid (Confidor) was the most effective treatment for the control of white grub larvae.

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Networking activities

Collaborative research activities with the private sector through the exporting companies: Agriplan, Alcosa, Verduflex. These companies are presently validating an IPM technological package in their broccoli fields.

Project Highlight

This research reconfirms the lack of effective white grub control by entomopathogenic fungi and entomophagous nematodes.

Evaluation of Leaf Miner Hosts (*Liriomyza huidobrensis*) for Massive Breeding of the Ectoparasitoid *Diglyphus* sp.

Investigators: José Manuel Márquez Hernández[1], Danilo Dardón[1], Luis Calderón[1], C. Richard Edwards[2]

Abstract

A total of 10 leaf miner hosts (*Liriomyza huidobrensis*) were evaluated as potential hosts for massive breeding of leaf miner parasitoids. Hosts were evaluated for growth, availability of foliar area and size of leaf miner pupae attained in each one. The research was conducted in the greenhouse facilities at the Experimental Center of ICTA, Chimaltenango (temperature variation between 24 and 32 °C). Regression analysis of the foliar area in function of the age of the plant, was the parameter used to identify the most promissory host for the process of breeding parasitoids larvae.

The species with the greatest regression coefficients were squash (25.53 cm_/day), green bean (20.64), and common bean (18.67). However, the largest pupae development was observed in lettuce, snow pea and yellow flower with 1.98, 1.96 and 1.95 mm in length, respectively. The average of the growth of the plant and the development of the pupae allowed us to select common bean, pea bean and snow pea as the most promising host plant species for breeding larvae of the parasitoid, *Diglyphus* spp.

Objectives

The specific objective was to evaluate the growth rate of 10 leaf miner host plant species and their effect on the leaf miner pupae size, in order to select those better adapted for leaf miner larvae production to be used in *Diglyphus* rearing in the future..

IPM Constraints

In Guatemala, snow peas (*Pisum sativum*) are infested at economically significant levels by *Liriomyza huidobrensis*, the pea leaf miner. It is well known that the hymenopteran *Diglyphus* constitutes one of the most important parasitoids groups that attack the leaf miner *Liriomyza spp.*, since almost all the studies of the parasitoids fauna have revealed one or more *Diglyphus* spp (Parrella et al.1989). According to the study of Johnson and Hara (1987), *Diglyphus begini* (Ashmead) was the most abundant species in 14 of the 23 studies reviewed about the parasitism in the 4 main species of *Liriomyza,* that infest agricultural crops in North America and Hawaii. Studies in the highland regions of Patzicía and the Experimental Center of ICTA, Chimaltenango have detected the presence of leaf miner parasitoids, particularly *Diglyphus spp.* (Hymenoptera:Braconidae).

The use of biological control in the integrated pest management programs in snow pea and other export crops represents one of the most promising pest management tactics. The use of chemical options is to become more restricted in the future, even though much damage has already been inflicted to natural populations of beneficial insects including predators and parasitoids. In addition, the apparent capacity of leaf miners to develop tolerance to the most commonly applied insecticides makes it imperative to research potential non-chemical and environmentally friendly options such as releasal of beneficials such as the *Diglyphus* parasitoid.

Research Methods

This research was developed under greenhouse conditions in the Experimental Center of ICTA, Chimaltenango, located to an altitude of 1740 masl, from September 1998 to March 1999.

The species of host plants were selected based on the study conducted by IPM CRSP research (Pérez et al, 1997) which indicates the alternate host in which leaf miner were found in the snow pea production areas of Guatemala. The list of alternate hosts included:

1. Snow pea (*Pisun sativum*) var. Oregón Sugar Pod II
2. Lettuce (*Lactuca sativa*) var. Great Likes
3. Calendula (*Tagetes sp.*)
4. Common bean (*Phaseolus vulgaris*)
5. Green Bean (*Phaseolus vulgaris*) var. Califormia
6. Tomato (*Lycopersicon esculentum*) var. Giant Rome
7. Beet (*Beta vulgaris* Var. *Cycla)*
8. Broccoli (*Brassica oleracea* Var. *Italic) Legacy*
9. Cauliflower (*Brassica oleracea* Var. *Geminifera)White Snow*
10. Squash (*Cucurbita pepo* Var. *aurantia)*

[1]Institute of Agricultural Science and Technology (ICTA), Guatemala.
[2]Purdue University, West Lafayette, Indiana, USA.

Host Plant Management: Each species was planted into 1000 cc polyethylene pots filled with topsoil, sand, dead leaves, and organic fertilizer in a 1:2:4:1 proportion. During a period of 5 weeks, one pot of each plant species was planted weekly (pot of each host plant) and introduced into mesh-covered growth cages. The cages were located inside the greenhouse subjected to room temperatures oscillating between 24 and 32 °C.

Fertilizer applications to the host plants began at 15 days after planting (dap) followed by weekly applications of 100 cc/pot of a 15-15-15 (120 g/8 lt) solution. Weekly readings of the following variables were also started at 15 dap: plant Height (cm), number of pods developed per plant and pod length and width (cm).

Pupae management: Due to the difficulty of measuring *Liriomyza* larvae because they are inside the plant mesophyll, pupae measurement is a valid tool as it is correlated with the quality of the larvas (Parrella et al, 1989), for this reason a total of 8 plants with enough foliage and with an age range between 45 and 70 dap were exposed to the infestation of leaf miner in breeding cages for 24 hours. This leaf miner colony had weekly additions of leaf miner adults collected in other environments such as Patzicia, Patzún, Santiago Sacatepéquez, and the Experimental Center of ICTA, Chimaltenango, mainly to avoid any complications resulting from endemic effects. Randomized 5 leaf miner larvae samples were collected from each host and their weight (milligrams) was determined. The length of all pupas included in the sampling was also measured (millimeters) with the aid of a stereoscopic microscope.

Data Analysis: To characterize the growth of the host plants, the foliar area was used as a function of the plant's age. The foliar area per plant per week (FA), in each host, was considered by means of the relationship: FA = (Length X Width X 0.75) x number of leaves. With this database and the statistical package "SAS", a simple linear regression analysis was made and used to determine the foliar area accumulation rate during the 35-40 dap time interval. The "t" test for mean differences was applied to the length and weight of leaf miner pupas. The statistical one was:
$t = (x1 - x2) / S (1/n1 + 1/n2, (S^2) = (n1-1)S1^2 + (n2-1)S2^2 / (n1 + n2 -2)$.
0.75 estimated value for the correction of the foliar area

Research Results

Vegetative growth in the greenhouse: The regression coefficient (ß) indicates the change expected in the foliar area (Y), associated with the unitary change in days of the plant. Therefore, the comparison of the ß's allowed to identify the hosts with the higher daily foliar area accumulation. Table 1 indicates that the squash showed the higher change per day with 25.53 cm^2, followed by green bean (20.64 cm^2), common bean (18.67 cm^2), tomato (11.04 cm^2), snow pea (7.49 cm^2) and broccoli (6.22 cm^2). The hosts that showed a very slow growth were: cauliflower, Tagetes, lettuce and beet with coefficients smaller than 4 cm^2/day.

An efficient process of breeding parasitoids requires a management that minimizes the space and time needed for host production. Therefore the plants to be used in the process of breeding parasitoids, should have the longest foliar area by 35 to 40 dap. The squash showed the highest rate of foliar area/day, but due to its large internodal length and the extensive horizontal growth, it requires too much greenhouse area. In contrast, green bean, common Bean, tomato and snow pea showed good vertical growth rates, which makes them more suitable to be grown in a limited greenhouse space.

Table 1. Simple linear regression equations for the foliar area as a function of the plant's age and the average plant height, length and width of leaves at 35 days after planting. ICTA-IPM-CRSP, 1998.

HOST ^Y=B X	REGRESSION PLANT (CM) SD	HEIGHT PLANT (CM) SD	NUMBER LEAVES (CM) SD	LENGTH OF LEAVES	WIDTH OF LEAVES
Squash	^Y=25.53 X	68.40± 0.96	6.0± 0.96	14.6± 0.89	14.0± 0.71
Green bean	^Y=20.64 X	48.00± 7.10	11.0± 0.83	8.9± 1.81	7.3± 0.67
Common bean	^Y=18.67 X	36.40± 2.30	13.2± 2.28	9.6± 2.07	7.7± 1.03
Tomato	^11.04 X	25.20± 3.84	21.0± 3.84	6.6± 0.96	3.4± 0.55
Snow pea	^7.49 X	30.4 ± 7.56	21.8 ±3.56	3.7± 0.45	2.8± 0.27
Broccoli	^6.22 X	18.8 ± 3.62	4.6 ±0.55	8.4± 1.08	6.3± 0.76
Cauliflower	^3.89 X	15.6± 2.19	5.2 ±0.44	8.3± 1.04	5.1± 0.74
Calendula	^3.58 X	10.0± 1.00	9.0± 0.99	5.8± 0.45	2.5± 0.50
Lettuce	^3.53 X	11.8± 1.48	4.20±.44	7.7± 0.76	5.1± 0.74
Beet	^3.17 X	13.8± 2.27	5.0± 1.06	7.9± 0.96	4.6± 0.65

*sd= Standard deviation

Relative size of leaf miner pupae: Table 2, indicates that the pupae developed on snow pea, lettuce and calendula showed the highest weight (superior to 3 mg). However, the lettuce and calendula (*Tagetes)* have a slow development in the greenhouse and for that reason there is no interest in using them for breeding the parasitoids. The pupae developed in common bean weighed 2.91 mg and were similar to lettuce and calendula (P(0.05) and are preferred for the massive breeding. The group produced by tomato, beet, broccoli, cauliflower and squash showed less weight.

Table 2. Weigh average of groups of 5 pupas of leaf miner (*Liriomyza huidobrensis*), developed in 10 plant hosts and their comparison by means of "t" test. ICTA-IPM CRSP, 1998.

HOST	NO.	weight±std	"T" TEST
Snow pea *Pisum sativum*	10	3.24 ± 0.23	a
Lettuce *Lactuca sativa*	9	3.07 ± 0.52	ab
Calendula *Tagetes sp.*	8	3.03 ± 0.34	ab
Common bean *Phaseolus vulgaris*	11	2.91± 0.35	bc
Green bean *Phaseolus vulgaris*	8	2.56± 0.29	d
Tomato *Lycopersicon esculentum*	12	2.44+-0.67	de
Beet *Beta vulgaris* var. cicla	6	2.27+-0.23	de
Broccoli *Brassica oleracea* var. itálica	7	2.10+-0.48	e
Cauliflower *Brassica oleracea* var. geminifera	7	2.09+-0.38	e
Squash *Cucurbita pepo* var. aurantia	8	2.06+-0.86	e

No.= number of samples

Lettuce, snow pea and calendula were superior in the length of pupae (Table 3) with average values ranging between 1.98 and 1.95 millimeters, however they cannot support a higher density of larvas due to their reduced foliar area.

Table 3. Length in millimeters of leaf miner (*Liriomyza huidobrensis*) pupae, developed in 10 plant hosts and their comparison by means of "t" test. ICTA-IPM-CRSP, 1998.

HOST	NO.	LENGTH ±STD (mm)	"T" TEST O.05
Lettuce *Lactuca sativa*	45	1.98±0.10	A
Snow pea *Pisum sativum*	50	1.96±0.11	AB
Calendula *Tagetes* sp.	39	1.95±0.11	AB
Common bean *Phaseolus vulgaris*	55	1.89±0.13	C
Tomato *Lycopersicon esculentum*	60	1.89±0.11	C
Beet *Beta vulgaris* var. cicla	28	1.87±0.11	CD
Green bean *Phaseolus vulgaris*	40	1.83±0.15	D
Cauliflower *Brassica oleracea* var. geminifera	29	1.80+-0.15	D
Squash *Cucurbita pepo* var. aurantia	39	1.80±0.15	D
Broccoli *Brassica oleracea* var. itálica	33	1.79±0.14	D

No. = Number of samples

Impacts

Even though this is only the initial stage in the development of a massive *Diglyphus* rearing procedure, a fundamental aspect of this process was achieved, as snow peas, common beans and green beans were determined to be suitable hosts for leaf miner larvae colonization. These larvae are to be utilized as hosts for the parasitoid, during the breeding process being developed at ICTA's experimental station in Chimaltenango. The long-term impact of this study will be to release vast numbers of *Diglyphus*, as a biological control for the snow pea leaf miner, *Liriomyza huidobrensis*.

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Networking activities

This research was conducted with the collaboration of Gremial de Exportadores de Productos No Tradicionales (AGEXPRONT) and Universidad del Valle.

Publications and Presentations

Presented in the XLV PCCMCA (Central American Cooperative Project for the Improvement of Food Crops) meetings held in Guatemala.

Project Highlight

The use of native parasitoids (*Diglyphus*) as leaf miner biological control agents is one step closer. In the future, release of this beneficial insect should help reestablish natural populations and reduce pesticide usage in snow peas and other important non-traditional export crops.

Preference of *Plutella xylostella* for Oviposition and Development of Immature Stages in the Wild Crucifer (*Brassica napus*) and Broccoli (*Brassica oleracea*) var. Italica.

Investigators: Humberto Carranza[1], Danilo Dardón[1], Luis Calderón[1], C. Richard Edwards[2]

Abstract

The purpose of this study was to evaluate the preference of *Plutella xylostella* to deposit eggs and complete its immature stages on the wild crucifer (*B. napus*) compared to and broccoli (*B. oleracea* var. italica). A bio-test was established in experimental cages at ICTA's Experimental Station in Chimaltenango, from September to November 1998. A completely randomized design was used with 2 treatments and 14 replications. The experimental units were individual plants of *B. napus* and broccoli. Variables measured were the number of eggs laid, larvae and pupae of *P. xylostella*/plant. Weekly insect counts were made from 10 days after the release of *P. xylostella* adults on the whole plant. Data was analyzed by analysis of variance and mean separation by Duncan's. Results indicate that *B. napus* was more attractive to *P. xylostella* for egg deposition and as host for larval and pupal development stages than was broccoli. *B. napus* may have potential as a trap crop for *P. xylostella* in commercial broccoli fields, and spatial distribution field trials are recommended.

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[2] Purdue University, West Lafayette, Indiana, USA.

Objectives

To determine if the wild crucifer B. *napus* is more attractive to *P. xylostella* compared with *B. oleracea* var. Italic (broccoli), for oviposition and later immature stage development.

IPM Constraints

The diamond back moth (*Plutella xylostella*) is the most important insect pest in broccoli in Guatemala. Populations usually do not affect gross yields but may result in rejection of the marketable product, because of the presence of larvae and/or pupae inside the floral head. The natural control by beneficial insects of diamondback moth has been reduced because of the excessive use of chemical insecticides. In 1995, ICTA researchers observed that a weed of the family *Brassicaceae*, could be a good alternative for the control of P. *xylostella* and *Leptophobia spp.* by acting as a cruciferous trap crop.

In the 1996-97 agricultural cycle, studies were conducted on the use of several wild crucifers as potential trap crops for *P. xylostella.* It was determined that *P. xylostella* preferred *B. napus*. Based on these results, experiments were established to evaluate whether *P. xylostella* had a preference for ovipositioning and larval development between *Brassica napus* and. *Brassica oleracea* var. Italica (broccoli). Future studies will investigate if different spatial distributions of B. *napus* have varying trapping effects on different lepidopteras species. The experiments described are the first phase of the study regarding the preference of P. *xylostella,* for either *B. napus* or broccoli.

Research Methods

Two tests were established at the ICTA Production Center at Chimaltenango, from September to November 1998.

Experimental design

A completely randomized design with 2 treatments and 14 repetitions was used. The experimental unit was individual plants of *B. napus* and *B. oleracea* seeded directly in the field. Treatments consisted of:

1. *Brassica napus*
   Common name: mustard, wild turnip.
2. *Brassica oleracea var.* italic
   Common name: broccoli.

Data collected included numbers of eggs laid, larvae and pupae of *P. xylostella* per plant. Weekly counts were taken beginning 10 days after the release into the experimental cages of the adults of P. *xylostella.* Data were analyzed using ANOVA and Duncan's multiple means test.

Experimental Management: *B. napus* was planted 20 days before the broccoli was planted inside the experimental cages. *Plutella* pupae were collected from the remains of broccoli residue from farmers' fields, and from host weeds. Adults of *P. xylostella* emerging from this tissue were released into the experimental cages. Measurements were taken beginning 10 days after the adults released were allowed ample time for development of larvae and pupae on either plant type. No pest control was done inside the cages.

Research Results

There was a highly significant difference between the numbers of insects (eggs, larvae and pupae) present on the two plant species, and between readings taken at different dates. The interaction between the dates of counts and the two *Brassica* species was also statistically significant (Table 1). These results indicate that at all dates and developmental stages of the two plants the *Plutella* adults prefer *B. napus* to broccoli, and that immature stages develop on B. napus.

Table 1. Summary of the variance analyses of the preference of P. *xylostella* for eggs deposition and to complete the larval and pupal stages in B. *napus* and *B. oleracea*, Chimaltenango 1998.

Source Variation	No. of eggs	No. of larvas	No. of pupas
Readings (R)	**	**	**
Species of Brassica (SB)	**	**	**
R x SBD	**	**	**
C.V. %	51.52	21.56	45.45

Source: ICTA IPM-CRSP
** High significance
V.C. Variation coefficient
No. of eggs of P. *xylostella/plant*

Number of larvae of P. *xylostella*/plant. *B. napus* had higher numbers of *P. xylostella* larva than broccoli with a general mean of 349 larvae/plant, compared to 63.45 larvae/plant for broccoli. A similar situation was observed in the study of Carranza et al, 1997, (IPM CRSP, year 5 annual report) in which B. *napus* was always more attractive to the larvae of *P. xylostella* than other *Brassicaceae*. It is important to note that by attracting large numbers of *P. xylostella* larvae, applications of the biological insecticide *Bacillus thuringiensis* can be effectively used to control *P. xylostella* in both the trap crop and broccoli.

Number of pupae of P. *xylostella*/plant. P. *xylostella* had higher pupae populations in *B. napus*, with a general mean of 45 pupae/plant compared to 12 pupae/plant in broccoli.

Impacts

B. napus has been shown to offer potential as a trap crop for *P. xylostella* in broccoli *(B. oleracea var.* Italic) culture.

Networking activities

This research was carried out with the collaboration with Alcosa, Agriplan, Universidad and Gremial de Exportadores.

Project highlight

It was confirmed that *Plutella xylostella* has preference for *Brassica napus*, however, field testing for its use as a trap crop must be conducted since many producers indicate that its use would reduce the area available for broccoli production and lower income expectations.

Integrated Pest Management of White Fly in Tomato At El Progreso, Guatemala

Investigators: Mario Morales[1], Danilo Dardón[1], Luis Calderón[1], C. Richard Edwards[2]

Abstract

Guatemala is among the countries that have experienced great damage by white fly (*Bemisia* spp.) in tomato crops. Yield losses in some areas of the country range from 60% to 100% which prompted the IPM CRSP, through ICTA and other institutions, to develop a technological package (consisting of 22 different(IPM practices) as a solution to this problem. The purpose of this study was to validate these IPM practices among tomato growers. The specific objectives were to: 1) determine the effectiveness of three or more tactics in the control of the white fly–viral complex, and 2) improve the yield and earnings in comparison to the traditional management practices used by the tomato growers of El Progreso. The tactics validated in the integrated format were: 1) tomato seedbed covered by a foamy cloth, plus tomato seedlings grown in newspaper transplant plugs; 2) use of in field sorghum barriers planted 45 days before tomato were transplanted; 3) use of plastic yellow plastic traps smeared with automobile motor oil every 8 days as sticky agent to monitor populations; and 4) use of chemical insecticides on a rotational basis every 8 days. The above tactics were compared to the traditional growers' practices which include: 1) producing or purchasing tomato seedlings grown in traditional open field seedbeds; 2) no use of field sorghum barriers; 3) no yellow sticky traps; and 4) programmed use of insecticides (without rotation of chemical groups) 2 times per week.

An economic analysis was done on data gathered from neighboring IPM and growers' plots (each 600 m^2 in size). The agricultural management with the crop, other than white-fly protection, were similar in both cases. Experiments were conducted from December 1997 to December 1998 at four sites: Conacaste, Llano de Morales, Sanarate, Magdalena and San Agustín Acasaguastlán, all villages of the eastern Department of El Progreso, during both the dry and rainy seasons. The general results obtained from the IPM technology in comparison to the tomato growers' were the following: 1) IPM-based yields were 30,149 kg/ha compared to 25601.75 kg/ha in the growers' control, 2) IPM-based variable costs were $1390 US/ha in comparison to $1584 US/ha in the growers' control, 3) IPM-based profits

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of $2475 US/ha in comparison to $ 1637 US/ha in the growers' control, and 4) IPM-based pesticide sprayings were reduced to 10 compared to 20 in the growers' control. There were significant reductions of white fly populations and viral incidence at 3 sites. The integrated technology of 3 or more management tactics were effective in controlling the white fly – geminivirus complex, and resulted in increased tomato yield and grower earnings while reducing white fly populations, viral incidence and the number of insecticide applications. The results obtained in this study warrant the transferal of this technology to tomato growers in eastern Guatemala.

Objectives

To determine the effect of 3 or more integrated pest management tactics on the white fly-geminivirus complex, in relation to tomato yield and earnings, compared to the traditional management practices used by tomato growers.

Research Methods

At the end of the 1980`s, several crops in the tropical and subtropical regions of the world were affected by the white fly (*Bemisia* spp [(Homoptera: Aleyrodidae)]. Due to the crisis in tomato caused by the white fly-viral complex in eastern Guatemala, the growers decided to abandon the crop and to seek new crops or non-agricultural activities. Other growers (mostly traditional tomato producers) opted for increased use of insecticides, at rates of once every 2-3 days or sometimes daily. This excessive use of insecticides increased the crop production costs, posed an increased danger to the food and water supplies, along with increased environmental contamination, a reduced population of beneficial insects, and an increase in insecticide-resistant pests. At El Progreso, Guatemala, from 1995 to 1996, the ICTA-IPM CRSP project carried out integrated management research, targeting the white fly-geminivirus complex in tomato. As a result of this work, growers selected 5 from a package of 14 management tactics, including, 1) tomato seedbed covered in a foam cloth, 2) transplant plugs, 3) sorghum barriers, 4) yellow sticky traps, and 5) plastic row covers. Based on the above, the ICTA - IPM CRSP Project decided to conduct a technology validation study, integrating 4 of the management tactics mentioned before, including 1) foamy cloth covered transplant speedlings, 2) use of sorghum barriers, 3) use of yellow sticky traps and 4) rational use of insecticides.

Methodology

Four tests were established at different sites in the eastern Department of El Progreso, from December 1997 to August 1998. These sites were 1) Finca Monte Grande, village of Conacaste; 2) village Llano de Morales, Sanarate; 3) Village Magdalena, San Agustín Acasaguastlán; and 4) Guastatoya.

Paired plots, each of 600 m^2 were established for both of the management programs under evaluation. The IPM validation package included the following white-fly management tactics.

Integrated application of four management tactics for white fly control including:

a. tomato speedlings planted in newspaper transplant plugs and seedbed covered by a foam cloth.
b. Sorghum barrier within tomato fields, planted 45 days before tomato transplant.
c. Use of yellow plastic traps smeared with automobile motor oil every 8 days as a sticky agent.
d. Rational use of insecticides (rotating chemical groups) based on white fly population counts.

In contrast, the control (farmer) management plot included the following practices:

a. Seedlings produced in a traditional open seedbed with chemical control based on insecticides, or transplant plugs either bought or produced locally.
b. No sorghum barriers
c. No yellow sticky traps
d. Programmed systematic use of insecticides (without chemical rotation) and no pest monitoring.

Data collection included 1) weekly white fly counts from a 20-plant randomly chosen sample, taking a compound leaf from the mid portion of the plant, 2) viral disease incidence, 3) variable production costs and 4) yields, distributed in three tomato grading sizes. A "t" student test was done on insect counts, disease incidence and yields, while earnings were estimated by means of a partial budget (variable cost) analysis.

Research Results

Table 1 shows the behavior of white fly populations in the IPM and control plots. At the Conacaste site, the populations in the IPM plot fluctuated between 2.35 to 60.60 adults/compound leaf compared to 1.3 and 63.5 in the grower's technology. The farmer attempted to eliminate the insect completely at the beginning of the crop, applying insecticides every 2 days. After the second reading the IPM plot's white fly population averaged less than 10 adults/leaf. It is important to highlight that in the IPM plot only 12 sprayings were made compared to 24 sprayings in the control plot. This indicates that white fly populations are significantly reduced by the combined effect exerted by the yellows sticky traps and sorghum barriers. Similarly leaf curling incidence was significantly reduced in the IPM plots compared to the farmers traditional agricultural management (Table 2). These results confirm the findings of Calderón et al, 1993.

Table 1. Average adult white fly numbers per Compound Leaf in IPM and farmer (control) tomato plots at four sites in eastern Guatemala, 1997-1998

Site	Conacaste		Magdalena		Plano de Morales		Guastatoya	
Days after transplant	IPM	Control	IPM	Control	IPM	Control	IPM	Control
8	2.3	1.3	1.0	1.1	0.1	0.2	0.0	0.1
16	10.6	13.8	0.3	0.6	1.2	2.7	0.4	0.4
24	5.7	20.9	0.2	0.4	3.2	3.6	0.2	0.3
32	7.9	14.6	0.8	2.1	0.6	1.6	0.1	0.2
40	9.1	28.8	1.0	1.8	0.8	1.4	0.2	0.3
48	8.0	23.3	0.4	1.6	1.4	1.8	0.2	0.5
52	12.4	20.4	0.4	1.0	1.0	2.8	0.2	0.9
60	37.3	70.4	0.5	1.1	2.9	3.4	0.5	1.1
68	60.6	63.5	0.5	0.9	3.1	6.6	0.2	0.0
X	17.1	28.5	0.6	1.2	1.6	4.0	0.2	0.5
Significance	NS	*	NS	*	*	*	NS	*

- Significant
- NS = Not significant (P>0.5)

Source: ICTA - IPM CRSP. 1998.

Percentage of plants with virus: Table 2 shows the percentage of plants with virus symptoms per site. At Conacaste, virus incidence reached 86% in the IPM plot compared to 98.3% in the control plot, at 68 days after transplant. At Llano de Morales and Guastatoya the difference between viral incidence in IPM program and the control plot was 11.2% and 13.2% respectively, statistically significant at p=0.05. At Magdalena, very low numbers of white flies were present, but symptoms resembling virus infection were found, as the crop suffered a strong mite infestation, also present in surrounding crops (papaya, tomato and cucumber).

Table 2. Percentage of tomato plants (incidence) exhibiting virus symptoms in IPM and farmer (control) tomato plots at four sites in eastern Guatemala, 1997-1998

Town	Conacaste		Magdalena		Llano de Morales		Guastatoya	
Days after transplant	IPM	Control	IPM	Control	IPM	Control	IPM	Control
20	3.4	4.2	6.42	7.40	2.80	4.00	1.33	2.66
28	6.50	11.50	16.00	16.00	6.40	8.40	5.33	5.33
36	16.50	25.50	30.33	30.33	8.40	11.20	8.00	11.66
44	41.44	58.00	55.00	59.33	14.50	20.00	17.30	24.66
52	55.50	66.50	70.34	73.37	19.00	28.00	20.10	34.00
60	75.00	87.00	96.30	97.00	24.40	32.40	25.32	39.25
68	86.00	98.30	100.00	100.00	26.00	37.20		
Significance (P<0.05)	NS	NS	NS	NS	*	*	*	*

Source: ICTA–IPM CRSP. 1998.

Economic analysis

Table 3 shows the partial budget economic analysis for each of the sites. As shown, the adjusted gross yields for the IPM plot was higher compared to the grower's plot for all 4 evaluated sites. The total variable costs were reduced in the IPM plots primarily due to the smaller number of insecticide applications. Between the reduction in pesticide spraying and increased yield, the net profits were considerably higher in the IPM tested plots, in contrast to the farmer management, ranging from US $ 822 in Magdalena to 4,857 (US$) in Llano de Morales. Table 3 also shows that the cost:benefit ratio was greater in the IPM plots, ranging from 0.63 to 3.54, in contrast to the farmer management, where it ranged from 0.16 to 1.81.

Table 3. Partial budget analysis for variable costs incurred in white fly IPM studies in Tomato, in 4 localities in eastern Guatemala, 1997-1998.

Description	Conacaste		Magdalena		Llano de Morales		Guastatoya	
	IPM	Control	IPM	Control	IPM	Control	IPM	Control
gross yield (Kg/ha)	3,825	2,859	2,373	1,867	6,919	6,768	4,063	3,094
Adjusted yield (kg/ha)	3,443	2,573	2,135	1,680	6,227	6,092	3,657	2,785
Transplants (US $/ha)	556	812	556	705	556	812	556	812
Yellow traps placement and maintenance (US $/ha)	242		242		242		242	
sorghum barriers (US$/ha)	62		62		62		62	
Cost of insecticides (US $/ha)	629	1,144	390	622	446	565	390	601
Insecticide sprays, wages (US $)	77	154	64	122	64	109	64	122
Total variable costs (US$)	1,566	2,110	1,314	1,448	1,370	1,486	1,314	1,527
Net profits (US $/ha)	1,876	463	822	232	4,857	4,606	2,343	1,250
Cost/Benefit ratio	1.19	0.21	0.63	0.16	3.54	3.1	2.78	1.81

Source: ICTA-IPM CRSP. 1998.

Yield of commercial fruit

Table 4 shows the yield of grade 1, grade 2 and grade 3 tomatoes. According to the student "t" test yields from the IPM plot were significantly ($P<0.05$) higher compared to the grower's technology. In addition, the economic return on the investment was also increased, as larger grade 1 yields represented a higher price for the marketed tomatoes.

Table 4. Tomato yields (Kg/ha) according to grading size, of integrated pest management experimental plots and farmer fields at four sites in the Department of El Progreso, Guatemala. 1997–1998

TOWNS	Conacaste		Magdalena		Llano de Morales		Guastatoya	
GRADE	IPM	Control	IPM	Control	IPM	Control	IPM	Control
First	16,074	10,929	9,348	8,119	37,422	30,608	19,456	14,862
Second	7,143	5,981	5,070	3,627	8,579	11,929	7,820	5,334
Third	6,620	5,388	4,089	2,824	7,965	8,836	4,417	3,931
Rejection	1,048	1,156	1,738	1,363	1,800	1,415	2,166	2,472
Total	30,885	23,454	20,235	15,933	55,766	52,788	33,859	26,599

Source: ICTA-IPM CRSP, 1998.

Impacts

The integrated technology of 3 or more management tactics were effectively validated as white fly management tools in tomatoes grown in Guatemala in the control of the white fly viral complex. Revenues were increased, mostly derived from increased yields and reduced variable costs associated with insecticide applications.

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Networking activity

This activity involved close involvement with local tomato growers in eastern Guatemala.

Project Highlight

The integrated management of white flies in tomatoes was successfully validated in eastern Guatemala. Yields in IPM tested plots were 1.23 times the yields of control plots. Insecticide applications were reduced by 50% in contrast to farmer spraying programs.

Use of Plastic Mesh (antivirus clothing) for the Integrated Management of White Fly (*Bemisia tabaci*) in Tomato, El Progreso, Guatemala, 1997-1998

Investigators: Mario Morales[1], Danilo Dardón[1], Luis Calderón[1], C. Richard Edwards[2]

Abstract

Planting of tomatoes in many areas of Guatemala was abandoned because of crop losses approaching 100%, caused mainly by the white fly–geminivirus complex (MBV). For that reason and because the farmers migrated to other planting areas, the development of new pest management technology was required for tomatoes. ICTA, jointly with other supporting organizations, generated a 22-component IPM program focused to allow continued tomato production in eastern Guatemala. However, the use of plastic mesh was not included in that technological program because it had not been validated. The purpose of this study was to: a) validate if the use of plastic mesh plus 3 other IPM components increase the effectiveness of the current whitefly-geminivirus management program, and b) to determine if tomato is still a profitable crop with the introduction of the new technology. The experiment was carried out at four towns from December 1997 to December of 1998, in the eastern Department of El Progreso, Guastatoya. The management technique was to compare one plot including plastic meshes surrounding the field as part of the IPM program with the farmer' control plot. Results indicate that the use of 2m tall plastic meshes with a 50 mesh pore, (holes per cm^2) + use of insecticides in rotation of chemical groups + populations' sampling, resulted in a 50% reduction in white fly populations, a 30% reduction of viral incidence, and the yield and the profitability in these plots surpassed the profit obtained using the farmer technique by 5477 kg/ha (32535 Kg/ha in IPM plot and 27058 Kg/ha in control plot) resulting in a reduction of the number of insecticide applications from 30 to 12; and a benefit/cost relation of 2.58 for IPM plot compared to 1.40 for the farmer' control plot.

Objectives

A key factor in a successful management program of the white fly –geminivirus complex, is to avoid the virus acquisition by the insect vector or the inoculation of the virus into the host plant. Prevention of the viral acquisition by the vector is extremely difficult, therefore efforts have been focused on the prevention of the inoculation process into healthy hosts. This management option can be achieved through several tactics such as interference, repellence and distraction, aided by the short life span of the insect pest. (Hilje, 1995). In general terms, the white fly-geminivirus management strategy targets its efforts on making sure tomato plants remain healthy during the first 45 days after plant emergence (Rojas Monterrey J. 1997).

The interference tactics are directed to avoid contact between tomato plants and the contaminated insect vector through practices such as physical barriers either inert or live. Given the importance of the white fly-geminivirus complex in tomatoes grown in Guatemala, it was necessary to generate and/or validate technologies that allow the insect's management in order to reduce the use of highly toxic or residual chemical insecticides. The purpose of this study was to determine the effectiveness of plastic screens surrounding tomato fields, as physical barriers to reduce white fly population and leaf curling (viral) in tomato, as well as to determine the profitability of the use of this technology.

1. To determine the efficiency of a plastic screen surrounding tomato fields to reduce white fly populations and leaf curling (virus) in tomato.
2. To determine if the incorporation of this technology into the current tomato IPM program is economically feasible.

Research Methods

Four sites were included in this study, two were conducted from December 1997 to August 1998 and published in the Fifth Annual Report, and two were established from August 1998 to December 1998, in the Department of El Progreso, specifically in the villages of Llano de Morales II and Conacaste.

Experimental methodology. The experiment included two 600m^2 plots, one managed through the IPM whitefly management program and a control plot managed by farmers. The management principles applied to each plot were as follows:

1. White fly integrated management plots of 600m^2.

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a) Use of plastic screen surrounding the experimental plot. The screens were 2 m tall and had 50 mesh pores. (Number of holes per cm^2)
b) Weekly sampling of white fly populations (applications of insecticides were done when counts surpassed the threshold of white fly in 20 plants).
c) Rotation of insecticides according to chemical classifications.

Two days before transplant, a roll of anti-virus 50-mesh plastic screen was placed around the planting area of the IPM-managed plot. After transplanting operations , the insecticide Evisect was applied immediately to eliminate the white flies that were caught in the plot after the placement of the screen. The remaining agricultural practices (speedling production, fertilizations, weeding, irrigation, etc) were done in similar fashion to the farmer.

2. Control plots (the farmer's technology)
   a) No plastic screens.
   b) No white fly sampling.
   c) No insecticide rotation.

Data collection.

1. White flies population counts, 3 times/week. Sampling was done on 20 randomly chosen plants, selecting a compound leaf on the middle portion of the plant.
2. Percentage of plants exhibiting virus symptoms in leaves (incidence)
3. net yield as indicated by local tomato quality grading (Kg/ha).
4. Economic analysis through variable costs incurred during the experiment (Q/ha).

Analysis of the information

1. Student "t" tests (probability = 0.05).
2. Economic analysis: partial budget analysis based on variable costgs (Q/ha), cost-benefit ratio.

Research Results

Table 1 shows white fly populations in tomatoes under the two management programs, where it can be seen that in all the towns the effects were very similar. White fly populations decreased by approximately 50% through incorporation of the plastic screens, threshold-based insecticide applications and weekly insecticide rotations. This behavior can be related with studies carried out in the south of Tamaulipas, Mexico, by INIFAP 1994, where it was determined that the synthetic barriers placed at two meters high around the crop, minimize the insects' entrance and function as wind breaks, while maintaining normal light, temperature and relative humidity.

The student "t" test was made with data transformed to Y= | x+1 in order to compare the evaluated treatments, and it was significant (P > 0.05) in the 4 towns. These results demonstrate that the use of a plastic mesh physical barrier and scouting coupled with insecticide rotation were effective in reducing white fly populations. In the IPM-managed program the populations fluctuated between 0.3 and 30 adult white flies per composite leaf, and for the farmer's technology the white fly population fluctuated between 0.55 at 39.

Table 1. Average whitefly counts per 20 composite leaves in IPM-managed and farmer plots in 4 villages of Sanarate, Department of El Progreso, Guatemala 1997 - 1998

	Upayón		Llano de Morales I		Conacaste		Llano de Morales II	
Days after transplant	IPM (plastic screen)	Farmer	IPM (plastic screen)	Farmer	IPM(plastic screen)	Farmer	IPM(plastic screen)	Farmer
5	0.4	1.0	2.0	3.30	2.2	3.8	0.3	0.3
8	0.3	0.6	4.8	10.3	5.1	6.0	0.8	1.4
10	1.1	1.1	0.9	2.1	12.4	4.8	0.7	1.8
12	0.9	2.2	0.1	12.0	23.8	8.9	0.1	2.0
15	0.7	1.1	0.3	0.6	15.2	11.3	0.4	1.3
17	1.1	1.4	1.4	3.4	18.5	11.9	1.1	1.6
19	0.5	1.4	1.7	2.8	27.7	34.1	1.8	1.9
22	1.8	3.0	1.7	4.5	29.9	28.3	1.6	4.3
24	1.6	3.5	2.2	3.5	6.0	5.3	2.4	2.4
26	1.7	3.4	3.4	9.8	11.3	12.8	1.5	2.5
29	2.6	4.4	2.6	11.3	4.1	14.8	1.0	2.1
31	1.3	4.6	4.9	15.3	3.3	21.9	1.1	2.0
33	1.0	2.7	7.6	11.1	2.8	19.4	0.8	4.8
36	0.8	4.9	9.9	19.7	4.2	24.2	1.4	5.4
38	1.3	3.2	24.3	42.8	6.3	13.3	0.8	1.3
40	2.4	3.5	19.4	38.1	7.1	13.5	1.50	3.7
43	1.3	2.9	14.8	34.5	8.2	21.0	1.1	2.5
45	2.0	3.1	21.3	50.8	8.7	32.8	2.5	7.0
47	9.2	18.6	26.8	43.5	4.3	27.5	3.3	7.8
49	2.4	8.8	31.1	56.5	6.3	22.4	4.1	9.3

Table 1. *continued*

	Upayón		Llano de Morales I		Conacaste		Llano de Morales II	
Days after transplant	IPM (plastic screen)	Farmer	IPM (plastic screen)	Farmer	IPM(plastic screen)	Farmer	IPM(plastic screen)	Farmer
52	3.7	8.4	44.0	75.3	2.7	12.8	5.7	20.9
54	5.2	24.0	----	----	----	----	6.1	24.8
57	6.8	23.5	----	----	----	----	7.6	40.4
59	14.3	25.7	----	----	----	----	10.1	41.9
61	6.6	39.1	----	----	----	----	5.7	49.5
63	29.9	33.4	----	----	----	----	8.1	30.7
Average	3.9	8.8	10.7	21.5	10.0	16.7	2.7	11.2
Significance (P>0.05)	*	*	*	*	*	*	*	*

Source: ICTA - IPM CRSP. 1998

Table 2 shows the percentage of plants infected with the virus in the four localities. It can be seen that in all the cases the plot with plastic screens had less virus incidence rates compared to the virus incidence in the farmers plots, a statistically significant event ($p < 0.05$).

Table 2. Percentage of plants expressing viral symptoms in IPM-managed and farmer plots in 4 villages of Sanarate, Department of El Progreso, Guatemala 1997 - 1998.

Towns	Upayón		Llano de Morales I		Conacaste		Llano de Morales II	
DAT	IPM (plastic screen)	Farmer	IPM (plastic screen)	Farmer	IPM(plastic screen)	Farmer	IPM (plastic screen)	Farmer
20	4.41	6.90	4.56	7.70	0.05	0.40	2.80	4.00
28	6.37	10.19	17.42	31.42	2.80	2.90	6.40	8.40
36	7.84	16.60	27.42	44.28	13.42	14.88	8.40	11.20
44	17.15	27.18	43.14	66.00	17.23	21.72	14.50	20.00
52	39.70	60.67	74.84	89.42	21.23	28.12	19.00	28.00
60	52.75	70.15			32.00	39.28	24.40	32.40
Average	21.37	31.94	33.47	47.68	14.45	21.46	12.58	17.33
Significance	*	*	*	*	*	*	*	*

Source: ICTA - IPM CRSP. 1998

Table 3 shows the economic comparison between the IPM-managed (plastic screens + insect counts + insecticide rotation) and the farmers' plots. As it can be seen, yields were higher in the IPM plots. It also seen that the costs changed, reduced by about Q.2000/ha with the use of plastic mesh compared with the farmer' technology. With the new technology each invested quetzal gives a return of Q.2.6, compared to a return of only Q.1.4 using the traditional farmer's technology.

Table 3. Partial budget in plots with plastic screens compared to the farmer's traditional technology, in 4 towns of Sanarate, El Progreso, 1997-1998

CONCEPT	USE OF MESHES	FARMER
Yield Kg/ha	4,171.00	3469.1
Yield adjusted 10% (kg/ha)	3754.23	3122.18
Gross benefits of field (US$/ha)	3754.23	3122.18
Cost of plastic meshes and materials (US$/ha)	354.87	-----
Manpower cost for handling (US$/ha)	44.87	-----
Cost of insecticide (US$/ha)	576.15	1101.79
Field labor cost for application (US$/ha)	73.72	197.18
Total of costs that change (US$/ha)	1047.05	1298.97
Net profits (US$/ha)	2704.74	1823.33
Relationship Benefit/cost	2.6	1.4

Source: ICTA - IPM CRSP. 1998

Table 4 shows the yield of the commercial fruit (tomato) by grading size (grade 1, grade 2 and grade 3)and, as it can be seen, tomato plots under the plastic screen program yielded a greater output of grade 1 tomatoes compared to their respective farmer plot. Similarly The student "t" test was applied to the yield and the difference was significant ($P<0.05$).

Table 4. Tomato yields in IPM-managed and farmer plots in 4 villages of Sanarate, Department of El Progreso, Guatemala 1997 - 1998.

Categories	Grade 1 Kg/ha		Grade 2 Kg/ha		Grade 3 Kg/ha		TOTAL Kg/ha	
Towns	IPM(plastic screens)	Farmer	IPM(plastic screens)	Farmer	IPM(plastic screens)	Farmer	IPM(plastic screens)	Farmer
Upayón	22,836	13,913	10,795	9,593	9,903	8,985	43,534	32,491
Llano de Morales I	6,882	4,041	5,220	4,720	6,473	6,515	18,575	15,276
Conacaste	6,636	5,557	4,293	3,886	6,314	5,671	17,243	15,114
Llano de Morales II	27,236	24,372	11,464	11,663	12,100	9,318	50,800	45,353
Significance *								

Source: ICTA - IPM CRSP. 1998

Impacts

The use of plastic screens of a 50-mesh size, incorporated into the previously developed integrated management for white flies in tomato, had the following effects: a) substantially reduced adult white fly populations; b) significantly reduced the incidence of viral diseases; c) reduced the variable costs compared to the farmer' technology; d) increased the yield and profitability; and e) reduced the number of insecticides' applications.

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Networking Activities

This experiment was conducted in collaboration with ARF-AGEXPRONT, Bayer of Guatemala and Norvartis.

Publications and Presentations

Presented at the Central American Cooperative Project for the Improvement of Food Crops (PCCMCA) XLV Meetings in Guatemala

Project Highlight

The use of 4 different practices, which include surrounding fields with 50-mesh plastic screens, greenhouse speedling production, white fly monitoring and chemical protection to the transplants with Imidacloprid, insecticides applications reduced white fly incidence by 50% and reduced viral infection by 30% in tomatoes.

Evaluation of Fruit Scent Traps for Leaf Miner (*Liriomyza huidobrensis*) Management in Snow Pea (*Pisum sativum*)

Investigators: José Manuel Márquez Hernández[1], Danilo Dardón[1], Luis Calderón[1], C. Richard Edwards[2]

Abstract

Traps baited with mashed flesh of pineapple, melon, papaya, orange and dehydrated chicken compost were compared to insecticide applications and yellow sticky traps as leaf miner management tactics. The experiment was conducted at the Experimental Center of ICTA, Chimaltenango, under a randomized complete block design with three repetitions, in a split-plot factorial arrangement. Traps were exposed once a week for 24 hours, starting at 26 days after planting (das) and the total number of leaf miner adults trapped during that period were counted. It was determined that yellow sticky traps lured a statistically significant ($p<0.01$) larger number of leaf miner adults, compared to most of the fruit pulp treatments, with an average of 7.45 adults per trap/week. Only the traps with pineapple pulp were statistically similar ($p<0.05$) to the attraction effect exerted by the yellow traps with average of 6.09 adults/trap/week. However, there were not statistically significant differences ($P>0.05$) between the number of leaf miners lured by traps containing pineapple, melon, mandarin or orange mashed flesh. The density of leaf miner adults present in the crop increased throughout the different crops stages, beginning with an average of 16 adults/meter-row, reaching 48 adults/m-row at flowering. A sharp increase was observed during the snow pea harvest cycle (54 to 75 dap) with average numbers of 94 and 82 adults/meter-row. The treatments had no effect on the gross yield of snow pea and on the percentages of pods damaged by leaf miner and thrips. The use of yellow plastic sticky traps should be used in cases when leaf miner populations are considered economically importance, as its use reduces insecticide usage minimizing risks of contamination to the environment and human population.

Objectives

Leaf miners (*Liriomyza huidobrensis*) have become one of most economically important insect pests in snow pea in Guatemala. The excessive use of chemical insecticides in vegetables production throughout the Guatemalan highlands has favored the increase of leaf miner populations. For this reason it is necessary to search for non-chemical options that, jointly with other methods or individually, can become effective alternatives to chemical control in the management of leaf miner in snow peas. Among these non-chemical approaches, trapping with scent baits represents a potentially important management tactic, as traps can be baited with substances or bio-agents lethal to the insect pest.

The purpose of this research was to determine if traps baited with mashed pulp of several fruits were effective luring agents for adult leaf miners in snow peas, compared to yellow sticky plastic traps.

Research Methods

The experiment was established from September to December 1998 at the Experimental Center of ICTA in Chimaltenango. The treatments included traps baited with mashed fruits, including pineapple, melon, papaya, orange and mandarin. Other treatments included the traps baited with dehydrated chicken manure, yellow sticky plastic traps, and the traditional chemical control that consisted on weekly aspersions of EPA-approved insecticides for in snow pea.

The treatments were evaluated in a randomized complete block design with 3 repetitions, using a factorial arrangement to evaluate the effect of the scent traps through time. The variety Oregón Sugar Pod II was used. The experimental parcel had 4 rows 15 m long, where 3 transparent 2 liter plastic traps, baited with 200 g of fruit pulp and 5 g Lannate MR 90L (Metomil), were placed.

The traps were exposed once a week for 24 hours periods starting at 26 days after planting (dap). The total number of leaf miner adults captured in each trap was counted during each trapping period. In the chemical control treatment, a

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weekly rotation of EPA-approved chemical insecticides was applied, including: ThiodanMR (Endosulfan), DiazinonMR (Diazinon), LannateMR (Metomil) and Malathion MR (Malathion). For the yellow sticky trap treatment, yellow plastic of 30 x 20 cm was posted on the trellising posts using a 1:1 solid and liquid Vaseline as sticky agent.

Weekly counts were taken on number of leaf miner adults captured per trap and per snow pea row-meter. In addition, net yield and percentage of pods showing leaf miner and thrips (*Frankliniella sp.)* damage were taken at harvest. For statistical analyses purposes, insect counts were transformed by means of the square root + 0.5. After checking the variances' homogenous with the test of Bartlet for each weekly reading, a multi-observations analysis was made. SAS was the statistical program used, using the DCA design and the arrangement of parcels divided in the time.

Results

In terms of number of adults captured by the different traps during 7 weeks, it was determined that the sticky yellow traps showed, with a weekly average number of 7.45 adults/trap, a significantly greater (P(0.01) capacity to lure insects, compared to the fruit pulp traps. Only the traps containing pineapple pulp showed a similar level of effectiveness with average of 6.09insects/trap. However, there were no statistical differences (P>0.05) among the captures observed in the pulps of pineapple, melon, mandarin and orange. This can be seen in Table 1.

Table 1. Effect of the treatments on the number of leaf miner adults captured, in Chimaltenango, 1998.

Treatments	Average weekly adult leaf miners captured per trap	**Duncan P (0.05)**
Yellow traps	7.45	A
Trap of pineapple pulp	6.09	AB
Trap of melon pulp	5.17	BC
Trap of mandarin pulp	4.88	BC
Trap of orange pulp	3.98	BCD
Trap of papaya pulp	3.34	D
Trap of dehydrated chicken manure	0.60	E
General average	4.21	

Source: ICTA-IPM CRSP 1998.

This behavior shows that the adults of leaf miner had higher response to the optical stimulus of the yellow traps, in contrast to the other scent baits. The pineapple pulp option warrants further research as it would be interesting to determine whether leaf miners were attracted to these traps by the yellow color or scent. However, at the rates utilized in this experiment, the usage of pineapple pulp as bait was more expensive than the yellow sticky traps.

The density of adults/row-meter increased as the crop developed, starting with an average of 16 adults/m-row and increasing to 48 adults per row-meter at flowering. The greatest increase was detected between 54 and 75 dap, during harvest with average numbers between 94 and 82 adults/meter. However, this rise coincided with the absence of traps in the field. At 75 dap traps were exposed again in the field and the population diminished to values smaller than 60 adults/meter as it is appreciated in Figure 1.

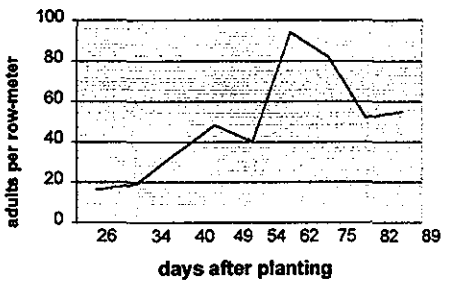

Figure 1. Population fluctuation of leafminer adults in scent traps experiments in snowpeas, located in Chimaltenango, Guatemala.

The populations of adults observed in the treatment with insecticides (results not shown) were statistically similar to those observed in the other treatments, which demonstrates that there are non-chemical alternatives that can control leaf miner adults.

The evaluated treatments did not have a significant effect on the gross yield of snow pea or pods damaged by leaf miner and trips, as it can be seen in Table 2. The yellow plastic traps and the traps with pineapple pulp captured higher quantity of adults, but were not able to reduce the damages in the pods. The percentage of leaf miner damage was of 7.56%, and thrips damage was 11.54%. The gross yield of snow pea was acceptable with 4216 kg/ha, even though development of *Fusarium* yellows was hastened by the excessive rainfall associated to the tropical storm named Mitch.

Table 2. Yield average and percentage of pods damaged by leaf miner and thrips. ICTA, Chimaltenango, 1998.

Treatment (Traps)	Yield Kg/ha ± Std	**Leaf miner damage** % ± Std	**Thrips damage** % ± Std
Mandarin pulp	4496 ± 443	8.68 ± 0.11	10.92 ± 0.22
Melon pulp	4419 ± 432	8.38 ± 0.22	12.97 ± 0.24
Yellow trap	4410 ± 667	7.34 ± 0.34	13.86 ± 0.38
Gallinaza	4266 ± 397	7.34 ± 0.38	10.72 ± 0.20
Orange pulp	4218 ± 450	7.17 ± 0.50	10.39 ± 0.20
Papaya pulp	4068 ± 183	7.28 ± 0.24	9.11 ± 0.16
Chemical control	3964 ± 579	6.79 ± 0.33	12.10 ± 0.56
Pineapple pulp	3887 ± 687	7.56 ± 0.40	12.68 ± 0.38
General average	4216	7.56	11.54

Source: ICTA-IPM CRSP 1998

Impacts

This work demonstrates that there is a higher response to the optic stimulus that yellow traps produce on the populations of leaf miner (*Liriomyza huidobrensis*), compared with the attractive stimulus of the pulp of fruits. The populations of adults were not different in the treatment with insecticides, compared with the use of traps, which confirms that non-chemical alternatives can be incorporated in the integrated pest management of snow pea. The use of yellow plastic traps with a sticky agent should be used in the crops where the leaf miner is considered as an economically important pest, since it is an affordable practice that reduces insecticide use and does not present risks of contamination to the environment.

Networking Activities

This research was conducted in collaboration with Universidad de San Carlos, Universidad del Valle and the chemical company Duwest.

Project Highlight

The non-chemical insect pest management practice of yellow sticky trap placement in snow pea fields is effective in managing adult leaf miner populations in the fields.

Effect of Strip-cropping on Yield and Leaf Miner (*Liriomyza huidobrensis* B.) Infestation in Snow Peas

Investigators: Jorge Luis Sandoval[1], Guillermo E. Sánchez[1], Glenn H. Sullivan[3], Stephen Weller[3], C. Richard Edwards[2]

Abstract

The introduction of labor and input-intensive, monocultural production has favored the development of secondary pests into pests of primary importance in different non-traditional agricultural export crops in Guatemala. Leaf miner dipterans are one such pest that have become a major problem as the result of the disruption in the balance between natural enemies and phytophagous insects due to alterations in the agricultural ecosystems. The purpose of this study was to determine the effect of intercropping on leaf miner infestations in snow peas grown in association with either carrots, beets, black beans, or lettuce. The experiments were located in Xeabaj, Tecpán in the highlands of Chimaltenango and conducted from February to June, 1999. Statistical analysis showed no statistical differences in the numbers of leaf miner larvae found in snow pea tissue, in any of the different cropping systems. The best snow pea yields (6337 kg/ha) were obtained in the monocultured snow peas, treated only with insecticides. The lowest yield 2763 kg/ha was observed in snow peas associated with carrots. The economic analysis showed the most profitable crop association was snow peas grown with black bean (119% revenues) while the carrot:snow pea association was the least profitable with a 54% revenue (based on revenues above invested capital). Even though monoculture snow peas treated with insecticides had the highest yield, costs of production associated with pesticide applications reduced the profit margin compared to the snow pea:lettuce system.

Objectives

The purpose of this study was to determine the effect of intercropping on leaf miner infestations and economic return in snow pea production. Specific objectives were to:

a. Determine the levels of leaf miner larval infestations in snow peas, strip-cropped with either carrots, beets, black beans, or lettuce.
b. Determine the best crop combination in terms of economic revenues and leaf miner infestation.

IPM Constraints

The sharp increase in non-traditional agricultural exports (NTAEs) experienced by Guatemala in the last 15 years has led to the expansion of intensive, monocultural food crop production. Nearly 20 million lb of fresh snow peas were exported in 1998-99, grown by 18,000 small, mostly native producers. The introduction of labor and input-intensive, monocultural production has favored the development of secondary pests into pests of primary importance in different cropping systems. Leaf miner dipterans are one such pest that developed as a result of the disruption in the balance between natural enemies and phytophagous insects due to alterations in the cropping ecosystems. Multicropping systems (intercropping, stripcropping, etc) may prove to be environmentally benevolent and to offer sustainable approaches for long-term NTAE agricultural production.

Research Methods

Field trials were established in Xeabaj (Table 1) from February to June 1999. Tested crop combinations (treatments) were: T1) snow pea+black bean (*Phaseoulus vulgaris)*, T2) snow pea+carrots (*Daucus carota)*, T3) snow pea+beets and T4) snow peas+lettuce (*Lactuca sativa)*. In addition, two monocultured snow pea plots were tested: T5) snow peas treated exclusively with insecticides as a leaf miner management tactic (farmers control), and T6) snow peas treated through non chemical leaf miner control, mainly using movable yellow sticky trap (torito). The experimental design was a completely randomized block, with 6 treatments and 4 replications. Each experimental unit was 58 m^2, consisting of 4 snow pea strips planted alternatively with 3 strips of the secondary crop (lettuce, beets, beans or carrots), or in the case of monoculture only snow peas.

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[2] Purdue University, West Lafayette, Indiana, USA

Table 1. Description of the location and planting date of the three experimental trials included in the snow pea cultivar trials.

Site name	Coordinates[1]	Altitude (masl)[2]	Planting date
Xeabaj, Santa Apolonia	LA 14°46'33" LO 90°549'09"	2,200	February 99

[1]LA, latitude; LO, longitude; [2]meters above sea level.

Factors evaluated in this study were snow pea export-quality yield and leaf miner larval populations at 35, 65 and 90 days after planting. One-hundred gram tissue samples from the two central rows were collected from the mid portion of the plant and placed in a moist plastic bag, where emerging larvae were counted daily for a period of 7 days.

With the exception of T5 (chemical control plot) all plots were managed according to the IPM CRSP Integrated Crop Management guidelines. Leaf miner populations were monitored twice a week and insecticide sprayings based on a 10 adult leaf miners per meter threshold.

Statistical analysis included ANOVA and Duncan's multiple range test when appropriate. Insect data were transformed to the square root value before statistical analysis.

Research Results

No significant differences were found between the numbers of leaf miner larvae harvested at the different sampling dates. Average larval counts ranged from 21 to 31 larvae/100 g of snow pea tissue, in the monoculture chemical system and the monoculture non chemical respectively (Table 2). These numbers show insect pressure was low throughout the experiment with a substantial, decline at the last sampling date.

Table 2. Average leaf miner larval counts (from four replicates) at 35, 65 and 90 days after planting (DAP) in snow pea strip cropping field trial located at Xeabaj, Chimaltenango, February-March, 1999).

Treatment (strips combination)	Larval count (DAP)			Average
	35	65	90	
Snow pea monoculture non-chemical	11	62	12	28
Snow pea:lettuce	19	60	13	31
Snow pea:black beans	14	55	12	27
Snow pea:beets	8	52	16	25
Snow pea:carrots	15	58	18	30
Snow pea monoculture chemical	7	45	11	21

No significant differences were found among the snow pea yields from the different crop combinations. The snow pea yields in the strip cropped treatments (either with lettuce, black bean, beets or carrots) were transformed to represent equivalent plant densities/ha. No significant differences were found between snow pea yields in any treatment. Interestingly, the snow pea:black bean combination yielded the highest output (6,494 kg/ha), while the second largest output was represented by the monocultured, chemically treated snow peas with 6337 Kg/ha (Table 3). These results are in agreement with past IPM CRSP snow pea intercropping studies in which, even though no significant differences were observed between the yields in the tested crop associations, slightly higher yields were obtained in the snow pea:black bean combination.

Table 3. Snow pea yields (kg/ha) of strip-cropping field trial, located in the Guatemalan highlands at Xeabaj, Chimaltenango. 1999.

Treatment (strips combination)	Yield (kg/ha)[1] Block				Average
Snow pea monoculture non-chemical	6312	5329	6872	5988	6125
Snow pea:lettuce	3189	5974	5877	6431	6166
Snow pea:black beans	3126	6779	5530	7414	6494
Snow pea:beets	2595	6313	5994	6357	5964
Snow pea:carrots	2379	6510	4874	5963	5526
Snow pea monoculture Chemical	7459	6597	5017	6275	6337

[1]Yields for strip-cropped treatments have been transformed proportionally to represent kg of snow peas per planted hectare.

The slightly higher yields observed in the snow pea:black bean cropping system becomes an important consideration when yield results are included in an economic analysis. The most profitable combination was the association of snow peas and black beans, with revenues equivalent to 119% of the invested capital. In contrast, monocultured chemical treated snow peas had a 57% profit margin (Table 4). The smaller margin obtained in the monocultured chemical treatment snow peas was the result of the added insecticide and associated labor costs. These chemical inputs (fertilizers or pesticides) have become increasingly expensive in Guatemala as a result of the devaluation of the local currency (Quetzal). The Quetzal's (Q) value has dropped from 6.9:1 (Q:US$) to 7.8:1 in one year, making it increasingly costly to grow export crops dependent on large inputs of synthetic chemicals.

Table 4. Summary of the economic analysis performed on yields and total direct costs of strip-cropping field trial for snow peas in the Guatemalan highlands. 1999.

Treatment	nit	Unitary Cost (US$)	Unitary Price (US$)	Yield (Ha)	Total Direct Cost (US$/Ha)	Net profit (US $)	Profit margin %
Snow pea monoculture non-chemical	Kg	0.37	0.73	6126	2252.00	2240	99.47
Snow pea + Lettuce	Kg Kg	0.36 0.07	0.73 0.17	3083 12727	1126.00 953.00	1135 1200	112.31
Snow pea + Black beans	Kg Kg	0.14 0.39	0.73 0.92	3247 1711	1126.00 673.00	1255 896	119.6
Snow pea + Beets	Kg Dozen	0.38 0.31	0.73 0.35	2982 1300	1126.00 401.00	1061 59	73.25
Snow pea+ Carrots	Kg Dozen	0.41 0.30	0.73 0.24	2763 1324	1126.00 403.00	1016 -80	53.66
Snow pea monoculture Chemical	Kg	0.47	0.73	6337	2965.00	1682	56.74

Impacts

Strip cropping becomes a attractive option for farmers in the highlands of Guatemala. The diversification of crops will favor the long-term sustainability of these export crops and locally marketed vegetables, as well. In addition, the higher diversity will promote the build up of the natural control and help maintain pests at manageable levels. The existence of a healthy agroecosystem will also prevent the emergence of new primary pests, and better natural control of existing pests. The results obtained in this study suggest that the Integrated Crop Management (ICM) strategy devised by the IPM CRSP in Guatemala is applicable to multi-crop systems, such as strip-cropping. The ICM strategy increases the economic benefits to the farmer, as profit margins are increased due to reduced usage of chemical pesticides.

Networking Activities

These studies were done in collaboration with AGEXPRONT's snow pea committee and the farmer's association of Xeabaj, Chimaltenango. Several groups of

farmers and field technicians visited the field trial as part of field trips organized by IPM CRSP and AGEXPRONT. One group of farmers from the western department of Huehuetenango (100 miles away) heard about the field experiments conducted by the IPM CRSP and visited the experimental plots.

Training Output

The intercropping study served as thesis research for Victor Hernandez, a senior Agronomy student from Universidad Rafael Landivar.

Project Highlight

Strip-cropping snow peas with either beans or lettuce, under Integrated Crops Management guidelines, proved to be economically and environmentally advantageous compared to monocultured, traditionally managed snow peas, as profit margins were 55-75% larger and pesticide use was decreased.

Yield and Leaf Miner (*Liriomyza huidobrensis* B.) Infestation Levels in Eight Sugar Snap Pea Cultivars in Guatemala

Investigators: Jorge Luis Sandoval[1], Guillermo E. Sánchez[1], Stephen Weller[2], C. Richard Edwards[2]

Abstract

As a result of the 1995 leaf miner crisis and detentions at U.S. ports of entry experienced by Guatemalan pea exports, the national non-traditional products association (AGEXPRONT) has shown increased interest in the evaluation of snow pea and sugar snap cultivars that may show less susceptibility to infestations by this insect pest. The objective of this study was to evaluate the yields and leaf miner infestation levels in eight sugar snap cultivars. The experimental field trial was established in Xeabaj, in the highland department of Chimaltenango. The most widely grown cultivar, Sugar Snap and a local material named "canche", produced the largest output with 9675 and 8567 kg/ha respectively. The cultivar Mega showed the largest rejection percentage among the evaluated cultivars, with 15% of its production not meeting export criteria. No significant differences were found in the number of leaf miner larvae taken from the tissue samples. The total number of leaf miner counts obtained from 4 tissue samplings dates and 4 replicates ranged from 1426 in sugar snaps to 916 in Mega cultivar. These results show that locally available sugar snap cultivars exhibit similar leaf miner infestation levels although Sugar Snap and Canche have the highest yields.

Objectives

To compare the yields and levels of leaf miner infestation on 8 cultivars of sugar snap peas.

IPM Constraints

Infestations by leaf miner are a major concern for snow and sweet pea growers in the Guatemalan highlands. The most common cultivar found in sugar pea fields in Guatemala is Sugar snap (Rogers N.K.). The possible introduction of less susceptible cultivars into the production system would be an important step towards achieving a holistic and fully integrated leaf miner management program in snow peas in Guatemala.

Research Methods

The field trial was established in March 1999 at Xeabaj, a village located in Santa Apolonia in the central highland department of Chimaltenango. Treatments consisted of 8 sugar pea cultivars, including Sugar Snaps (Rogers N.K.), Sugar Snaps (Dorsin), Sugar Daddy (Rogers), Sugar Daddy (Dorsin), Cristal, Mega, Asgrow and the local material "Canche".

Individual experimental plots were 13.5 m^2 and contained 3 sugar pea rows each 4.5 m long. Treatments were replicated four times following a completely randomized block design.

[1] Universidad del Valle, Guatemala City, Guatemala.
[2] Purdue University, West Lafayette, Indiana, USA.

The factors evaluated in this study were sugar pea export-quality yield and leaf miner larval populations at 35, 65, 95, and 125 days after planting. One-hundred fifty gram tissue samples from the central row were collected from the mid portion of the plant and placed in a moist plastic bag, where emerging larvae were counted daily for a period of 7 days.

Plots were managed according to the IPM CRSP Integrated Crop Management guidelines. Leaf miner populations were monitored twice a week and insecticide sprayings based on a 10 adult leaf miners per meter threshold.

Statistical analysis included ANOVA and Tukey's multiple comparison of means when appropriate. Insect data were transformed logarithmically before applying the statistical analysis.

Research Results

No significant differences ($p<0.01$) in the level of leaf miner larval infestations were found among the cultivars tested. As Table 1 shows, total leaf miner counts per replicate varied from 917 in Sugar Daddy from Rogers N.K. to 1434 in Sugar Snaps (Rogers N.K.).

Table 1. Total leaf miner larvae counts obtained from tissue samples taken at 4 different dates in sugar pea cultivar evaluations conducted in Xeabaj, Department of Chimaltenango, Guatemala, 1999.

Cultivar	Block 1	Block 2	Block 3	Block 4	Total	Average
Sugar Snap (Rogers)	358	338	398	340	1434	359
Canche	319	283	243	320	1165	291
Mega	259	304	349	272	1184	296
537 Asgrow	343	410	349	316	1418	355
Sugar Daddy (Rogers)	333	260	172	152	917	229
Sugar Daddy (Dorsin)	326	338	416	210	1290	323
Cristal	267	409	268	236	1180	295
Sugar Snap (Dorsin)	214	358	293	500	1365	341

In terms of export-quality yields, three statistically distinct groups were detected. Sugar Snap from Rogers N.K. and the local "canche" variety outperformed the 6 other genotypes. A second category included Mega, Asgrow 537, Sugar Daddy (Rogers N.K.) and Sugar Daddy (Dorsin), with yields ranging from 5802 kg/ha to 3765. A lower yielding third category included Crystal and Sugar Snap (Dorsin) (Table 2).

Table 2. Export quality yields (kg/ha) obtained from eight sugar pea cultivar evaluation trial, held in Xeabaj, Department of Chimaltenango, Guatemala, 1999.

Cultivar	Block 1	Block 2	Block 3	Block 4	Total	Average
Sugar Snap (Rogers)	11617	9476	9047	8564	38704	15481 A[1]
Canche	9181	9622	9055	6408	34267	8567 A
Mega	6081	4241	7127	5761	23210	5802 B
537 Asgrow	4103	5506	3950	3327	16887	4222 B
Sugar Daddy (Rogers)	4779	4444	3872	3216	16310	4078 B
Sugar Daddy (Dorsin)	4161	3367	4110	3421	15059	3765 B
Cristal	4227	2450	3067	2643	12387	3097 C
Sugar Snap (Dorsin)	3667	3050	2436	2858	12010	3003 C

[1]Average yields followed by the same letters are in the same statistical group according to Tukey's multiple comparison of means test (=0.01).

Impacts

This research shows that in general, the locally available cultivars of sugar peas do not vary greatly from one another, in terms of numbers of leaf miner larva they can support. They do, however, vary in yielding capacity with Sugar Snap from Rogers N.K. being the best cultivar available. The lesser known "canche" is an interesting material that deserves more attention as a possible alternate genotype.

Networking Activities

Direct and constant communications between co-principal investigators and collaborating companies, primarily Agropecuaria Popoyan, who kindly provided the seed material.

The field plots were also visited by a number of technicians working for different export companies associated to AGEXPRONT.

Training Output

Sergio Torres, a senior agronomy student at San Carlos University, partially completed his undergraduate thesis research with this study.

Project Highlight

Even though great differences were found among the 8 cultivars in susceptibility to leaf miners, the yield results show certain cultivars are preferred high pod producers. This research has helped involve the snow pea committee of the Guatemalan guild of Non-Traditional Product Exporters as a very close collaborator and strong supporter of the IPM CRSP research being conducted in the Guatemalan highlands.

Evaluation of Snow Pea (*Pisum sativum*) Cultivars as related to Yield and Leaf Miner (*Liriomyza huidobrensis*) Infestation

Investigators: Jorge Luis Sandoval[1], Guillermo E. Sánchez[1]; Stephen Weller[2], C. Richard Edwards[2]

Abstract

Infestations by leaf miner are a major concern for snow pea growers in the Guatemalan highlands. The most common cultivar grown has been Oregon Sugar Pod II (OSP), a small-sized cultivar that has exhibited high susceptibility to leaf miner attack. Recently, seed companies, have halted OSP seed exports to Guatemala, making it imperative to search for new appropriate planting cultivars. With the objective of comparing leaf miner infestations and yields of several snow pea cultivars, field trials were established at three different sites in the Guatemalan central highlands of Chimaltenango, from May 1998 to June 1999. Treatments consisted of cultivars OSP (as control), Snowflake, Giant Oregon, and the experimental lines SP6, SP18, SP 517 and SP 40. Treatments were replicated four times following a randomized complete block design. Factors evaluated in this study were snow pea export-quality yield and leaf miner larval populations at 35, 65 and 85 days after planting. Statistically significant differences were found in the numbers of leaf miner larva collected from tissue samples, ranging from 289 to 1071 larvae/100 g of tissue in SP 18 and SPB 40, respectively. No significant differences were found between cultivar yields at any site. Cultivar SP18 consistently supported the lowest larval populations at all 3 sites, ranging from 38% to 75% less larvae compared to the other cultivars. Even though compared to OSP, SP 18 yielded 13.3% less snow peas, its smaller size suggests that a higher plant density could be evaluated in an attempt to compensate for any productivity deficiencies it may exhibit.

Objectives

To compare the yields and levels of leaf miner infestation in 7 snow pea cultivars.

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[2] Purdue University, West Lafayette, Indiana, USA.

IPM Constraints

Infestations by leaf miner are a major concern for snow pea growers in the Guatemalan highlands. The most common cultivar found in snow pea fields, Oregon Sugar Pod II has exhibited high susceptibility to the attack of leaf miners. The introduction of less susceptible cultivars would be a great step towards a holistic and fully integrated leaf miner management program in snow peas in Guatemala.

Research Methods

Field trials were established in Xenimajuyú, Xeabaj and Zaragoza, in the Department of Chimaltenango (Table 1). Treatments consisted of 7 cultivars, including Oregon Sugar Pod II (as control), Snowflake, Oregon Giant, SP6 and SP18, SP517, and SPB-40.

Table 1. Description of the location and planting date of the three experimental trials included in the snow pea cultivar trials.

Site name	Coordinates[1]	Altitude (masl)[2]	Planting date
Xenimajuyú, Tecpán	LA 14°48'15" LO 90°48' 15"	2,300	March, 98
Puerta Abajo, Zaragoza	LA 14°39'21" LO 90°52'41"	2,200	September 98
Xeabaj, Santa Apolonia	LA 14°46'33" LO 90°549'09"	2,200	March 99

[1]LA, latitude; LO, longitude; [2]meters above sea level.

Individual experimental plots were 22 m^2 and contained 4 snow pea rows each 5 m long. Treatments were replicated four times in a randomized complete block design. Individual plots consisted of 4 snow pea rows, each 5 m long.

The factors evaluated in this study were snow pea export-quality yield and leaf miner larval populations at 35, 65 and 85 days after planting. One-hundred gram tissue samples from the two central rows were collected from the mid portion of the plant and placed in a moist plastic bag, where emerging larvae were counted daily for a period of 7 days.

Plots were managed according to the IPM CRSP Integrated Crop Management guidelines. Leaf miner populations were monitored twice a week and insecticide sprayings based on a 10 adult leaf miners per meter threshold.

Statistical analysis included ANOVA and Tukey's multiple comparison of means when appropriate. Insect data were transformed logarithmically before applying the statistical analysis.

Research Results

Significant differences ($p<0.01$) in the levels of leaf miner larval infestations were found among the cultivars tested at Zaragoza, Chimaltenango, the locality with the highest leaf miner population. Larval infestations at the other two sites did not differ significantly among the cultivars. As Table 1 shows, the most susceptible varieties to leaf miner larvae infestation were SPB-40, Oregon Sugar Pod and Snowflake, with similar results to the trials conducted in 1997 (year 5, IPM CRSP annual report). Also, similar to previous results, cultivar SP 18 (total larval count) had the smallest LML population, significantly ($p<0.01$) different than the traditional cultivar OSP.

Yields varied greatly between experimental sites; however statistically significant differences between cultivars were only observed at Xenimajuyú (Table 3). Average export-quality yields ranged from 8525 kg/ha (SPB 40 planted in Zaragoza) to 4015 kg/ha (SP 6 in Xeabaj). Cultivar SP 6 offers an interesting option for growers because even though it yields less than the other cultivars, its pods are considered by exporters to be of high quality, due to their consistent flat shape, and acceptable length and dark green color. In addition, the plant is considerably smaller than OPS, therefore, plant density studies would be appropriate to determine if a greater plant density can compensate for the loss in productivity. Exporters discarded SPB 40, even though it had large yields in Zaragoza, primarily because pods did not meet the standards demanded in the international market. This is the reason why this cultivar was not planted in Xenimajuyú or Xeabaj. The experiment located in Xeabaj was planted during the dry season, which explains the lower yields. Snow peas planted during the dry season typically yield less, unless they are continually irrigated.

Table 2. Total[1] leaf miner larval counts at 35, 65 and 85 days after planting (DAP) in cultivar field trials held in three Guatemalan highland localities, Chimaltenango, Guatemala, 1998-99.

Cultivar	DAP, Zaragoza			DAP, Xenimajuyú			DAP, Xeabaj			Average
	35	65**	85**	35	65	85	35	65	85	
SP-18	181	279	324	76	136	247	98	211	296	205
SP-6	365	536	541	371	238	417	129	328	432	373
SP-517	230	375	426				114	143	370	276
SPB-40	330	920	1071							774
Oregon S. P. II	353	455	565	120	254	370	201	295	461	342
Snowflake	265	605	374	114	278	374	232	312	307	318
Oregon Giant							229	307	345	294

Total leaf miner larval counts represent the sum of 4 replicates for each cultivar in each of the experimental sites.** Indicates statistically significant differences ($p<0.01$) between cultivars at that specific sampling date. SP-517 was not planted in Xenimajuyú because there was no seed available. SPB-40 was not planted in Xenimajuyú and Xeabaj because the pod quality did not reach market expectations and was discontinued. Oregon Giant was not planted in Zaragoza and Xenimajuyú due to seed unavailability.

Table 3. Average export-quality yields (kg/ha) per experimental site for 7 snow pea cultivars evaluated in the Guatemalan central highlands. Chimaltenango, Guatemala, 1998-99.

Cultivar	Average yield (kg/ha)			Average
	Zaragoza	Xenimajuyú *	Xeabaj	
SP-18	8085.8	7036.69 C	4351.90	6491.2
SP-6	7686.86	7843.17 B	4015.62	6515.22
SP-517	8762.62		5068.28	6915.45
SPB-40	8525.25			8525.24
Oregon S. P. II	9171.72	7673.72 B	5354.58	7400.00
Snowflake	8451.51 A	9815.75 A	5075.78	7781.01
Oregon Giant			5863.28	5863.28

**Indicates statistically significant yield differences ($p<0.01$) between treatments (cultivars). Letters following the numbers indicate ranking in statistical groups according to Tukey's multiple comparison of means (=0.05).

Impacts

This research suggests that new cultivars such as SP 18 or SP 517 may effectively replace Oregon Sugar Pod II as the primary seed material for snow peas grown in Guatemala. However, the experimental line SP-6 could also meet productivity criteria if plant density and yields can be increased. An added attractiveness of SP 6 is the lower numbers of leaf miner larvae it supports, in contrast to the other tested cultivars. Results indicate that SP 6 may be an acceptable cultivar for snow pea production in areas heavily infested with *L. huidobrensis* or, during the dry season when high leaf miner populations are common in the Guatemalan Highlands.

Cultivar options other than Oregon Sugar Pod II (in terms of productivity and attractiveness to leaf miner infestation) will prove valuable to farmers and the snow pea industry as a more diverse genetic background in the field should decrease the risks for future pest outbreaks.

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Networking Activities

Direct and constant communications between co-principal investigators and collaborating companies, primarily Agropecuaria Popoyan, who kindly provided the seed material.

The field plots were also visited by a number of technicians working for different export companies associated to AGEXPRONT.

Project Highlight

Snow pea cultivar trials in Chimaltenango determined that several new experimental snow pea lines show great potential to replace the traditional Oregon Sugar Pod II cultivar. Among these materials, SP18 exhibited significantly lower levels of leaf miner (*L. huidobrensis)* infestations in contrast to all the other material under study. Cultivar SP-18 could prove to be extremely useful in growing areas having large leaf miner populations.

Yield and Leaf Miner (*Liriomyza huidobrensis*) Infestation in Four Long-cycle Snow Pea (*Pisum sativum*) Cultivars

Co-Principal Investigators: Jorge Luis Sandoval[1], Guillermo E. Sánchez[1], Stephen Weller[2], C. Richard Edwards[2]

Abstract

Snow pea exports represent one of the two most important agricultural commodities grown in the Guatemalan highlands. However in the recent past, infestations by leaf miner in the export product have become a major concern for snow pea growers. Among the commonly found snow pea cultivars in Guatemala, Oregon Sugar Pod II (DSP) is the most popular. However when leaf miners develop on the pod, a quick sudden change in pod color renders the product unmarketable. With the objective of comparing leaf miner infestations and yields of four long-cycled snow pea cultivars, field trials were established at two different sites in the Guatemalan central highlands of Chimaltenango, from May 1998 to June 1999. Treatments consisted of non-released cultivars from Rogers N.K. (2 genotypes) and Baker Seeds (2 genotypes) Treatments were replicated four times following a randomized complete block design. No statistically significant differences were found in the numbers of leaf miner larva collected from tissue samples of the 4 evaluated materials. Similarly, no significant differences were found between cultivar yields at any site.

Objectives

To compare the yields and levels of leaf miner infestation in 4 long-cycle snow pea cultivars.

IPM Constraints

Infestations by leaf miner are a major concern for snow pea growers in the Guatemalan highlands. The most common long-cycle (16 months) cultivar found in snow pea fields, Mammoth Melting Sugar, has exhibited high susceptibility to the attack of leaf miners (*Liriomyza huidobrensis* B; Diptera:Agromyzidae). The introduction of less susceptible cultivars would be a great step towards a holistic and fully integrated leaf miner management program in snow peas in Guatemala.

Research Methods

Field trials were established in Xeabaj and Zaragoza, in the Department of Chimaltenango (Table 1). Treatments consisted of non-released cultivars, 2 from Rogers N.K. and 2 from Baker Seeds.

Table 1. Description of the location and planting date of the three experimental trials included in the snow pea cultivar trials.

Site name	Coordinates[1]	Altitude (masl)[2]	Planting date
Puerta Abajo, Zaragoza	LA 14°39'21" LO 90°52'41"	2,200	March 99
Xeabaj, Santa Apolonia	LA 14°46'33" LO 90°549'09"	2,200	March 99

[1]LA, latitude; LO, longitude; [2]meters above sea level.

Individual experimental plots were 22 m^2 and contained 4 snow pea rows each 5 m long. Treatments were replicated four times in a randomized complete block design. Individual plots consisted of 4 snow pea rows, each 5 m long.

The factors evaluated in this study were snow pea export-quality yield and leaf miner larval populations at 35, 65, and 90 days after planting. One-hundred gram tissue samples from the two central rows were collected from the mid portion of the plant and placed in a moist plastic bag, where emerging larvae were counted daily for a period of 7 days.

Plots were managed according to the IPM CRSP Integrated Crop Management guidelines. Leaf miner populations were monitored twice a week and insecticide sprayings based on a 10 adult leaf miners per meter threshold.
Statistical analysis included ANOVA and Tukey's multiple comparison of means when appropriate. Insect data was

[1] Universidad del Valle, Guatemala City, Guatemala.
[2] Purdue University, West Lafayette, Indiana, USA

transformed logarithmically before applying the statistical analysis.

Research Results

No significant differences were found in the larval counts done to the tested cultivar at any given date. The largest larval populations were found in Rogers 847-2 (188 larvae/100gr tissue) while Rogers 1 supported the smallest numbers. Baker and Asgrow 85-27 supported 142 and 138 leaf miner larva/100 g of tissue, in average.

Table 2. Total[1] leaf miner larval counts at 35, 65 and 90 days after planting (DAP) in cultivar field trials held in three Guatemalan highland localities, Chimaltenango, Guatemala, 1998-99.

Cultivar	DAP, Zaragoza			DAP, Xeabaj			Average
	35	65**	90**	35	65	90	
Roger 1	49	289	171	32	133	140	136
Baker	51	318	164	30	142	146	142
Roger 847-2	54	334	177				188
Asgrow 85-27	45	325	147	33	137	139	138

Total leaf miner larval counts represent the sum of 4 replicates for each cultivar in each of the experimental sites. Roger 847-2 as not planted in Xeabaj due to seed unavailability

No significant differences were found among the yields obtained in the 4 evaluated cultivars (Table 3). Average export-quality yields ranged from 7278 kgs/ha (Roger 1, planted in Zaragoza) to 5916 kg/ha (Roger 847-2, in Xeabaj).

Table 3. Average export-quality yields (kg/ha) per experimental site for four long-cycle snow pea cultivars evaluated in the Guatemalan central highlands. Chimaltenango, Guatemala, 1998-99.

Cultivar	Average yield (kg/ha)		Average
	Zaragoza	Xeabaj	
Roger 1	7278	7199	7239
Baker	6077	6655	6366
Roger 847-2	5915		5915
Asgrow 85-27	6960	6320	6640

Impacts

Even though no significant differences were found among the tested cultivars, either in susceptibility to leaf miner juveniles or yield, this type of research is extremely important in Guatemala. The continuation of this type of activity will ensure the long-term sustainability of dynamic and intensive non-traditional commodities such as snow peas.

Networking Activities

Direct and constant communications between co-principal investigators and collaborating companies, primarily Agropecuaria Popoyan, who kindly provided the seed material. The field plots were also visited by a number of technicians working for different export companies associated to AGEXPRONT.

Project Highlight

Even though no overwhelming findings were obtained through the study of 4 long-term snow pea cultivars, the snow pea committee of the Guatemalan guild of Non-Traditional Product Exporters has become a very close collaborator and strong supporter of the IPM CRSP research being conducted in the Guatemalan highlands.

Compilation of Ancestral Knowledge among the Quiché and Cackchiquel Ethnic Groups Quiché and Cackchiquel, on the Ecological Management of Agricultural Pests in the Departments of Chimaltenango, Quiché and Totonicapán in Guatemala

Investigators: Rafael Solórzano[1], Mario Chinchilla[1], Juan José Socop[1]; Guillermo Sánchez[2]

Abstract

This research involved interviews of ethnic groups whose agriculture is based on ancestral practices and total organic approaches to crop production. The research was carried out from October 1998 to April 1999, consisting of meetings and interviews with elderly Cackchiqueles and Quichés in the Departments of Chimaltenango and Quiché. People interviewed (men and women) were older than fifty, and were selected for their extensive knowledge on agricultural development and knowledge of pest management strategies in their native areas. The information was gathered through 2 separate meetings at Comalapa, Chimaltenango; and 1 meeting each at Santa Apolonia, Chimaltenango, San José Poaquil, Chimaltenango, and Chiché, Quiche. The procedure also included interviews at San Andrés Itzapa, Chimaltenango. This research is ongoing, as only 30% of the data have been compiled in the Department of Quiché and Totonicapán. Preliminary results indicate traditional practices for crops include use of cultural organic practices including manure, garbage, and organic waste management, planting based on the moon cycle, use of lime to control plagues, and use of multiple plant associations and rotation of crops to sustain their agriculture. A fundamental aspect of their culture and farming practices is the religion, and their respect of nature and the universe in which man is one part.

Objectives

To compile ancestral knowledge from indigenous cultures of Quiché and Cakchiquel regarding their ecological based approaches for management of pests in the agricultural practices.

IPM Constraints

Project based on interviews without field experimentation to verify the widespread applicability of these cropping practices to general NTAE production. Compilation of information is baseline and can be useful in future field based IPM research.

Research Methods

The research methodology is based in the compilation of indigenous ancestral knowledge through meetings and interviews. A questionnaire with 33 questions served as the basis for interviewers. This guide included questions regarding the production crops and social and cultural aspects of each community over the last sixty years. Bibliographical information will be collected (although very little information exists) in the future.

Compiled data concerning the traditional practices used for crops indicated that cultural organic practices include use of manure, garbage, and other organic wastes, planting based on the cycle of the moon, use of lime, crop associations, crop rotation, use of legumes, use of native seeds, and insect repellent plants, as important components of their pest management systems in a holistic approach to agriculture production. A fundamental aspect of their culture is their religion, which requires strong respect for nature and the universe in which man is but one part.

Impacts

The results obtained from this compilation of ancestral agricultural knowledge, will allow field testing of some of these ancient practices for validation of effectiveness and eventual incorporation of useful techniques into Integrated Pest Management programs for non-traditional crops.

Networking Activities

a. Exchange of results with ALTERTEC personnel (technical personnel and promoters that work in 17 departments of Guatemala).
b. Exchange of results with technical personnel of CARE Guatemala.

[1] ALTERTEC, Guatemala
[2] Universidad del Valle, Guatemala City, Guatemala

c. Exchange of results with technical personnel of SHARE Guatemala.
d. Exchange of results with students of the Faculty of Agronomy, at University of San Carlos, Guatemala.
e. Involvement of ICTA in future field research activities.

Project Highlight

In ancient times there was a different knowledge base and specific techniques used for management of pests in crops. Interviews suggest this knowledge and these practices may allow small producers to maintain sustainable agricultural production for rural families. The survey indicated that farmers using these practices rely on their own farm-based resources, while maintaining the rich soil. These surveys will insure that much of this knowledge will be rescued, documented, and validated in future research as to its potential for use and incorporation into Integrated Pest Management programs for NTAE crops.

IPM CRSP Activities at the Department of Crop Protection, Zamorano, Honduras

Introduction

The Crop Protection Group of the IPM CRSP group at Zamorano was involved in three main activities:

I. **Identification of viral and rickettsial infections in papaya for Honduran small-holders**

II. **Identification and distribution of plant virus pathogens that threaten pepper and watermelon production in vegetable cropping systems in Honduras**

III. **Integrated management of a mealybug, (*Dysmicoccus brevipes*, Homoptera: Pseudococcidae) and an associated closterovirus in organic pineapple.**

Host country researchers

- Maria Mercedes Roca de Doyle, Ph.D. (Virologist, permanent)
- Mario Bustamante, M.Sc. (Plant protection specialist, permanent)
- Elsa Barrientos, M.Sc.. (Researcher, molecular techniques, permanent)
- Antonio Jaco B.Sc. (Agronomist, IPM specialist, permanent)
- Oscar Vasquez (Student researcher)
- Jose Luis Guaman (Student researcher)
- Gabriel Chiriboga (Student researcher)
- Carla Cruz B.Sc. (Researcher, molecular techniques, temporary)

Integration of activities and leverage funds

The 1999 activities of the IPM CRSP group were more integrated to other IPM activities, and in particular to those of the Bean/Cowpea CRSP project regarding management strategies for whitefly transmitted viruses in vegetable cropping systems. Also, two student researchers visited Guatemala to interact with Guatemalan IPM scientists working in related areas.

There was a concerted effort by the Honduran team and collaborators at the University of Arizona to leverage funds through other projects to augment the IPM CRSP activities. To this effect, a proposal was submitted for IPM supplemental funds in July 1999 and a proposal on Virus vector/pest complexes affecting pepper in the Caribbean and Honduras, is currently being reviewed. In addition, there is a growing interest from various groups involved in vegetable production in Central America, to evaluate virus resistant germplasm, to identify sources of resistance to the tomato viruses already characterized through the Bean/CowPea CRSP and the pepper viruses that will be characterized through the IPM CRSP project. It is possible that some funds may be accessed from these groups that should result in the identification of resistance varieties which will be used in regional plant breeding programs. The eventual deployment of varieties resistant to viral infections should reduce insecticide use in the region and make products more appropriate for export.

Training for IPM CRSP researchers

Fidel Mendez (M, El Salvador)
In-service training period in 1999 at Purdue University; started M.Sc.. program in Sep. 1999

Ana Saballos (F, Nicaragua)
In-service training period in 1999 at Purdue University; will start M.Sc./Ph.D. program in Jan. 1999

Elsa Barrientos (F, Honduras)
Attended a training course (10 days) at CIAT, Colombia in molecular techniques (mainly RFLP's, RAPD's) used by this institution in their bean/biotechnology program. The visit was funded by a small collaboration project with CIAT on whitefly epidemiology.

MM Doyle also visited CIAT for 2 days to discuss the whitefly epidemiology project and future collaboration.

Jose Luis Guaman and Gabriel Chiriboga (M, Ecuador)
Visit to the Universidad del Valle, Guatemala, to meet other IPM CRSP scientists and learn serological and molecular techniques for virus detection.

Students currently supported by IPM CRSP funds

Oscar Vasquez (M, Ecuador)
Integrated management of a mealybug, and an associated closterovirus in organic pineapple.

Jose Luis Guaman (M, Ecuador)
Characterization of geminiviruses in peppers and watermelon in Francisco Morazan and Comayagua Valley.

Gabriel Chiriboga (M, Ecuador)
Identification of papaya diseases in Honduras

Students and technical personnel trained in IPM related activities

Luis Jara (M, Ecuador)
Characterization of the incidence and management of whitefly in the Comayagua Valley

M. Luisa Guerra (F, Ecuador)
Evaluation of genetic resistance to geminiviruses in beans and tomato

Lubia Aranda (F, Bolivia)
Training in molecular techniques such as PCR and RAPD's to assist with the molecular component of the bean plant breeding program

Andrea Campana (F, Ecuador)
International Foundation for Science Project, Gliricidia disease Project

Barbara Harrison (F, Honduras)
USAID project on Coconut Lethal Yellowing

After the aftermath of Hurricane Mitch, it was deem necessary to undertake an assessment of the new phytosanitary priorities of the main crops of interest. This reflected a concern that in 1998, the worst drought in 30 years, was followed by the worst flooding in 250 years. It was expected that these drastic changes in climatic conditions would have a profound effect on disease epidemiology, including the population dynamics of the whitefly, which had to be accurately assessed and recorded. Four students, supervised by CRSP researchers, conducted field evaluations and farmer surveys to document the change in disease epidemiology in two regions in Honduras.

Olenka Garcia (F, Peru)
Evaluation of methods of whitefly control used by small farmers. Diagnosis of main diseases of beans and tomatoes after Hurricane Mitch in the Yeguare Valley.

Ingrid Fromm (F, Honduras)
Diagnosis of main diseases of vegetable crops after Hurricane Mitch in Comayagua Valley with emphasis on geminivirus/whitefly complex.

M. Luisa Guerra (F, Ecuador)
Impact of Hurricane Mitch on the population dynamics of whitefly in the Zamorano Valley, Honduras.

Note: Two of the students trained in molecular techniques and IPM in 1998 will enter postgraduate programs at Cornell and Purdue Universities.

Meetings with other CRSP researchers

IPM CRSP meeting in Zamorano to plan year 7 activities – March 1999 (3 days)

- Dr. Ray Martyn (Purdue University)
- Dr. Judy Brown (University of Arizona)

Bean/CowPea CRSP meeting in Puerto Rico – February 1999 (3 days)

- Dr. Doug Maxwell (University of Wisconsin)
- Dr. Pilar Ramirez (University of Costa Rica)

American Phytopathological Society -Caribbean Region Annual meeting, Puerto Rico, June 1999 (4 days)

- Dr. Judy Brown (University of Arizona)
- Dr. Mike Davis, University of Florida, Papaya specialist

Visit to the Universidad del Valle by two student researchers, Guatemala, June 1999 (2 days)

- Maragarita Palmieri (member of Dr. Guillermo Sanchez group)

Visit to CIAT, Colombia (2 days)

- Dr. Francisco Morales (CIAT)
- Dr. Pamela Anderson (CIAT)

REDCAHOR (Vegetable growers network), September 1999 (2 days)

- Dr. James Karkashian (University of Costa Rica)

RESEARCH ACTIVITIES

II. Identification of Viral and Rickettsial Infections in Papaya for Honduran Small-holders

Host Country researchers

- Maria Mercedes Doyle
- Gabriel Chiriboga
- Antonio Jaco
- Elsa Barrientos

Introduction

Papaya is a non-traditional fruit crop that has an export potential given an appropriate marketing structure. Honduras has been a small-scale papaya producer for several years, supplying only local markets. Caledonio (personal communication) reports that organically-grown papaya cultivated in San Pedro Sula is appropriate for industrial processing and has potential for export.

The country's largest papaya-producing region is the Comayagua Valley. However, viral diseases and pests such as the fruit fly are a production constrain. Papaya is also susceptible to fungal and bacterial diseases, but the greatest constraints to production are viral infections for which, little is known about disease management. Papaya ringspot virus (PRSV) and a rickettsial disease "bunchy top" have devastated papaya production in the United States, Mexico, Jamaica, Hawaii and Guatemala (Calderon and Cepeda, 1998).

Characterization of papaya diseases

In the Comayagua Valley, papaya has been cultivated for the past four years. Several development organizations and institutions have supported farmers to get started, and market opportunities make papaya a profitable crop. Surveys with local farmers in Comayagua show that farmers are still facing problems with disease management and are willing to adopt disease management technologies. As a first step to diagnosing the most important production constraints, farmer surveys were undertaken and the main papaya disease were identified.

Disease identification in Comayagua and Zamorano

Samples were collected from plants that presented symptoms of disease including fungal and viral infections, in both the Comayagua and the Zamorano Valleys. An accurate diagnosis of fungal infections was undertaken and samples were sent to the plant clinic laboratories of CABInternational in England, to confirm the diagnosis done at the Plant Diagnostic Centre a Zamorano. CABI has a bilateral agreement with certain countries for fungal and bacterial disease diagnosis, free of charge, and Honduras is one of the beneficiaries countries.

The most common fungal infections found in papaya were the following:

- Leaf spot *(Asperisporium caricae)*
- Antracnosis *(Colletotrichum gleosporoides)*

The leaf spot does not pose a threat to production and control with fungicides is not recommended. Antracnosis attacks flowers causing premature fall and can also attack the fruit. According to technical manuals, a strict control during flower formation is necessary. However, antracnosis in passion fruit was studied as part of the IPM CRSP years 4 and 5. The results showed that organic fungicides could be effectively used against *Collectotrichu gleosporoides* and in conditions of low humidity, no fungicide application was necessary.

Other diseases common to papaya in Honduras include:

- Damping off *(Pythium sp., Phytophtora sp. y Rhizoctonia sp.)*
- Bacterial decline *(Erwinia sp.)*
- Root rot (Pythium sp. and Fusarium sp.)
- Stem rot (Phytophtora palmivora)

Preventive control methods can be used to manage these diseases which include the use of sterile soil for the establishment of nurseries, soil desinfection with vapour or boiling water, use of organic amendments to promote soil health and adequate irrigation to prevent high relative humidity. No research is required to manage these diseases, but appropriate technology adoption by small farmers is an important limitation.
Papaya diseases caused by viruses or other agents in Central America include:

Papaya Ring Spot Virus: one of the most destructive diseases of papaya caused a potyvirus, occurs in nearly every region were papaya is grown except Africa.

Papaya bunchy top: a very destructive disease caused by a rickettsia, a fastidious bacterium; it has been reported throughout much of the Caribbean region, Guatemala and the northern part of South America. It has not been reported in Honduras.

Identification of an unreported papaya disease in Honduras

From the onset of the collection visits to Comayagua, it was noticed that most plantations were severely affected with a systemic disease that we originally assumed to be "Papaya bunchy top". The symptoms are different from those of Papaya Ring Spot Virus or any other reported disease. The disease symptoms included severe or total defoliation, a severe shortening of the internodes, the remaining leaves were very small and translucent and sometimes only one or two apical leaves remained at the apex. The stem was often bare giving a pencil-like appearance after which, the defoliated stem succumbs to secondary fungal infections and rots (Fig.1). A similar disease also affected papaya plantations at Zamorano.

However, the assumption that the disease is bunchy top is now in doubt for several reasons:

- the symptoms of bunchy top do not match those of the observed disease exactly, although symptomatology is not a reliable diagnostic criteria
- a crude diagnostic test for bunchy top includes cutting the apical portion of the stem with a pen knife; in bunchy top-infected plants, there is no latex exudate, as it occurs with non-infected plants. This test was applied to 20% of a Zamorano papaya plantation (around 30 trees) and latex exuded from all plants.

Given this, a different etiology from the rickettsial agent is suspected for the observed symptoms. Several tests have already been done to establish the etiology of the unknown disease as it was suspected that it could have a viral or phytoplasma etiology. Since papaya is a host for whitefly, and *Bemisia tabaci* can transmit geminiviruses, tests were done to rule out the presence of this type of virus. Also test were done to detect a possible phytoplasma. Fifteen papaya plants were tested by PCR (Polymerase Chain Reaction) using universal primers that detect geminivirus and phytoplasmas, respectively. All tests were negative. Molecular methods such as PCR, are also used to detect the rickettsial agent of bunchy top. We are currently awaiting the delivery of specific primers for the rickettsia to undertake PCR tests for bunchy top. ELISA kits to test for Papaya Ring Spot Virus have already been received and testing will start in December 1999.

Samples of the unreported disease were recently sent to the Tropical Virology Unit at Rothamsted Experimental Station in England, were a similar arrangement to that with CABI exists for viral detection. Samples were analyzed by Electron Microscopy and long filamentous particles resembling a closterovirus were observed. Closteroviruses have not been reported in papaya and the only other viruses known is a potyvirus (Papaya Ring Spot Virus) and a rhabdovirus (Papaya Droopy Necrosis, only reported in Florida). Further tests are necessary to confirm these findings and Reverse Transcriptase PCR will be used as a next step.

Training in Guatemala

A training course for the student working on the papaya project in Guatemala was organized. The student learned serological and molecular techniques for virus detection in Dr. Margarita Palmieri's lab at the Universidad del Valle. Other information on Papaya Ringspot Virus and genetic variation was also provided. The visit was also an opportunity to build closer links with the two collaborating institutions in Central America.

Other Activities

Farmer surveys will also be conducted to determine the extent of papaya cultivation by small farmers in Comayagua and their potential for export. The study will also focus on the most important limiting factors for papaya production and exports such as the fruit fly, viral diseases, marketing constraints, potential for export of processed products and organic production. The latter has serious potential since the most important diseases affecting papaya can not be managed by chemical control and require genetic resistance. There are interesting developments in the area of transgenic papaya with resistance to papaya ring spot virus and bunchy top (Calderon, personal communication)

II. Identification and Distribution of Plant Virus Pathogens that Threaten Pepper and Watermelon Production in Vegetable Cropping Systems in Honduras

Host Country researchers

- Maria Mercedes Doyle
- Elsa Barrientos
- Jose Luis Guaman
- Antonio Jaco

Introduction

In recent years, crop losses due to damage caused by plant virus-vector and pest complexes have become serious deterrents to pepper and cucurbit production throughout the Caribbean and Central America (Brown and Bird 1992). The increased production of monoculture crops in two to three cropping cycles per year have contributed to the ability of farmers in these areas to produce crops that benefit both local consumers and have added greatly to export initiatives.

However, crop production under the mild climatic conditions that prevail year round in subtropical agrosystems is highly conducive to attack by insects that are both pests and vectors of plant viruses. Typically, plant viruses hinder crop production by interfering with normal physiology of the plant and infection frequently inhibits the ability of farmers to produce quality crops for local and export markets.

The present study is focused on the following activities:

- **Identification of the most economically important viruses in pepper and watermelon crops. Virus detection and identification is being accomplished using established serological and molecular (PCR) diagnostics, appropriate for the detection of viruses most commonly found in these crops.**

Preliminary results show that in Comayagua and Zamorano, less than 50% of collected samples of pepper and watermelon with viral symptoms, are infected by a geminivirus transmitted by the whitefly *Bemisia tabaci*. The samples were tested using universal primers for geminiviruses developed at the Univesity of Arizona (UA). Some of these samples will be sent to the UA for further characterization through sequencing. This information will be important for second phase of the project. In recent meetings with regional vegetable plant breeders, the need to charachterize viruses infecting vegetable crops was evident, to focus plant breeding efforts towards local problems. A network of virologists and plant breeders from Costa Rica, Guatemala, Honduras, Panama and the Dominican Republic will be established to conduct simultaneous variety trials to identify possible sources of resistance to local viruses.

- Virus presence and associated disease severity is being assessed to establish a base line inventory of the specific viruses present in the cropping system.

Given the dramatic climatic changes experienced in the region in the last two years, where the worst drought in 30 years was followed by the worst flooding since records began (Hurricane Mitch), a survey was carried out to document the shift in disease incidence and severity. Typically, during the dry periods there is an increase in the population of whitefly and other insects and thus, a high incidence of viral infections. After the heavy rain brought by hurricane Mitch, the whitefly population plummetted and viral infections were no longer significant for a period. Fungal and bacterial diseases were very prevalent and still are, as a result of another year of heavy rainfall. However, close monitoring of the populations dynamics of whitefly have shown that the population number has steadily recovered with a concommitant increase in viral infections. (A detailed study of the population dynamics of whitefly in the Zamorano Valley since 1997 is available on request).

- A farmer survey is being conducted to determine the kinds of practices tipically employed to control perceived virus disease problems, with an emphasis on identifying potential missaplication of pesticides, which are not in line with effective disease control.

Visit to The Universidad del Valle in Guatemala City, Guatemala.

(Jose Luis Guaman, student researcher)

Objectives :

- Improve molecular skills and learn new protocols for virus detection.
- Review appropriate literature for the research project.
- Establish contacts with professionals in the field and meet other IPM CRSP reserchers.

Skills

The visit had a duration of two days, in which, the visitors had the opportunity to practice molecular techniques, learning the protocols that are used in the field and laboratory research in Guatemala. Some of the techniques included :

DNA extraction
Polymerase Chain Reaction (PCR)
Electrophoresis
Viral inclusion bodies
Identification of the biotypes of White Fly (*Bemisia tabaci* and *Bemisia argentifolii*) by esterasse analysis by electrophoresis
Enzyme Linked Inmunosorbent Assay (ELISA)
Plants preservation methods
Tissue culture.

III. Integrated Management of a Mealybug, (*Dysmicoccus brevipes*, Homoptera: Pseudococcidae) and an Associated Closterovirus in Organic Pineapple.

Host Country researchers:

- Mario Bustamante
- Maria Mercedes Doyle
- Oscar Vasquez
- Antonio Jaco

Introduction

Pineapple (*Ananas comosus*) is an important crop in Santa Cruz de Yojoa, Honduras. This crop is produced as an export crop as well as for processing and local consumption as fresh fruit.

Pineapple has been solidly established as a crop in this region because of the soil's quality: very low pH and low fertility levels, which are appropriate conditions for pineapple crop rather than to other crops.

Pineapple represents the main source of income for most farmers in this areas. Some Non Government Organizations (NGO's) have carried out agricultural training courses directed at many farmers in the region that has promoted better pest management rpactices. (Aguirre M.)[1].

The mealybug (*Dysmicoccus brevipes*) (Homoptera: Pseudococcididae) is widely distributed in this area, and it accounts for most of the pest problems farmers have. Hu, *et al*, (1996), demonstrated that this insect is the vector of PMWaV (Pineapple mealybug wilt-associated virus), know also as Pineapple's Shriveling Virus. The presence of this pathogen has not been confirmed yet in this area altogh samples have been sent to Dr. Hu in Hawaii for identification. The group in Hawaii has developed a molecular probe that permits PMWaV identification, unavailable anywhere else.

Local farmers carry out several practices to control this pest problems. Approximately 30 of the farmers that produce pineapple immerse the sowing material in a lime solution with the purpose of removing insects as a preventive practice. As a curative practice the farmers spray a lime solution and extracts of *Gliricidia sepium* leaves to the growing pineapples.

Most of the farmers that were interviewed agree that mealybugs and *Phyllophaga* spp. are the most damaging pests pineapples have. It is possible that other unknown pests also affectthe pineapple yield. Other pests, such as arthropods, find the three productive cycles per plant used in local plantations favorable for their establishment.

What can be done to solve pest problems in pineapple? Solutions are not clear yet, but researchers are trying new ideas. Biological control offers clues to find solutions. Programs being carried out involve the evaluation of entomopathogen fungus as *Beauveria bassiana, Metarhizium anisopliae* and *Entomophtora virulenta*; as well as garlic (*Allium sativum*) and neem (*Azadirachta indica*), soap and lime.

Activities

Lab research

Lab research was conducted in CEMPLA Diagnostic Laboratory in Zamorano,. Evaluated treatments and the doses used appear in Table 1.

[1] Mauricio Aguirre, Field Technician, Organics Fruit International.

Table 1. Treatments for the bioassay.

No.	TREATMENT	DOSAGE
1	Beauveril ® (*Beauveria bassiana*)	0.05 g/L
2	Destruxin ® (*Metarhizium anisopliae*)	0.05 g/L
3	Vektor ® (*Entomophthora virulenta*)	2.5 cc/L
4	Garlic barrier ® (*Allium sativum*)	5 cc/L
5	Organim 4 SL ® (*Azadirachta indica*)	5 cc/L
6	NUTRISOAP ® Soap	10cc/L
7	Lime	90 g/L
8	Bioport ® Surfactant	0.125 cc/L
9	Control	

Assay in an established plantation

The products used in this assay are the same listed in table 1, with the exception of the surfactant. A Complete Randomized Block design was used in this study, with eight treatments and five repetitions. The experimental area was of 35m^2, in 25 plant plots.

The spraying of chemical products was conducted every 15 days and were suspended when the rainfall increased, because the infestation levels decreased to a similar percentage in all the treatments.

An initial evaluation of each plot was made to determinate the infestation level, using the method of direct observation. A sampling was made to determinate the infestation level in every experimental unit after two sprays, detecting the presence of mealybug in the 25 plant plots.

Identification of the ant species associated with the mealybug

Several samplings in different locations of Chorritos and Ceiba were made. The ants were recollected from pineapple plants infested with mealybugs. The specimens found were kept in recipients with alcohol at 70%, for its latter identification in the Diagnostic Center of Zamorano by Dr. Ronal Cave.

Pineapple mealybug wilt-associated virus (PMWAV), sampling.

It was not possible to identify the virus in the Diagnostic Center of Zamorano, therefore the samples were sent to Dr. Hu, at the University of Hawaii. The samples were taken at an 8 month old plantations and a year-old plantation.

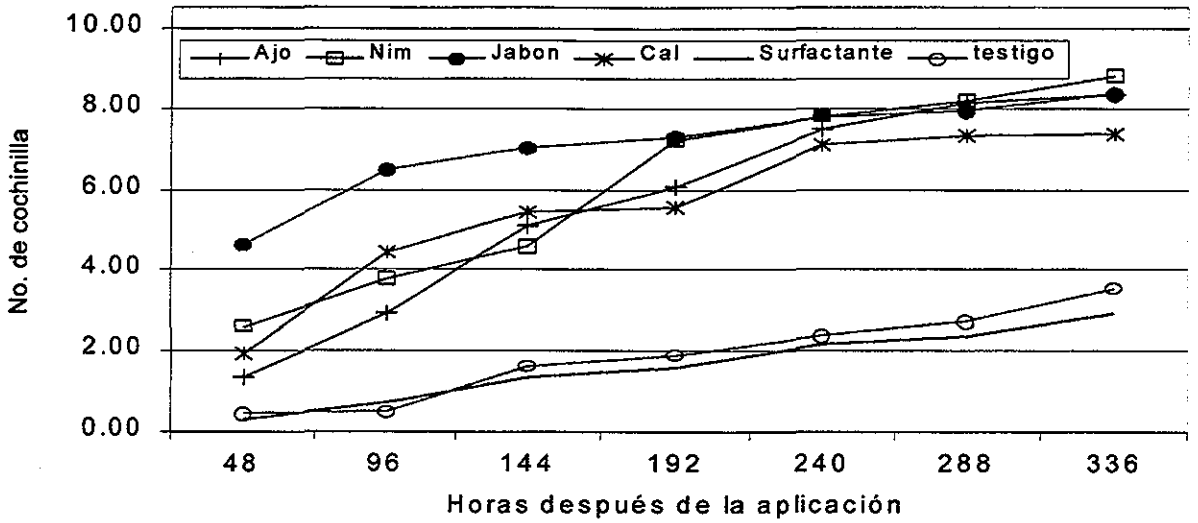

Figure 1. Mortality of insects through time

No. de cochinillas = no. of mealybugs
Horas después de la aplicación = hours after application
ajo = garlic; nim = neem; jabon = soap; cal = lime; surfactante = surfactant; testigo = control

Results

Bioassays

After 48 hrs, the soap shows an increase in mortality. Nim solutions have a statistical difference with the control. Soap and lime started present a difference with the control, maintaining the tendency throughout the assay. The enthomopathoges showed no difference compared with the control (Figure 1).

The physical damage to the cuticle and the spiracle obstruction, were probably the effects of the soap on the insects, resulting in a rapid mortality of the pest. Nim and garlic had a slower effect, due to its mode of action..

The effect of the lime was expected to be faster, however, the lime solution didn't affect the mealybug because of a hydrophobic wax that covers the insect body. It appears that the cause of mortality was inanition of the insect, since the leaves were covered with a layer of lime.

After 336 hours the garlic, Nim, soap, and lime present a similar result and a significant difference with the control

In conclusion, these products have a great potential to be used for the control of this pest.

Field results

After the first sprays of Nim and soap, there was no reduction in the level of infestation. Lime, garlic and Nim produced a similar effect, different than the control In the last sampling, September 10th, none of the treatments were different (Figure 2).

Despite the results of the bioassays, the soap did not have an effective control in the field, this is due to the fact that soap does not fell directly over the insects that are deeply between the leaves, besides, soap is washed easily. Garlic and Neem were the first ones to have a controlling effect, probably in the plants the absorption of them is faster and a bigger amount of product reaches the insect, causing escape and mortality. Lime covers completely the space between leaves and the residues prevent the access of the ants. It acts as a cover of the leaves, impeding the scales to feed. It also has a dehydrating effect over the scales.

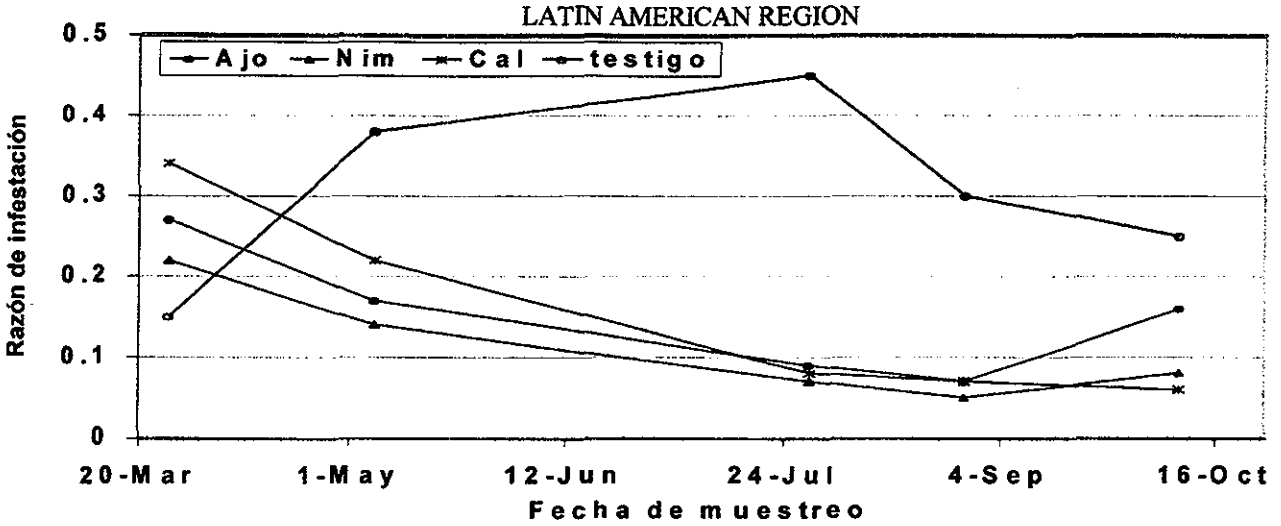

Figure 2. Mealybug infestation level.

Razón de infestación = level of infestation; Fecha de muestreo = date of sampling
ajo = garlic; nim = neem; cal = lime; testigo = control

The last sampling of September 10th showed no difference between the control and the treatments. The rain caused mortality in the scales and therefore there was a natural reduction in the infestation levels. However, lime treatment had a more stable tendency, the rain left residues in the plant tissue that were dissolved again and penetrated the plant. After lime dries, it forms a paste that avoids the ants to add more scales in the plant. This causes mobilization and later death of the scales for dehydration.

Identification of the ants associated with scales

Two species of ants were found to be closely associated to the scales:

Solenopsis geminata is mostly found in established plantations. Its activity peak begins with the flowering of the pineapple, the ants carry the scales over the fruit's stem, covering them with dirt to avoid dehydration.

Tranopelta sp. is a smaller ant, yellow in color and it is found in young plantations (a year or less). It does not perform a transportation of the scales as active as *Selenopsis,* but it does clean the sugary excretions and provide and adequate environment for the scale's development.

Identification of closterovirus

Samples were sent to Dr. Hu in Hawaii, but the result is not available yet.

Ongoing Activities

- Organize and analyze data of the initial plantation
- Identify *Phyllophaga* species
- Collect data on annual rainfall
- Determine the presence of virus in the area

The statistic design used was DBCA with Medias Repetidas through Time and as covariable, initial number of mealybugs was used. For the data analysis was used "Statistical Analysis Systems" SAS version 6.12.
The spraying of the treatments was done using a manual spraying bomb. Mortality was monitored each 48 hours during 14 days.

Field investigation in initial plantation:

This essay was done on a new plantation. The spraying of the products began when the plants had 2 months from sowing. The land plots were established in La Ceibita (660 m.a.s.l.), 7 Km apart from Santa Cruz de Yojoa.

The same treatments of the bioassays (Table 1) were tested, except the Surfactant, and the lime was used applied to the soil in dosage of 1400 pounds per hectare. A DBCA in Divided Plots was used as statistical design, were the main plots were treatments with or without lime applied to the soil and the secondary plots the products shown in Table 1. Fifty pineapple plants were considered as experimental units of the useful area. The sampling was done by direct visual observation in the leaves' bottom of the 50 plants of the experimental units to determine the presence of mealybugs.

Overview of South American Site in Ecuador

Site Chair: Roger N. Williams[1]
Sierra Site Coordinator: Patricio Gallegos[2]
Littoral Site Coordinator: Carmen Suárez[3]

Description of the Collaborative Program

A. This is the second year of activity at the South American Site/Ecuador. A total of 8 regular activities and two special projects were conducted. This site operates under a Memorandum of Understanding with INIAP, the research arm of the Ministry of Agriculture in Ecuador. Two site coordinators manage activities under the CRSP because the crops we work with are primarily located in two locations. Patricio Gallegos currently serves as the Site Coordinator of the Sierra (higher elevations). He is located at the INIAP Experimental Station at Santa Catalina near Quito and coordinates activities with potato and Andean fruits. Carmen Suarez currently serves as Site Coordinator for the Littoral (lower elevations). She is a researcher at the INIAP Tropical Experimental Station at Pichilingue near Quevedo and coordinates activities with plátano (plantain or cooking banana).

Cooperation between the two Site Coordinators facilitates institutional communications and collaborations. Each Activity (research project) has a leader that is responsible for interactions with their respective coordinators and cooperators.

B. Activities in Year 6, second year for the South American Site, were funded primarily through USAID IPM CRSP and collaborating institutions: INIAP, PROEXANT, CIP, FORTIPAPA and the U.S. Universities that are involved.

C. Even though research activities at the South American site are relatively recent, we are developing collaborative ties with several local organizations which are well established in Ecuador: CIP (Centro Internacional de la Papa), FORTIPAPA, PROEXANT, and an Inter-CRSP with the SOILS CRSP. Through student employees and especially graduate students we are also developing collaborative ties with the local Universities.

D. Jointly developed collaborative research plans have allowed us to buy into ongoing research programs and initiate new projects with joint funding. This approach has been used with the three primary crop areas on which research was initiated, (plantain, potato and Andean fruits) and has been particularly effective in Year 6. Since trained personal were already on board, we were able to take advantage of their skills to conduct collaborative investigations. This system will allow us to provide deliverables at a much faster pace.

IPM Constraints Addressed

A. The South American Site/Ecuador is addressing some of the known production constraints of some key horticultural staples in the area. Late blight of potato is a worldwide limiting factor in potato production. In Ecuador we have been selecting resistant potato clones with horizontal (durable) resistance. Activities in clonal selection are currently underway, and several lines have been selected for use in future research activities. Andean fruits are a source of healthful food for the entire nation, and have potential for export. However, mites, nematodes, fruit and stem borers, and especially diseases such as *Fusarium* vascular wilt have made it difficult to produce these fruits economically. We feel that great strides are being made in this area. Plantain is a staple food for people living in the littoral (lowland Tropics). In fact, plantain is a substitute for potatoes at the lower elevations. Disease and pest problems of plantains are thought to be similar to those of bananas. A survey of pests and diseases is helping define the critical research needs of this crop as are research activities and evaluation of various IPM practices for use in plantain.

B. Substantial progress in the use of safer compounds for the control of insects has been made. Research on the use of biorationals to control the Andean potato weevil has given rise to two potential candidates. Laboratory and field studies have confirmed the efficacy of Spinosad and Naturalis-L. They both are biorational insecticides, which may have important roles in the future control of the Andean potato weevil. Research during year 6 has led us to do more detailed investigations with Spinosad. It has been found to be a useful IPM tool to potato farmers. These are both new compounds which represent a major step in pesticide safety to humans and the environment.

One objective of the research in the plantain pest-survey is the identification and quantification of nematodes associated

[1] Ohio State University
[2] INIAP, Santa Catalina
[3] INIAP, Pichilingue, near Quevedo

with this crop. This is the first such investigation of its kind that we are aware of. Unfortunately the pesticide safety manuals being developed by the Ministry in cooperation with IPM CRSP have not been developed.

C. The results of plantain research will have benefits in Ecuador and to the region. The U.S. and Europe are becoming major importers of plantain and as production increases relative prices will encourage and expand global acceptance.

Potato research to find clones long term resistant to late blight and that are highly acceptable to consumers will benefit Ecuador, the region and the world. This is a top priority for North America as well as for our neighbors in South America and steady progress is being made.

Institution Building

A. We have been able to supply INIAP researchers with some of the new biorationals that are being approved by EPA for food crops use in the U.S. Two of these have been tested and appear to have promise in the control of the Andean potato weevil. This is a case where only a small amount of foliage is treated and put under a cardboard and this acts as a trap, which is capable of controlling the weevil.

B. Several Ecuadorian undergraduate and graduate students are presently being funded through various activities of the IPM CRSP for their Independent Study theses and their MS theses from Ecuadorian Universities. This system is helping the CRSP and the Universities to get research accomplished and to train individuals in applied agricultural research.

C. One of our researchers on the Andean fruit project has taken a short course on diseases at Turrialba Research Center in Costa Rica.

D. Our student-training plan is to use as many Ecuadorian students as possible in country in conducting the various activities. In addition, plans have been made to allow two junior researchers have research internships in the US beginning in the summer/fall of 2000. They are presently studying English. We are hopeful a third candidate, a senior researcher, will start on his Ph.D. at Ohio State in 2000.

Networking

We conducted our first one-day Mini Workshop on October 23, 1998. This workshop reviewed results for the first year activities and also reviewed plans for the second year activities (Yr. 6) which began September 29th. Over 30 people including most of the investigators of the IPM CRSP from Ecuador and US universities attended this Workshop. We were fortunate to have Bob Hedlund and two representatives from the INIAP administration and several visitors from other agencies in attendance. We plan to make this an annual meeting which will gradually grow into a larger forum to include students, researchers, extension workers, agricultural buyers and suppliers.

Research Accomplishments

Even though this is a new site, at which funding actually begun in March 1998, we have been able to make some significant accomplishments. Through working with researchers that were involved in related work and by collaborating with established agencies, great strides have been made in the control of the Andean potato weevil by finding effective biorational insecticide that replace some of the traditional, more toxic materials. Several studies on Andean fruits have been centered around the mayor mite and disease problems of babaco (Mountain Papaya) and surveys have been conducted to determine the organisms involved. *Fusarium* vascular wilt is the most important disease. It can kill up to 100% of the plants in a commercial orchard. Control of *Fusarium* has been under investigation and the most effective treatments are reported in this annual report. Seed piece rot, causes by *Pythium* spp., is the second most important. Mite control strategies for babaco in the greenhouse have shown that their are several effective materials available. One of the most effective compounds was a botanical soap. We have defined the dosage and application timing for the control of the Andean potato weevil. We have demonstrated that the Central American Tuber Moth can be controlled with a virus (biological agent) originally found in the region. In addition, *Bacillus thuringiensis* is effective in controlling the moth. Several potato cultivars have been identified that are acceptable to consumers, and have strong (horizontal) resistance to late blight. A survey of the incidence and importance of the major potato diseases has also been conducted. Farmer field schools are being conducted, and will enhance our abilities to introduce integrated crop management practices emphasizing control of the Andean potato weevil. The survey conducted on plantain has provided information that will aid in the biological control of important insect pests through natural enemies.

Development of IPM Programs for Plantain Systems in Ecuador

Investigators: C. Suárez, Danilo Vera, Iván Garzón, Raul Quijije[1]; Carmen Triviño[2], Roger Williams, Mike Ellis[3]
Collaborating Scientists: Karina Solis[4]; Miriam Arias[5], Wimper Vera[6]

Abstract

IPM components used to control banana pests and diseases were evaluated to form the framework of an IPM program for plantain pest and diseases. Both crops are attacked by the same pests; however, levels of pest resistance, and management practices, and type of farmers are very different. Production regions also have some climatic differences which influence pests and diseases. Main constraints for plantain production are black sigatoka disease caused by (*Mycosphaerella fijensis*), the black weevils (*Cosmopolites sordidus* and *Metamasius hemipterus*) and several species of nematodes (mainly *Radopholus similis*). Plantain is managed like a perennial crop, and the lack of management practices, combined with successive attacks of pests results in a weakened plant that is readily infected by *M. fijensis*.. No or very little research has been conducted with plantain. Disease control tactics recommended to farmers are the same as those recommended for banana, a high input crop.

Two experiments were set up during 1999. One examines the rehabilitation of existing plantain plantations using components of the banana package that may be used economically by plantain farmers. The other is developing IPM procedures for newly established plantings. Both experiments have been set on a farm within the main plantain production area (El Carmen). The rehabilitation experiment is a randomized complete block design with 4 treatments and 4 replications. Treatments are: 1.) technical package recommended (but seldom used by farmers) by the main plantain buyer (export company) of the area; 2.) IPM practices with a reduced fungicide program, modified from above; 3.) IPM practices without fungicides, and 4.) a control treatment using current grower practices with no fungicides. From March to September, a disease index that takes into account total number of healthy and functional leaves, the youngest infected leaf and the level of disease was used to evaluate treatments every other week on 10 plants per experimental plot. Data are also taken on numbers of weevils trapped on pseudostems of harvested plants. Analysis of soil and roots at the start of the experiment and six months later was also conducted to establish the type and populations of nematodes.

For new plantings, the three factors considered were: 1.) 2 plantain varieties; 2.) 2 planting systems, and 3.) 2 levels of management, resulting in a total of 8 treatments. Randomized blocks with 4 repetitions on a split plot design is being used. Data will be collected in a similar manner to the former described above, however, another model is being used to classify the disease index.
The experiments are still in progress and some differences have started to develop. Weekly sanitary pruning and removal of infected leaves plus monthly fungicide applications seem to be more effective than other treatments, in reducing disease. Well managed plots appear to suffer less damage from weevils and nematodes. A better comprehension of the damage caused by pests and diseases is being derived from these trials.

On the newly established planting, results indicate that both varieties are susceptible to black sigatoka. To date, no insect or root damage is significant in any of the treatments.

Objectives

1. Evaluate the insect and disease control programs originally developed for banana, and to identify IPM components that can be successfully transferred to plantain under on-farm conditions.

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2. Identify and measure factors related to incidence of major pests and black sigatoka disease, in relation to phenology of the crop and its major production areas;
3. Determine the economic benefits of developing and implementing an IPM program for plantain.

IPM constraints

The incidence of pests and diseases is the main reason for low plantain production in Ecuador. Plantain (*Musa* sp, genome AAB) is normally more resistant than banana (*Musa* sp, genome AAA) to pest and diseases. Therefore, before the arrival of black sigatoka in the late 70's, little or no control measures were being used; farmers were harvesting around 11 tons/ha/year. Twenty five percent of the production was exported to the USA and other Latin American countries. After the appearance of black sigatoka, many production areas were abandoned. The production area was reduced from 72,000 ha in 1970 to 60,000 ha in 1984. Banana growers were very concerned about inoculum build up in abandoned plantain plantings. Since plantain is a major part of the Ecuadorian diet and a cash crop for poor farmers in the El Carmen-Santo Domingo region, more production areas were established, and by 1994 there were approximately 100,000 ha. However, current yield is 2 tons less (9Tm/Ha) than before Sigatoka disease was introduced.

Micosphaerela fijensis, the causal agent of black sigatoka is a very aggressive pathogen on all *Musa* spp, including plantain. Its establishment on the crop not only affects yields, but also enhances other constraints of plantain. The lack of sound agronomic practices results in weakened plants that are much more susceptible to black sigatoka disease, and pests such as the black weevils (*Cosmopolites sordidus* & *Metamasius hemipterus*), nematodes and bacterial rots (*Erwinia* sp.).
There are two main differences between banana and plantain that have to be taken into account before developing control strategies. First, banana planting systems are designed for high input technology, and an internal fungicide program is only part of the program. Irrigation improved drainage, and fertilization is also considered. Plantain on the other hand, has always had a very low level of agronomic management. Even farmers that produce it for export have a low input cropping system. Due to pressure from black sigatoka, production practices developed for banana growers have been introduced into the plantain production system. However, farmers are reluctant to apply these practices because of costs, and (according to the farmers) they are not very effective.

A second important difference is that plantain is consumed at different stages of development as well as maturity, while bananas are eaten only when mature; therefore chemicals applied to plantain may not have enough time to degrade, resulting in higher residues on the fruit. The use of integrated disease management programs, with minimal pesticide use should be adequate for plantain farmers in Ecuador.

Another serious constraint to plantain production is the application of the Glyphosate herbicide, one of the few agronomic practices commonly used by growers. Excessive use of glyphosate is damaging suckers and sucker emission; therefore, alternative control measures for weeds are needed.

Research Methods

Two experiments were established based on the information gathered from farmers and extension workers obtained from a 5 year study. One is for rehabilitation of old plantain plantings that still have some potential for yield; and the other is for reestablishment of plantings that have become totally non productive.

Both experiments were established in finca Santa Marianita (Carranza family), San Agustin parish in Canton El Carmen, Manabi province (42 Km west of Santo Domingo).

Experiment 1. Rehabilitation of plantings

This experiment was established in January 1999 and has been running for 8 months.

Characterization of the experimental field

The experimental field is a plantain plantation which is 18 years old. The plots have lost their original design and plants are unevenly scattered with concentration of plants in some areas and empty spaces in others. Plants have hanging dead leaves that serve as a source of fungal inoculum. Many plants fall over due to black weevil damage and root destruction. Weeds covered the plots. *Euphorbia heterophyla* (lechosa); *Bidens pilosa* (cadillo morado) and *Priva loppulaceae* (pega-pega) were the predominant weeds. Black sigatoka was rampant and many plants close to harvest had only 1 or 2 functional leaves. Closer examination of many plants showed severe damage of the corm by the black weevil (*Cosmopolites sordidus*).; and of the roots, apparently by nematodes (mainly *Radopholus similes*). Farmers were harvesting every 2 weeks for the local market and for export they have to sell 2 and 2.5 bunches to be equivalent to one bunch from a healthy plant.

Experimental design.

A randomized complete block design with 4 treatments and 4 replications were used. Due to the uneven distribution of plants, each plot consists of an area of 375 m2 (25 x 15 m), making blocks (reps) 1500 m2 . The treatments are:

1.) Technical package recommended (but not often used by farmers) by the main buyer (export company of the area, the Noboa Company).

2.) IPM practices with a reduced fungicide program, modified from above.
3.) IPM practices without fungicides.
4.) Growers currently used minimum technology.

Description of treatments.

The "package" recommended by Noboa included: 1.) leaf pruning, or weekly removal of leaves with more than 50% of the area infected by sigatoka; 2.) six cycles of fungicide applications (same as for banana). This involved monthly applications of Benomyl, 280 g/ha –Tilt, 0.4 lt/ha- Calixin, 0.6 lt/ha. in 2 successive sprays each, mixed with agricultural oil. 3.) weed control based on hand weeding followed by glyphosate once or twice a year just before and after the rainy season. More frequent applications are made when plantains have a good price; 4.) elimination of water suckers, leaving an average of 5 suckers per production unit; and 5.) harvests every 15 to 20 days.

The IPM package under evaluation includes: 1.) phytosanitary leaf removal. Every 15 days, infected leaves are cut and placed with the lower side towards the ground to reduce ascospore dispersal; 2.) 3 cycles of fungicide application (one each of Benomyl – Tilt and Calixin, with doses and methods recommended by Noboa) applied every 45 days, immediately after leaf removal; 3.) hand weeding as needed to keep weeds under control. The orejuela was allowed to spread covering the ground. This was complemented with localized spraying with glufosinate-ammonium (Finale, 150 cc/ha). A 0.50 m area around the production unit was kept free of weeds and leaf residues (corona); 4.) all dry leaves and leaf stalks are eliminated, and weak and unnecessary suckers are removed every 7 weeks.; 5.) plots were replanted with 1.2 m high and 2 kg weight suckers, to reestablish plant populations and improve production efficiency. 6.) Nitrogen was applied (88g Urea/plant) according to need established by foliar analysis around daughter plants and new plants; 7.) plants were kept free of foliar pests and monthly trapping of black weevil was conducted to lower pest populations; 8.) plants were harvested every 15 days. IPM practices as described in (b) but no fungicides.

Control plots using current grower technology which consists only of weed control by hand followed occasionally by application of Glyphosate once a year. Plants are harvested every 15 to 20 days.

All border plants are kept clean through leaf removal and spraying fungicides.

Response variables

Due to the variable number of plants on each plot, data are taken on 10 plants/treatment/repetition. The following data are taken every 15 days:

1. Black sigatoka incidence and severity. Following Stover's method, modified by Gauhl* a disease index is calculated that takes into account infection (on a 6 point scale: 1= 10 streaks-leaf; 2 = >5% through 6 > 50% leaf area infected) on every leaf of a plant with the exception of the "candle" (unopened leaf), and those that are broken down. A combination of disease incidence and the number of infected leaves/plants give the severity of the disease.
2. Number of leaves per plant. As a relation between the total number of leaves counted and the number of plants under evaluation (10 in this trial).
3. The youngest infected leaf. This gives an indication of the progress of the disease. It is an average of the total of the youngest leaves with visible symptoms from the plants under evaluation. The younger the infected leaf, the larger the incidence (and severity) of disease.
4. Black weevil and nematodes. Monitoring of insect and nematode populations was initiated before applying treatments and repeated at various intervals throughout the study.
5. Variable cost (US$). All labor and materials (mainly agrochemical) used on every treatment being recorded and priced. They will be used as a reference to calculate the cost/benefit ratio of each treatment after one year of harvest.
6. Harvest. Number of plantain bunches and weights per plot. Production per plot is being recorded since the beginning of the trial.

Research Results

Black sigatoka disease

Figures 1 and 2 show the development of *M. fijensis* on banana and plantain, respectively, during 1999 in the humid tropics of Ecuador. A commercial banana plantation 42 Km North of Pichilingue was used to record the disease. The plot of plantain used was at the Experiment Station. Weekly removal of the infected leaves, as well as all the agronomic practices were applied but fungicides were applied to either crop. Evaluations for this study were conducted immediately before every pruning. Both crops showed a very similar pattern of infection from March to September,99. The main phenological difference between the two crops is the total number of leaves. The infection process seems to be very much influenced by humidity. As shown in fig. 2, the disease index decreases as the dry season progresses, but increases in September as aerial irrigation is applied to the plots in Pichilingue. In La Laguna, there is only subfoliar irrigation; therefore, the infection curve keeps decreasing steadily. Figures 3 and 4 show disease development in terms of disease index and the youngest leaf infected on every treatment in the rehabilitation trial. In this case, the pattern reflects another factor that seems to

*MARIN V., D. & ROMERO C., R. 1992. El combate de la Sigatoka negra. Corporación Bananera Nacional, S. A. Costa Rica. Boletín No. 4, Departamento de Investigaciones. 13p.

influence infection which is the agronomic well being of the plantation. In general, the disease index (Fig. 3) shows a tendency to increase from the rainy to the dry season (from 25-30 to 35-40%). The El Carmen area is more humid than Pichilingue. This year (after the year of El Niño), weather conditions remain atypical, with lower temperatures than expected and unusual rains around weeks 14 to 15. Some differences appeared between treatments. Conventional recommended management, with weekly leaf pruning (T1) provided the lowest disease index, followed closely by the IPM program with fungicides (T2). The effect of leaf pruning is more conspicuous from week 28 onwards, when disease increased in all treatments, but disease in those with weekly pruning (T1) remained well below the other treatments.

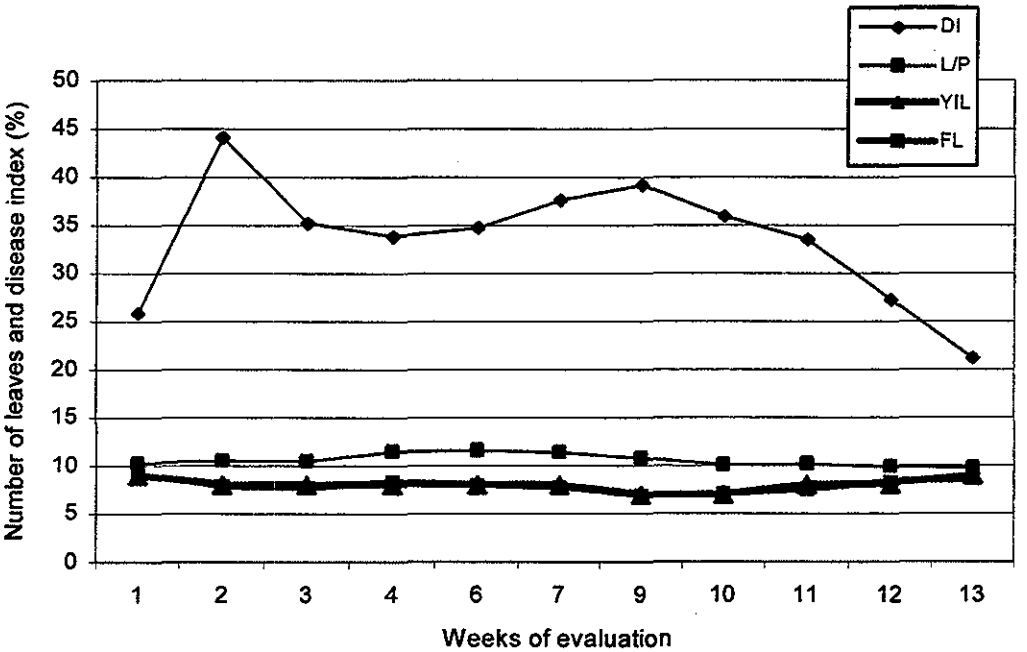

Figure 1. Evolution of the infection index for *M. fijensis*, total and functional leaves and the youngest infected leaf per plant of banana, var Cavendish from March to September, 1999. La Laguna. INIAP-IPM CRSP. 1999.

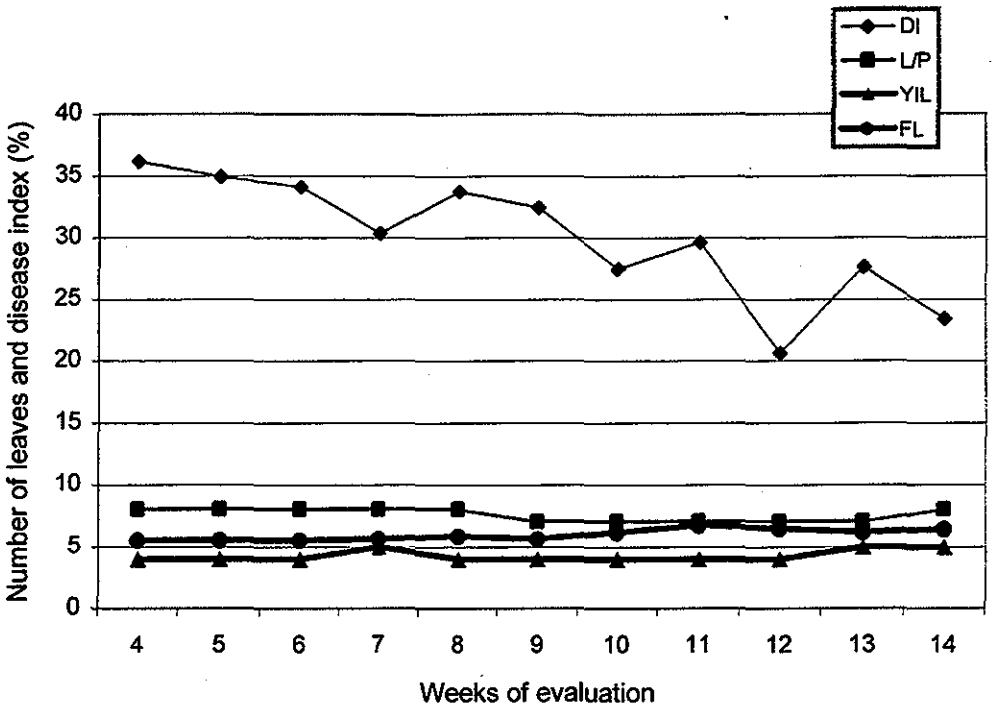

Figure 2. Evolution of the disease index for *M. fijensis*, total and functional leaves and the youngest infected leaf per plant of plantain Harton type horn from March to September, 99. EETPichilingue. INIAP-IPM CRSP. 1999

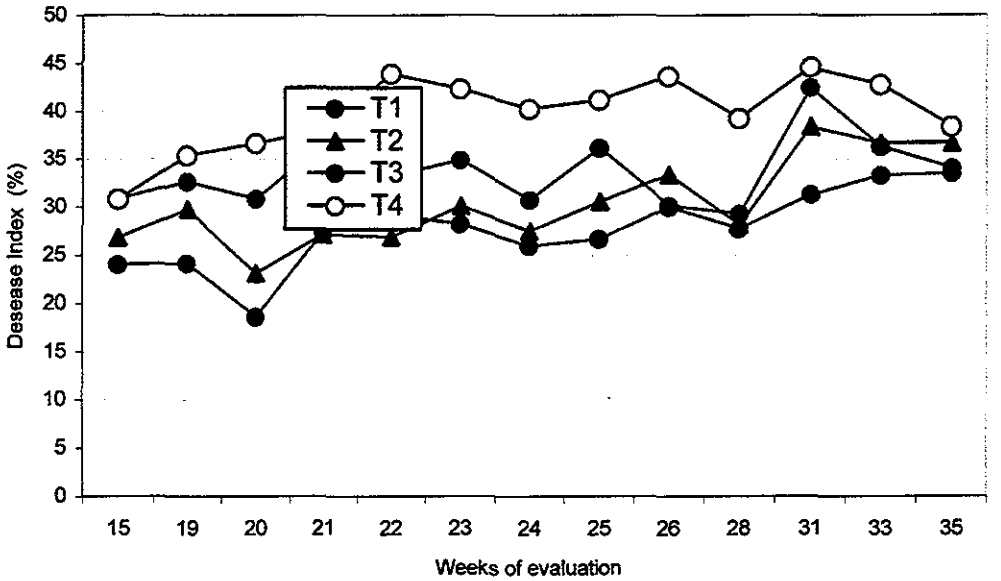

Figure 3. Evolution of infection by *M. fijensis* in young plantain plants. El Carmen. Rehabilitation trial. INIAP-IPM CRSP. 1999

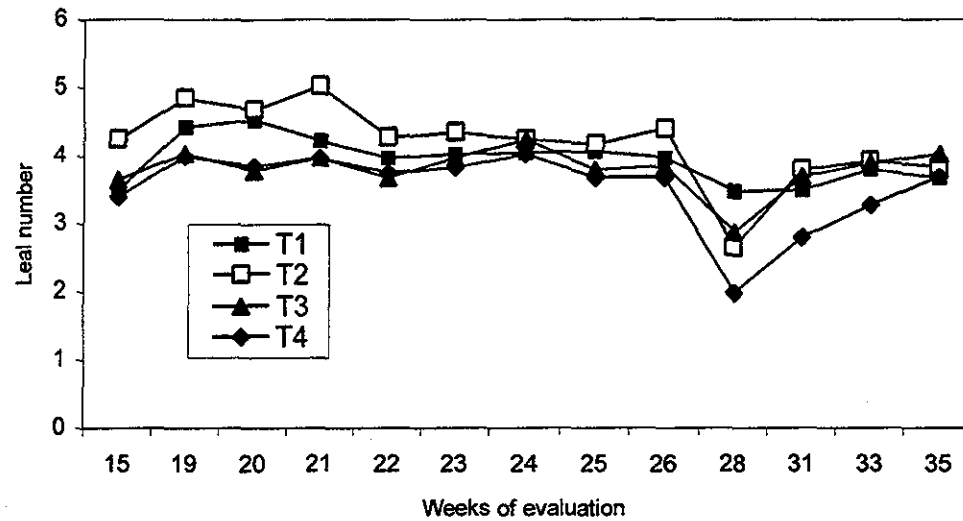

Figure 4. Evolution of incidence of *M. fijensis* on the youngest leaf of plantain suc. El Carmen. Rehabilitation trial. INIAP-IPM CRSP. 1999

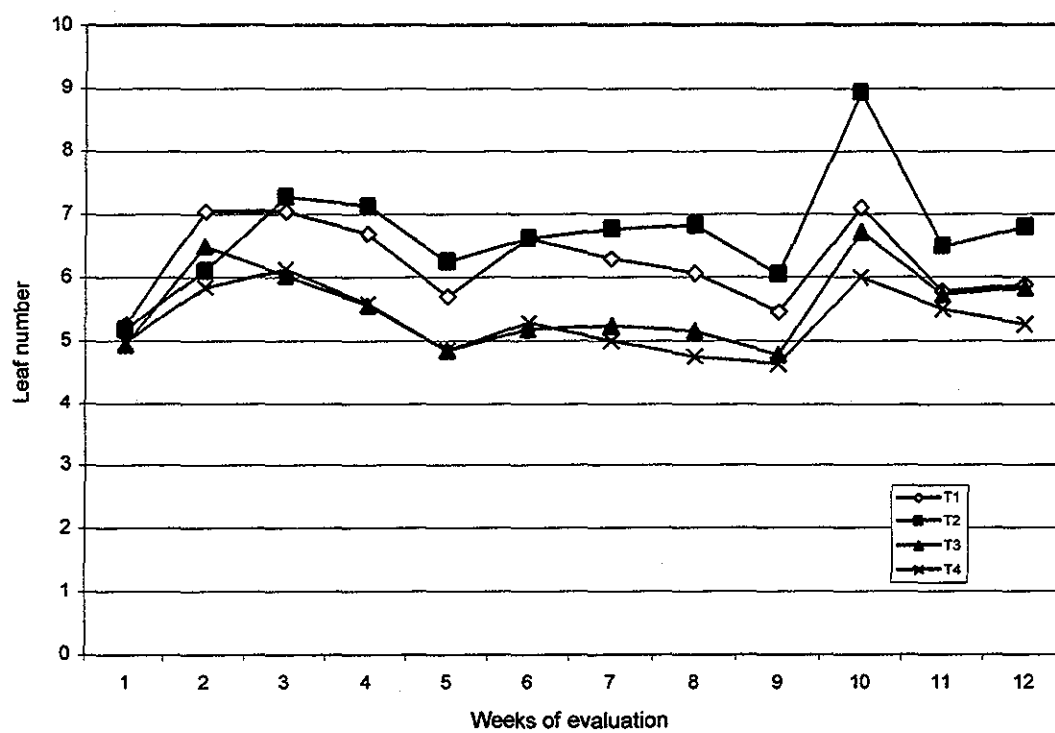

Figure 5. Average number of functional leaves in plantain. El Carmen. Rehabilitatión trial. INIAP-IPM CRSP. 1999

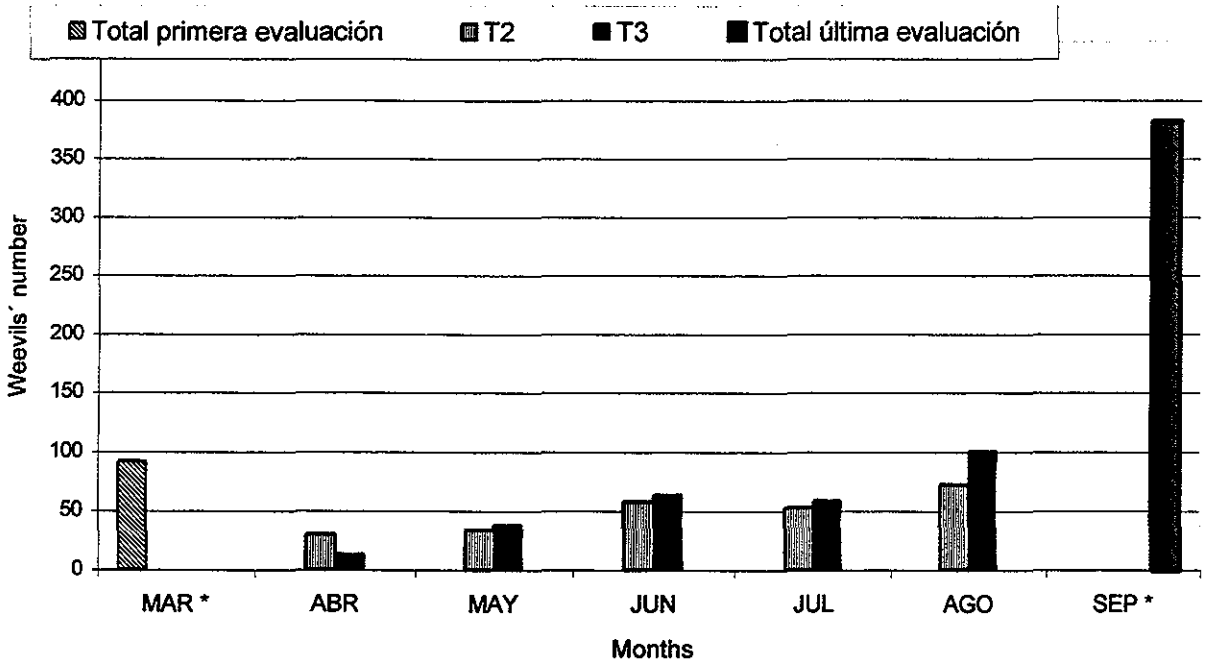

Figure 6. Weevils numbers collected from March to September in the rehabilitation trial of plantain. El Carmen. INIAP-IPM CRSP. 1999

Observing treatments 2 and 3 at Weeks 15 to 26 shows the effect of the fungicide. The IPM treatment without fungicide (T3) has a higher disease level than T2 (IPM + fungicide). This difference remained throughout the experiment. On the other hand, It seems there is negative effect of leaf surgery on T3, because by September, this treatment shows the higher youngest diseased leaf (No.4) but as well the lowest number of leaves per plant (Table 1).

The effect of treatments on the disease became visible four weeks after the establishment of the trial (April 16th) and is showing that differences of the index between them were highly significant (Table 1).

Table 1. Disease index, youngest diseased leaf and total number of leaves per plant at three different dates of the yield cycle of plantain. INIAP-IPMCRSP. 1999

September, 1st,99				June 23rd,99			
		Leaves				Leaves	
Treatments	disease index**	Youngest sppotted (ns)	Total/plant*	Treatments	disease index**	Youngest sppotted (ns)	Total/plant *
Conventional	33.56 c	3.67 a	7.45 b	Conventional	26.76 d	4.8 a	8.33 ab
IPM+ Fung.	36.71 b	3.85 a	8.18 a	IPM+ Fung.	30.54 c	3.75 a	7.72 c
IPM-No fung.	34.06 c	4.03 a	6.6 b	IPM-No fung.	38.72 b	3.92 a	8.40 a
Farmer's	40.67 a	3.7 a	7.98 b	Farmer's	41.21 a	4.35 a	7.93 bc

April, 16th,99			
		Leaves	
Treatments	disease index*	Youngest sppotted (ns)	Total/plant (ns)
Conventional	24.05 b	3.75 a	6.37 a
IPM+ Fung.	26.86 ab	4.25 a	6.65 a
IPM-No fung.	28.44 ab	3.65 a	6.75 a
Farmer's	30.86 a	3.40 a	6.52 a

Numbers with the same letter within columns do not differ significantly (ns) using Tukey's mean separation test ** P = < 0.05 * P = < 0.01

Although there was no significant difference between the youngest infected leaf at any stage of the disease, Fig. 4 shows that in those treatments with fungicides (T1 and T2) the youngest spotted leaf remains one value over the other 2 treatments during the epidemic (rainy) season. In the same way, Fig. 5 shows the effect of fungicide application on the number of functional leaves. T1 and T2 with fungicide keep more functional leaves throughout.

Weevils and nematodes

After black sigatoka, the main production constraint found on plantain were two weevils. These include the banana root borer, *Cosmopolites sordidus* and the striped weevil, *Metamasius hemipterus*. Recommended control measures consist of good agronomic practices plus traps made with psudostems of harvested plants. Insecticide (Carbofuran 10 G) is sometimes added to traps. This type of control was used in treatments 2 and 3 (IPM practices). Figure 6 shows total counts of both species of weevils at the start of the trial (March) and in September, as well as monthly recordings on treatments 2 and 3. Apparently, the traps and the management practices being applied were not reducing populations of the weevils. As shown in the figure, populations were increasing steadily from March to September.

In relation to nematodes, there is little information for plantain in Ecuador. Farmers make management decisions based on what is known for bananas. Table 2 shows the nematode situation on this trial. The most conspicuous feature is the percentage of healthy roots found in all plots 8 months after initiation of the experiment. It is important to note that no specific treatments for nematodes were applied. The importance of nematodes in plantain production needs further study.

Table 2. Evaluation of nematodes on the plantain rehabilitation experiment. INIAP-IPMCRSP. 1999

Initiation of the trial
March, 17th, 1999

Treatments	Healthy roots %	Nematodes in 100 g of roots		
		Meloidogyne	*Helicotilenchus*	*Pratylenchus*
T1	18	0	0	0
T2	4	1000	0	0
T3	3	750	750	0
T4	20	2000	1000	0

5 months after treatment aplication, in
Aug.19, 1999.

Treatments	healthy roots %	Nematodes in 100 g of roots				
		Meloidogyne	Helicotilenchus	Tylenchus	Dorilaimus	Rabditis
T1	72	187.5	450	0	100	150
T2	74	400	450	50	0	150
T3	69	262.5	162.5	0	0	150
T4	70	800	350	0	0	0

Another important feature was that by September species of some beneficial nematodes (*Tylenchus, Dorilaimus* and Rabditis spp) were present on treatments 1 to 3.

Radopholus similis, *Pratilenchus coffea* and *penetrans* and *Helicotilenchus* sp are the most important root lesion nematodes reported for plantain. In this study only *Helicotilenchus* was present and the root knot nematode *Meloydogine* sp., but since the root system did not present much damage, it was not considered necessary to apply any nematicide. The extensive damage of the root system found at the beginning of the experiment seemed to be more related to corm destruction by the weevils. Apparently, treatments applied at the start of the experiments (general cleaning and weeding) was enough to control both the weevil and nematodes damage.

Harvest and variable costs.

Table 3 shows production in terms of bunches collected from plots and average weight/bunch/treatment coming from each experimental plot, although no differences can be seen.

Lower yields of T2 and T3 in this period are a result of suckers elimination as part of the management of the trial. As stated before, the effect of treatments may only become apparent by the end of 1999.

Table 3. Yield and variable cost per treatment. Rehabilitation trial. El Carmen. INIAP-IPMCRSP. 1999

Treatments	Yield (Kg.)	Total costs (USD $)
T1	569.4	95.00
T2	477.0	128.00
T3	482.8	108.00
T4	553.9	53.00

Variable costs/treatment are shown in the same table. In this case we have recorded hand labor and agrochemicals used on each plot. Differences between T1 (where more fungicide was used) is due to the cost of the herbicide.

Experiment 2. Establishing plantings of plantain.

This experiment was established in April, 1999 on the same Carranza's farm. Two areas were used, one is an abandoned plantain plantation (El Rodeo) and the other is an area where the grower intended to convert old pasture to plantain (La Carretera). Both plots were cleaned and crop residues left for about a month to decompose. Soil analysis was done during this period and showed low levels of N and Mg and medium levels of P and K. This was used to calculate fertilization at time for planting.

Experimental design

The design was a randomized complete block with 4 replications, arranged in a split plot manner with varieties and planting systems as main plots and level of management as subplots. Factors evaluated were:

a. Varieties. "Common Barraganete" (plantain Harton) and "Dwarf Barraganete"; both belonging to the subgroup of *Musa* sp. AAB. The second variety has recently been introduced by the Corporacion PROEXANT. They claim it is resistant to black sigatoka. This plant reaches 2 to 3.5 m in height compared to 3 to 5 m of the common Barraganete. The smaller variety permits higher planting densities and is easy to spray.

b. Planting system. Plantain is normally planted at 3 x 3m spacing between rows and plants in Ecuador even when it is intercropped with other crops like cocoa and coffee. Reports from Colombia and Central America mention that a planting system of double rows allows both higher densities and better control of Sigatoka disease. Each variety was planted both in single (2.5 x 2.5m) and double rows (2.5 x 0.5) with 3 m between each pair of rows.

c. Management. Over each variety and planting system, treatments were established to have two types of management. An IPM program as described for treatment 3 in the rehabilitation trial and current grower technology do not use fungicides in either management strategy in order to test for resistance to disease.

The combined factors gave a total of 8 treatments. Each treatment has 12 plants for evaluation.

Response variables.

The same variables as in the rehabilitation trial will be evaluated. For black sigatoka incidence and severity, a modified scale is being used. The modified scale, considers only the number of leaves, total, healthy and functional (those with an incidence of the disease from 1 to 3 in the Stovers' scale of 6 points).

Research Results

Figure 7 shows the development of the variables considered for black sigatoka, during the short period of establishment. The El Carmen area has high humidity throughout the year. This year (1999) seems to have been similar in terms of humidity, with rains at the beginning of September, but is very atypical in relation to temperature as it has been 3 to 5 degrees below normal. In spite of nonoptimal conditions, the disease continues infecting leaves, probably due to high levels of inoculum from nearby plantations without any disease management program.

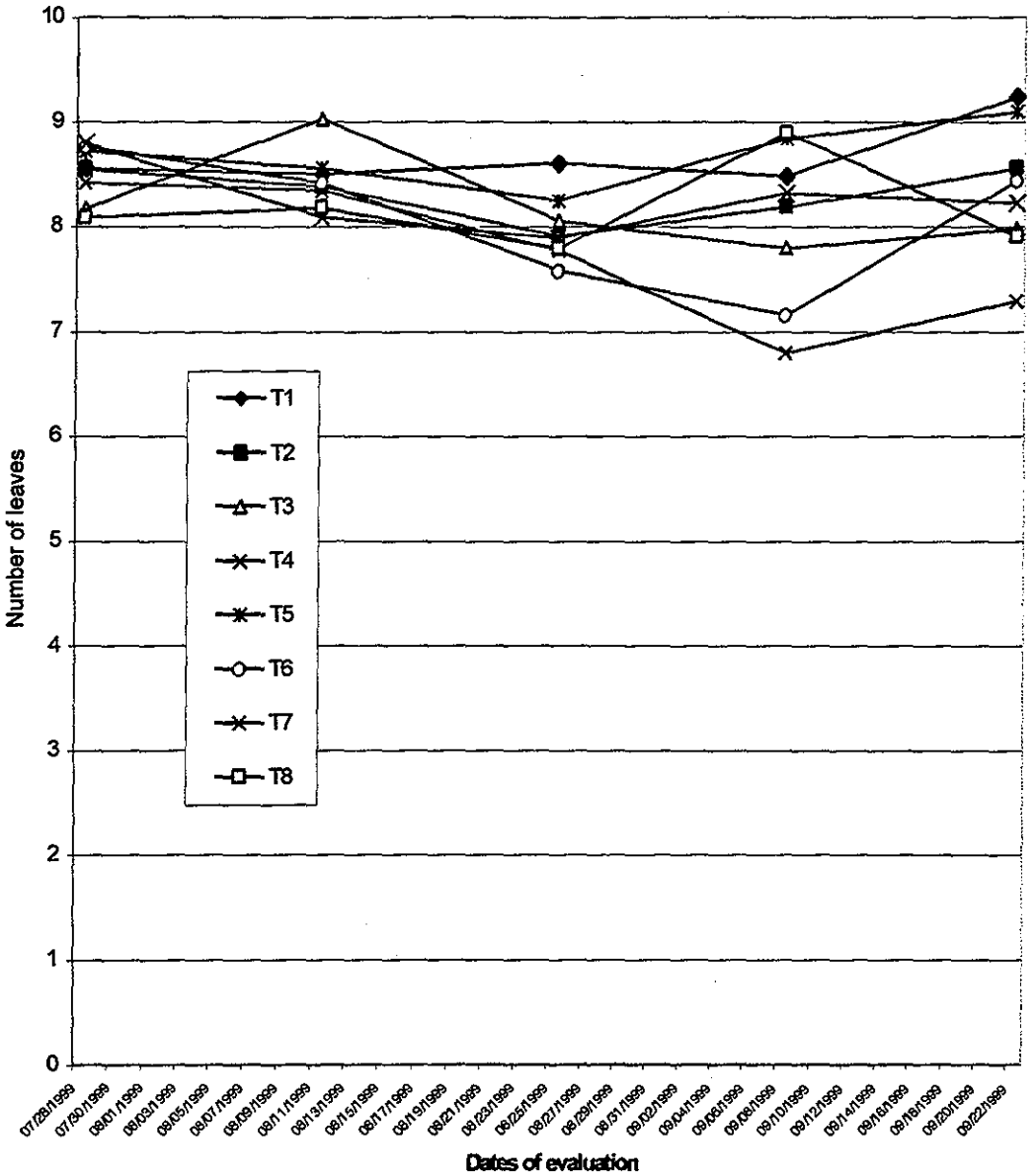

Figure 7. Average number of total leaves/plant on new plantings of plantain. El Carmen. Renovation trial. INIAP-IPM CRSP. 1999

Some treatment differences became apparent in September. Treatment (T) 5 (common Barraganete single rows, high level of technology) shows the largest number of healthy leaves (fig. 7), while T2 (B. dwarf Barraganete single row, low management shows largest number of functional leaves). However more time for observation and more data collection is required before drawing any conclusions on this trial.

Networking Activities

Workshops

- On October 23, 1998 a workshop for the first year activities was held at Santa Catalina. Over 30 people

including most of the investigators of the IPM CRSP from Ecuador and the US attended this Workshop. We were fortunate to have Bob Hedlund and two representatives from the INIAP administration and several visitors from other agencies in attendance.

Publications and Presentations

- Dr. Suarez presented a research report on the Plátano Project to the Technical Committee in May 1999 at Purdue University.

Project Highlights

- The most damaging nematode to bananas, *Radopholus similis* was not encountered in our trials. Very little root damage was noticed in the experiment from other species, therefore, no nematicide was used.

- The banana root borer, *Cosmopolites sordidus* and the striped weevil, *Metamasius hemipterus* are more abundant than initially anticipated.

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Survey of the Incidence and Importance of Potato diseases in Ecuador

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Collaborators: G.A. Forbes[3], Julián Pucha[1], Charles Crissman[2]

Abstract

This is the first report of this activity. During the initial stage of this activity, a literature review on soil-borne diseases of potato in Ecuador was done. Four areas of research have been initiated. The first involves the bating of soils taken from Carchi (Northern Ecuador) for nematode and root pathogens. The second involves the investigation of the effects of soilborne pathogens on yield. This will be done with soils taken from Carchi which have been placed in pots and into which clean potato seed was sown. The third area of resarch involves the in-field evaluation of potato roots for disease symptoms and subsequent isolation of soilborne pathogens. For this experiment, fields were selected to have variability in cropping history and to take advantage of the Soil CRSP, and ECO-Salud work already going on in Carchi. The fourth area of research involves the evaluation of isolates of P. infestans collected from three main potato producing regions in Ecuador. While all of these research projects have been intiated, only preliminary data are available at this time. Nonetheless, some of the results are significant. Little research has been done on soilborne pathogens of potato in Ecuador and most of this has focused on diseases of tubers. These are related but not necessarily equivalent to diseases of roots. The nematode and root disease baiting experiments have not yet produced data. In-field Evaluations in Carchi demonstrate root disease symptoms in all areas surveyed. The most commonly isolated pathogens at this time are Rhizoctonia spp. and Pythium spp. These data are preliminary. Over 100 isolates of P. infestans were collected in the South and Central parts of the country. Collection in the north is under way. Preliminary evaluations indicate that there has not been a change in the pathogen population in the past 5 years.

Objectives

To assess the incidence of main potato diseases caused by soilborne pathogens in Carchi

To determine the importance of cropping history on soilborne diseases.

To initiate studies relating severity of soilborne diseases to yield.

To update information on the *P. infestans* population structure in major potato growing areas of Ecuador.

IPM Constraints

Soilborne disease can limit production (emergence, wilting) and especially reduce potato tuber quality.

Research methods

Survey of soilborne diseases

A survey was conducted to fill the gaps posed by lack of consistent information on the nature and place where specific potato diseases occur in the country. The survey was initiated in the province of Carchi to link with the soil CRSP project that is being implemented there, and take advantages of a great deal of background information that has already been gathered. The survey took place in the four main potato areas of the province: Santa Marta de Cuba,.San Gabriel, ...etc. In total, 35 fields were sampled. These were chosen primarily because of a long history of potato cropping. Ten samples were taken in a 'W' pattern from each field. Each sample consisted of one plant, which was dug up carefully to minimise root damage, washed, and then evaluated for root health, based on degree of necrosis. Of these 10 plants, five were chosen at random, placed in paper sacs and transported in insulated coolers to the laboratory in Quito. Isolation from diseased root tissue was done on penicillin amended water agar. The cultures were examined after a week of incubation at room temperature under indirect light. Unknown isolates were transferred to PDA or a specific medium. Identification was based on morphological structures. Soil samples were sent to the Department of Soil and Water (INIAP) for chemical and

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physical determination. The following chemical aspects were determined: N-total, NO3, K, P, Mg, pH-KCl, Organic matter and Ca. Texture, soil type, and water holding capacity were also registered. These last features are complemented by observation in situ of the profile , and the soil structure. Data on the history and management of the fields were recorded. Most of this information was gathered by the Soil CRSP.

Baiting assays for soilborne pathogens and nematodes

The plastic sac method (Technical bulletin 2, Nematology, IBTA- Bolivia) was used to assess the presence of some nematodos, like the *Globodera* spp and *Heterodera* spp. A sample of 0.5 Kg soil was brought to field capacity and a pre-sprouted potato seed was put in the center of the soil in a plastic bag. The sample was incubated at 26^0 C for 30 days in the dark. After incubation, roots were examined through the plastic for developments of galls and cysts. Three replicates of the test were done. Additionally, a 0.5 Kg sample was washed and sieved to look for cysts and free living nematodes. Roots will be examined for soilborne pathogens.

Survey of Phytophthora infestans

Sampling was done in the same general areas as those sampled for an earlier study [Forbes, 1997 #4737]. This would allow us to measure changes in the population in the last few years. For this study, a total of 90 fields were sampled in the three main potato areas of the country: Carchi in the North, Chimborazo in the Central part, and Cañar in the South. Four leaves with lesions of *P. infestans* were taken from each field, on a diagonal. After washing and drying, each leaflet was put between the two halves of the R-gene free potato var. *Uvilla* and transported to CIP in Quito. Isolations, isolate maintenance, and analysis with markers (mating type, metalaxyl resistance, allozymes and RFLP fingerprint) were as described previously [Forbes, 1997 #4737].

Relations between soil-borne disease severity and Yield

Commonly, the most conspicuous factor explaining root diseases is the cropping frequency. Soil type and management interact to cause soil conduciveness or suppressiveness to a particular disease. An initial greenhouse experiment was designed to observe some root diseases and agronomic characteristics of potato when grown on soil samples from fields with increasing potato cropping frequency. The fields consisted of typical black *Andisols* from the INIAP Experimental Station at Santa Catalina. The cropping history of the last 20 years was constructed and fields with a frequency of 13,12,11,10, and 9 potato crops were sampled, processed and potted. A tuber seed of the var. Gabriela was placed at 8 cm depth. Soil was brought to field capacity and covered to avoid evaporation from top soil during emergence. A soil sample was taken from a field with no potato history, and processed to serve as control. Four replications were taken for each cropping history. At harvest root rot development, colour and root structure will be evaluated. If necessary, pathogens will be isolated and identified.

Analyses

Complementary, descriptive multivariate analysis of field data and root and tuber infections will be performed.

Results

Literature search

Reports on soil-borne pathogens of potato in Ecuador are scarce and ambiguous. The most extensive work is the "Guia de enfermedades de plantas en el Ecuador" for Fungi, bacteria and nematodos. Several conspicuous and ubiquitous pathogens, such as *Phoma* spp., *Verticillium dalhia*, *Sclerotinia* and *Pseudomonas* spp..... etc., do not appear in the list. Others pathogens are named but no location or further description is given. Lanosa, a fungus causing severe root and tuber rot was studied by Estevés And Ayala, 1987, who reported severe disease in organic soils under wet conditions. *Rumex acetocella* and Ru*mex obtisifolium*, two common weeds, are very susceptible to the fungus, and probably to maintain, or even increase inoculum potential. Recent studies on potato seed by Fankhauser (Fortipapa annual reports: 1995-1997) reports severe infections by *Rhizoctonia solani* and several forms of scab. *P infestans*, which commonly survives as tuber infections in temperate areas, has not been shown to infect tubers in Ecuador. Further research on the subject is still needed.

Survey of soil-borne pathogens

Sampling of the crop and field was done in July and August. Tubers will be collected after harvest in October to November. At this time, the bulk of the isolations and identifications are being done. First observations show a high incidence of *Rhizoctonia solani*. Some minor pathogens, including *Pythium*. *Mucor* spp. and several *Pencillium* spp were found. Information on several soil characteristics were recorded. A low incidence of *Erwina* spp. was found, which is probably explained by extreme rainy weather early this year. Data on crop management practices are being recorded by field collaborators, which will continue until after harvest. Databases containing pathogen and other information have been established.

Survey of *P. infestans*

To date about 120 isolates have been collected from Cañar and Chimborazo. The collection in Carchi was delayed and is now in process. These have been isolated in pure culture, put in medium-term storage and grown in liquid medium to produce large amounts of tissue for marker analyses. At this

time, about 40 isolates are being evaluated for mating type, metalaxyl resistance, allozyme genotype and RFLP. Preliminary assessment of a subset (*ca.* 20), all from Cañar, indicates that they belong to the EC-1 clonal lineage of the pathogen and therefore, that no change in the population has occurred in the past five years. Assessment of all isolates should be finished by late October.

Impacts

Research on soil-borne disease in Potato has been neglected in Ecuador. Most of the farmers do not use a cropping plans, crop rotation is reduced and the frequency of potato, an important cash crop, is often high. Elucidating the nature of these diseases, and their role in potato production will help formulate a management strategy for increasing productivity through higher production and improved tuber quality. At this time, only one mating type of the late blight pathogen, *P. infestans*, is known to occur in Ecuador. This study will demonstrate if any changes have occurred in this situation.

Networking Activities

Plant Protection Dept- Strategic Planning IPM CRSP evaluation 1997.

FORTIPAPA Annual Operation Plan Training of Trainers for Farmer Field Schools.

Organization the Potato Crop Management Methodological Guide.

Research Investigator Exchanges

Visit to Cochabamba, Bolivia. Exchanging experience on Nematode Control.

Visit of Dr. R Nelson to discuss population dynamics of *P. infestans*.

Research Information and Product exchange

The IPM CRSP project is part of the several projects managed by the National Potato Program of INIAP. The CRSP activities are an integral part of INIAP's Annual Plan, and of the Strategic Plan of the Department of Plant Protection. Information generated by this activity will complement information coming from several other projects in Ecuador, including the Resource Management and Late Blight projects of CIP, the Soil CRSP and Eco-Health.

Training output

At this time, the only training has been to an Ecuadorian university student who has learned to sample, assesses disease severity and isolate and identify soilborne pathogens.

Project Highlights

- There is apparently no change in the pathogen population of *Phytophthora infestans* in the southern part of Ecuador.
- The primary soilborne pathogen affecting potato appears to be *Rhizoctonia solani*, based on a small sample done to date

Development of IPM Alternatives for Major Potato Pests in Ecuador

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Abstract

To develop an integrated management program of late blight (LB) *Phytophthora infestans*, Andean weevil (AW) *Premnotrypes vorax*, and potato tuber moth (PTB) *Tecia solanivora*, on 15th May, 1998, we developed four activities in a farmer's field in Monteverde - Carchi, with the following objectives: a) To determine the efficiency of combining genetic components of resistance and fungicide application to control late blight; ethological control of AW plus individual applications of acephate and the biopesticide Spinosad; control of PTB using sexual pheromone traps in the field, and Baculovirus during storage; b) to determine adult population dynamics of AW and PTB under field conditions and storage; c) to identify the type of baculovirus strains obtained from infected moth larvae of the zone. The duration of the field study was one year (one cycle of potato followed by one of pea).

The resistant (variety) Fripapa allowed, with minimal fungicide protection, an efficient and profitable control of late blight. The alternated applications of Mancozeb and Rhodax provided an efficient and profitable control of late blight in the Superchola variety, although the rainy season. The use of traps during the time elapsed from soil preparation to crop germination plus two foliage applications of acephate, allowed the elimination of AW adults and an efficient and profitable control of this pest. The low population level of PTM (34 adults per week compared to 100 adults per week reported in Colombia) have not allowed to visualize control differences between field treatments, but the pheromone traps allowed adult reduction. It was also established that the farmers do unnecessary applications with high doses of fipronil to control this pest. The highest adult population of the AW was found after soil preparation, the shortest at planting time, and no population at all at emergence; the latter remained the same during the rest of the cropping cycle and the rotation crop. The PTM adult population was none at planting time, then it showed a small increase at the beginning of emergence, afterwards it showed a large increase that remained almost constant during the rest of the cropping cycle and the rotation with pea. This phenomenon was probably due to the fact that the pheromone traps traped PTM adults coming from nearby potato plots. During storage it was not possible to determine differences between treatments in the damage caused to the tuber because the adult population was low in the control (16 adults/month). However the Baculovirus treatment was the most profitable with a marginal return rate of 220%. The PTM larvae collected in Chamizo and Monteverde were infected by the nucleopolyedrosis of baculovirus.

The following components can be integrated to control LB, AW and PTM. First, use of the resistant cultivar Fripapa with minimum fungicide protection. In case of susceptible varieties, they should be protected with alternated applications of Mancozeb and Rhodax. Second, elimination of the AW adult population with traps, from the moment of soil preparation until crop emergence, plus two acephate applications to the foliage. Third, reduction of the PTM adult population by placing traps with pheromones at the beginning of emergence and maintaining them up to harvest time. These components allowed and efficient and profitable control of the three pests and reduce the amount of pesticides used.

In Ecuador, potato is cultivated in the Andean region from 2400 to 3800 masl. The provinces with the largest production of this tuber are Carchi, Chimborazo, Cotopaxi and Cañar. Every year, 67000 ha are planted with an average yield of 7.16 t/ha. The per-capita consumption is 46 kg/year (INEC, 1996).

The main factors that limit potato production in Ecuador are: late blight (LB) *Phytophthora infestans*, the Andean weevil (AW) *Premnotrypes vorax*, and lately the potato tuber moth (PTM) *Tecia solanivora*. The first two pests are present every year in the potato zones, and the third one in Carchi and Cotopaxi. These pests are controlled simultaneously by the farmers as a routine component of the potato production, but not in the

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best way (Hibon *et al.*, 1995; Chamorro *et al.*, 1996; Revelo *et al.*, 1997).

With the previous mentioned antecedents, we established the need to develop an integrated management program for the three pests, to benefit farmers, consumers, and the environment. This was the main purpose to carry out this study in which we combine genetic resistance, ethological control, pheromone use, biopesticides and an adequate storage. This study took one year. (one cycle of potato and one cycle of pea)

Objectives

1. To determine the efficiency of the following: Genetic resistance to late blight combined with chemical control; ethological control of Andean weevil plus application of Spinosad and acephate; ethological control of PTM with sexual pheromone, and in storage, with Baculovirus.

2. To determine adult population dynamics of AW and PTM under field conditions and of PTM during storage.

3. To identify the baculovirus type in strains obtained from infected PTM larvae of the area.

Hypothesis

The components use in an integrated way and the knowledge of AW and PTM population dynamics allowed an efficient control of the three pests and a significant reduction in the use of chemical pesticides.

Research methods

With the UVTT-Carchi technicians we selected the area of Monteverde, based on the fact that these three pests are permanently present there. The zone is located at 3100 masl in Cantón Montúfar, Carchi Province. The annual mean precipitation and the mean temperature are 1046 mm and 12.1-oC, respectively.

Experiments: To achieve the proposed objectives we designed four experiments:

Experiment 1

Evaluation of potato IPM components: This experiment was installed on May 15th, 1998. We evaluated 12 treatments that resulted from 2x3x2 factorial plus 6 controls (Table 1), under an experimental design of divided plots repeated four times. The experimental unit was a plot of 22 m^2 (5 x 4.4 m) formed by four rows separated 1.1 m and 46 plants planted at 0.3 m.

One month and a half before planting, we prepared the soil and divided the field it in two plots. One plot was assigned to the proposed treatments, and the second one, for the controls; both plots were separated with a barley border of 0.5 m to avoid mutual effects that could alter the results.

In the experimental area (1584m^2) we eliminated the Andean weevil adult population by using 22 traps and 12 bait plants that were installed immediately after soil preparation. The traps were made of potato foliage (2 or 3 branches) sprayed with acephate (2g/l) and covered with cartons. The bait plants we used were potato plants transplanted to the experimental area and sprayed with the same insecticide. The traps were renewed after 15 days. At planting time, we placed the same number of traps and bait plants, and we renewed them every 15 days up to crop emergence. The number of Andean weevil adults was counted at the moment of renewing the traps (Gallegos *et al.*, 1997). To eliminate the remaining or migrant adult population from nearby plots, we applied with a back-pack sprayer, according to the treatments, the insecticides: Spinosad (4 cc/l) and acephate (2 g/l), x 40, 60 and 80 days after planting. This control activity was not carried out in the control plots.

The number of sprays to control LB depended on variety resistance and weather conditions. With the Fripapa variety (resistant) we decided to carry out three aspersions (at the beginning of flowering, once it was completed and at the end of it), and with the Superchola variety (susceptible), the number necessary to keep the plants healthy. When the first symptoms appeared, we started spraying. The fungicides Rhodax 70 (fosetil –Al + mancozeb) in doses of 3 g/l and Dithane M-45 (mancozeb) in doses of 2.5 g/l, were applied every 10 to 12 days and every 8 to 10 days, respectively. During the cropping cycle we considered a maximum of four applications of Rhodax. In relation to the farmer's LB control system, we registered the products used, doses, frequency and number of sprays. The plants that were used as controls fo AW, were protected against LB with alternated applications of Rhodax and Dithane.

To evaluate the ethological control component of PTM, we placed, at crop emergence, eight traps with sexual pheromone in the borders of the experimental area and keep them until harvest time. Every 15 days, we registered the number of adults and renewed the water of the traps. In a farmer's plot located 10m from the experimental area, we evaluated the control efficiency of his system and registered the products, doses, number of applications, and cost. We did not considered a control without control of PTM due to the ample radio of action of the sexual pheromone.

Table 1. Factors, levels, treatments, individual effects, and interactions.

Factors	Levels	Treatments		Individual effects and interactions
Varieties (v)	v1 (Fripapa – resistant)	1. v1e1c1	10. v2e2c2	V
	v2 (Superchola – susceptible)	2. v1e1c2	11. v2e3c1	E
		3. v1e2c1	12. v2e3c2	C
Late blight control strategies	e1 (Rhodax, Mancozeb)	4. v1e2c2	13. t1*	VE
(e)	e2 (Mancozeb, Rhodax)	5. v1e3c1	14. t2	VC
	e3 (Farmer control system)	6. v1e3c2	15. t3	EC
		7. v2e1c1	16. t4	VEC
AW control strategies	c1 (Traps and Spinosad applications)	8. v2e1c2	17. t5	
(c)	c2 (Traps and acephate applications)	9. v2e2c1	18. t6	

*Checks: t1 (without late blight control in the Fripapa variety) (v1e4); t2 (without late blight control in the Superchola variety) (v2e4); t3 (farmer control system for AW plus late blight control in Fripapa) (v1c3); t4 (farmer control system for AW plus late blight control in Superchola) (v2c3); t5 (without Andean weevil control plus late blight control in Fripapa) (v1c4); t6 (without Andean weevil control plus late blight control in Superchola) v2c4)

The following variables were evaluated:

Late blight severity. Severity was measured in values of area under the disease progress curve (AUDPC), according to Berger (1988). To do that, on each plot and at the first disease symptoms, we started registering the percentage of infected leaf area every 15 days. We used an arbitrary scale from 0 to 100, where 0 is a healthy plant and 100 a dead plant.

Yield. We determined the total weight of the tubers at harvest time, and registered them in t/ha.

Damage caused by Andean weevil and moth. At harvest time we took 100 tubers from each plot. In this group of tubers, we registered the number of healthy ones and those affected individually by both pests, and registered the incidence percentage. We identified the damage (severity) with a scale from 1 to 5, where 1 was a healthy tuber and 5 completely damage.

Economic analysis of components to control LB, AW and PTM. The profitability of the components was determined through a budgetary partial analysis of CIMMYT (1998), considering the following variables: costs of traps and location, renewal, number of sprays of each product (fungicides, insecticides). To measure the net benefits increase for each component, we calculated the marginal return rate for each case (MRR).

Research Results

The tubers did not show any damage or incidence level caused by the AW (Table 9). We decided to evaluate factors such as varieties and strategies to control late blight. Then, we carried out a statistical analysis for 2x4 factorial (two varieties x 4 strategies to control Late blight = 8 treatments).

The statistical test detected a statistical difference (0.01) for the variety factor in the severity of LB and yield variables (Table 2). Variety 1 (Fripapa) presented the lowest severity value (86 of AUDPC) and the major yield (21.3 t/ha) compared to variety 2 (Superchola) with values of 1035 AUDPC and 12.3 t/ha of yield (Table 3). These values showed the Fripapa resistance to LB.

With the same variables, the test registered a statistical difference (0.01) for Late blight control strategies (Table 2). According to Tukey's test (0.05), the disease severity in the strategies 1, 2 and 3 were similar to the check (without control) in the resistant Fripapa variety and the opposite with the susceptible Superchola. With the yield

variable, the strategies 1, 2 and 3 presented similar weight of tubers, within each variety and the strategy 4 (without control) lower yield (Table 4).

The statistical test registered statistical difference (0.01) for the interaction varieties x strategies (Table 2); according to Tukey's test (0.05) (Table 4), values of severity (AUDPC) and the yield depended mainly of the variety resistance and the control degree of the strategies.

Table 2. Variance analysis for severity and yield in Monteverde, Carchi. 1999.

Source	DF	MS (Severity) (AUDPC)	MS (Yield) (t/ha)
Total	31		
Repetitions	3	3401.6	4.9*
Factor A (varieties)	1	7179444.6**	791.0**
Error A	3	3899.6	0.7
Factor B (strategies)	3	2159289.9**	114.8**
A x B (varieties x strategies	3	2125446.3**	34.8**
Error	18	13017.8	1.8
C.V. (%)		20.4	7.9
Average		559.6	17.2

Table 3. "t" test (0.05) for varieties with variables for severity and yield. Monteverde, Carchi. 1999.

Varieties	AUDPC	Yield (t/ha)
Fripapa	86.0	21.3
Superchola	1034.8	12.3
"t" test	-4.1**	14.1**

Table 4. Tukey's test (0.05) strategies with variables for severity and yield in Monteverde, Carchi. 1999.

Treatments	Severity (AUDPC)	Yield (t/ha)
1. V1E1	84.9 C	22.5 A
2. V1E2	95.1 C	23.4 A
3. V1E3	71.3 C	23.1 A
4. V1E4	92.6 C	19.6 B
5. V2E1	519.3 B	15.2 C
6. V2E2	470.3 B	14.8 C
7. V2E3	558.8 B	15.3 C
8. V2E4	2585.0 A	3.4 D

The high severity (AUDPC) and low yield values registered in strategy 4 for the Superchola variety (Check, without control), show a disease high incidence in the experiment, and confirm the reliability of results.
The yield registered was lower, compared to the potential yield for both varieties, 30 t/ha for Superchola and 47 t/ha for Fripapa, due to the damage caused by a hailstorm and the unexpected attack of leaf mines (*Liriomyza* sp) during cropping.

Economical analysis: In Table 5, we can appreciate that the domination analysis show treatment 4 (check - Fripapa without control) and 2 (Fripapa + 1 Rhodax application + Dithane), and

according to the marginal analysis (Tabla 6), both treatments were efficient with a MRR of 579.3%.

The analysis of the partial budget, done separately to control chemical strategies with the variety Superchola (susceptible), showed that strategy 2, (Mancozeb and Rhodax) applied alternatively (3 Mancozeb applications, 2 of Rhodax and 1 of Rhodax + Mancozeb) gave a 625.3% MRR. This result meant that it was more efficient than the farmer's strategy to do three applications of Curzate + Mancozeb, one of Patafol + Mancozeb, one of Rhodax + Mancozeb and one with Mancozeb). (Tables: 7 and 8).

Table 5. Domination analyses of late blight treatments. Monteverde, Carchi. 1999.

Treatments	Total net benefit (USD)	Total variable costs (USD)	
4. V1E4	528.2	0.0	
8. V2E4	109.4	0.0	D
1. V1E1	612.1	18.8	D
2. V1E2	637.3	18.8	
6. V2E2	444.8	53.7	D
3. V2E3	584.8	62.9	D
7. V2E3	452.4	62.9	D
5. V2E1	447.6	64.4	D

Table 6. Marginal analysis for no dominated treatments to control late blight. Monteverde. Carchi. 1999.

Treatments	Yield (t/ha)	Variable costs (USD)	Net benefits (USD)	Marginal costs (USD)	Marginal benefits (USD)	MRR (%)
4. V1E4	19.6	0.0	528.2			
				18.8	109.2	579.3
2. V1E2	23.4	18.8	637.3			

Table 7. Marginal analysis of chemical strategy controls (not dominated) for late blight with the variety Superchola (susceptible). Monteverde, Carchi. 1999.

Treatments	Yield (t/ha)	Variable costs (USD)	Net benefits (USD)	Marginal costs (USD)	Maginal benefits (USD)	TMR (%)
8. V2E4	3.4	0.0	109.4			
				53.6	335.5	625.3
6. V2E2	14.8	53.6	444.8			
				9.3	7.5	81.1
7. V2E3	15.3	62.9	452.4			

According to the results, treatment 2 (Fripapa with minimum fungicide protection) was the best to obtain an efficient and profitable LB control.
The control of chemical strategies, showed that strategy 2 (Mancozeb and Rhodax applied alternatively) was the most convenient to control LB, this results agreed with Garcés *et al.* (1998) report.

The analysis in Table 8 registered the names of fungicides, doses, individual or mixed applications, number of applications, complied by the farmer and us according to the strategies proposed for LB control. We observed that farmers ignored the Fripapa resistance, they made unnecessary applications adding Dithane to the Curzate and Patafol, for LB control in the variety Superchola. If we compare this situation with strategy 2, the farmer's control system was not profitable for both varieties.

According to Barrera and Norton (1998), the farmers in Carchi used to mix products in high doses because they ignore the alternatives for disease control.

Andean weevil control: In Table 9 we can observe the strategies to control AW: C1, C2 and the one from the farmer (C3), were similar to the control (C4), with values between 0 and 1 % of incidence and 1 to 2 for damage. We believe this fact is due to the effect of the traps and bait plants placed in the treatment plot. Both eliminated adult insects in the control plot, despite the barley barrier and the insecticides applied by the farmer in high doses.

The strategy C2 (trap plus acephate application to the foliage) besides efficient (eliminated 962 adults from the soil preparation until crop germination) was the most profitable (330 % MRR) compared to the farmer's strategy, which applied Regent (fipronil) 4cc/l, Cazador (fipronil) 4cc/l mixed at 45 and 60 days after planting, and Spinosad, which has a high cost in the market. The recommended doses for this insecticide is 1 cc/l. The farmer again showed a lack of knowledge regarding existing alternatives for adequate pest control.

Moth control: The strategies to control PTM presented similar conditions in relation to the percentage of damage tubers and its damage degree (Table 10). This was caused by a low population level of the pest registered during the experiment, 34 adults per week compared to 100 adults per week reported in Colombia (Saenz, 1996).

In Table 10, we can observe that the farmer applied fipronil twice to control AW and PTM. The doses used were eight times more than the recommended one, which increased the production costs. This fact proved the farmers' lack of knowledge with regards to the alternatives that could be applied for an adequate pest control, and their fear to lose their crops, this agrees with the results reported by Barrera and Norton (1998).

Table 8. Products, spraying date and number of sprays to control Late blight, according to treatments. Monteverde, Carchi 1998.

Treatments	June			July				August				October			
	Planting			Emergency				Development				Flowering end			
	11				15		24	6	14		26	3			
1. v1e1					---		---	---	---		---	R+M			
2. v1e2					---		---	---	---		---	R+M			
3. v1e3					C+M		P+M	C+M	C+M		M	R+M			
4. v1e4 (check)					---		---	---	---		---	---			
5. v2e1					R		M	R	M		R	R+M			
6. v2e2					M		R	M	R		M	R+M			
7. v2e3					C+M		P+M	C+M	C+M		M	R+M			
8. v2e4 (check)					---		---	---	---		---	---			

C = Curzate (2.5g/l), M = Mancozeb (2.5g/l), P = Patafol (2.5g/l), R = Rhodax (3g/l)

Table 9. Ethological control: number of adults trapped, used products and application frequency, *P. vorax* incidence and damage and marginal return rate (MRR) for the best strategy. Monteverde, Carchi, 1998.

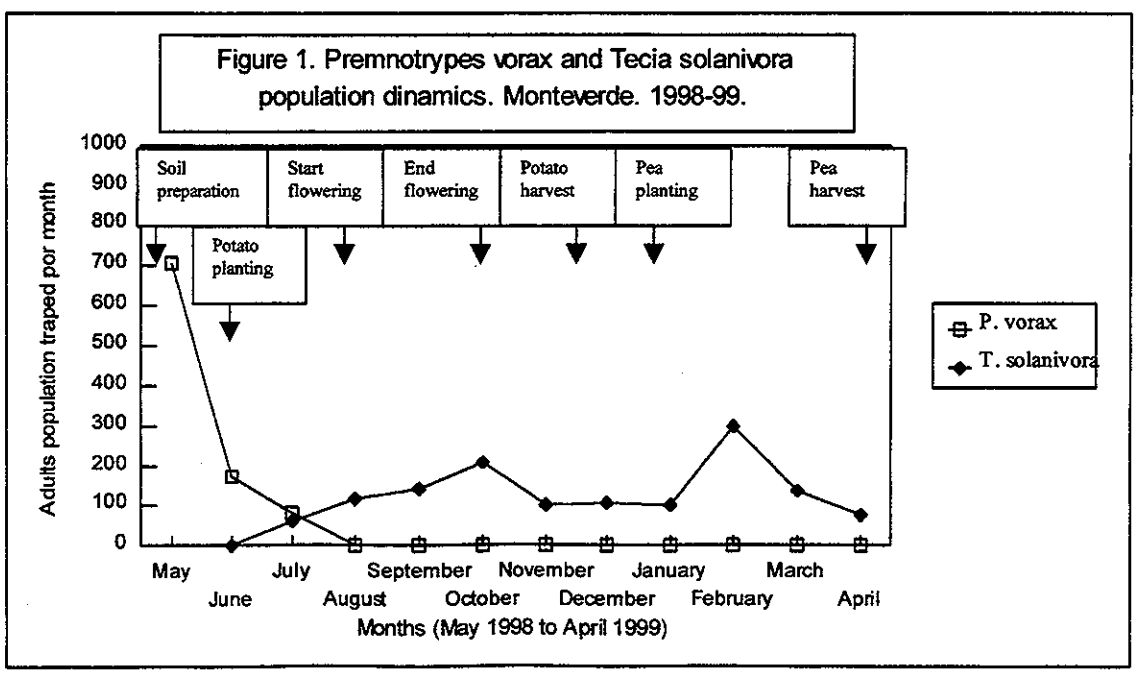
Control strategy	After soil preparation	Days after planting							Incidence (%)	Damage[1]	TRM (%)
		Planting	Germination								
		1	30	40	45	60	70	80			
C1	Tr. y Pc	Tr. y Pc	962 adults trapped	S		S			0.06	2	
C2	Tr. y Pc	Tr. y Pc		A		A		A	0.0	1	330
C3*	---------	--------			R+C		R+C		0.0	1	
C4	---------	--------		--	--	--	--	--	1.75	2	

* = farmer control system, R = Regent (fipronil, 4 cc/l), C = Cazador (fipronil, 4cc/)
Tr = Tramps, Pc = Bait plants, S = Spinosad (4cc/l), A = Acephate (2g/l),),.

Table 10. Incidence and damage values registered for *Tecia solanivora* in treatment and costs. Monteverde, Carchi, 1998.

Treatments	Incidence (%)	Damage	Cost/ha (USD)
T1 (pheromone traps)	0	1[2]	7.8
T2 (farmer's system)[1]	0	1	262.4

[1] Regent (fipronil, 4 cc/l) plus Cazador (fipronil, 4cc/l).
[2]:1 healthy tuber and 5 tuber completely damaged



Experiment 2

AW and PTM adult population dynamics under field conditions

Research methods, results an impacts

A. *Research methods*

To learn about AW adult population dynamics we registered the number of adults caught in the experimental traps, on each renewal, from soil preparation time up to emergence. We continue registering the traps placed in neighbor plots, and the rotation crop (pea) up to one year. The population was stated in adults/month.

In the same way, we monitored the PTM adult population from soil preparation up to harvest time, and then in the rotation crop. Every 15 days, we registered the number of adults caught in the sexual pheromone traps placed in the borders of the previous experiment. Then, we registered the traps placed in nearby plots, and the pea rotation crop. Same as above, the population was expressed in adults/month..

B. *Research Results and Discussions*

Figure 1 shows high AW adult populations present after soil preparation, then it decreased progressively after planting to zero during emergence. The rotation crop (pea) only registered three adults in February.

The PTM adult population was none at planting time, a small increase was present at the beginning of emergence, and from then increased. The population maintained constant up to harvest. The highest population level of pea was registered on February. We believe this phenomenon was caused by the pheromone attracting moth adults from the nearby potato crops located near the pea crops. The population of 34 adults/week was low in relation to that one reported in Colombia of 100 adults/week (Saenz, 1996).

Experiment 3

Efficiency evaluation of different alternatives for PTM control in healthy stored tubers

Research methods, results an impacts:

A. *Research methods*

We took tubers from Experiment 1, which were stored to control the experiment, in units of 45 kg, which under the design were repeated four times to evaluated the following treatments:

T1. *Bacillus thuringiensis* (150 g of product to 10% /45 kg potato)
T2. Baculovirus (100 g/45 kg potato)
T3. Chemical control (Malation 10%, 100 g/45 kg potato)
T4. Repellent plant (Eucalipto)
T5. Farmer system (Vitavax 60g + Curacron 40cc + Methofan 40cc/20L)[1]
T6. Control (without control)

[1] = The products mixed were applied to the tuber seeds with a back-pack spray.

We considered as variables the percentage of tubers damage (incidence) and the damage intensity (severity). To measure the damage intensity we used an arbitrary scale from 1 to 5, where 1 = healthy tuber and 5 = tuber completely damaged. The evaluations were at 40 and 60 days after storage.

B. *Research Results and Discussions*

The studied treatments presented similar responses to pest incidence and damage to the tubers in storage. The low adult population level (16 adults per month) registered on the pheromone traps, with the control, and located in a nearby storage close to the one where the experiment took place, did not showed major difference in the response to the treatments. The Baculovirus treatment was more profitable with MRR of 220% (Table 11).

Table 11. The damage caused by *T. solanivora* to the tubers in storage, treatment, cost, and efficiency. Monteverde, 1998.

Treatments	Incidence (% tubers damage)	Damage[1]	Cost per 45kg of treated potato (USD)	MRR (%)
T1 = *Bacillus thuringiensis*	0.0	1	2.70	
T2 = Baculovirus	0.0	1	0.07	220[2]
T3 = Malathion 10%	0.0	1	0.22	
T4 = Eucalipto, repellent plant	0.7	2	0.15	
T5 =Farmer control system (Vitavax + Methofan + Curacron)	0.0	1	0.15	
T6 = Check (without control)	5.5	2	0,00	

[1] = 1 healthy tuber and 5 tubers completely damage [2] = treatment not dominated

Experiment 4

Identification of Baculovirus type on isolated strains of moth infected larvae from Carchi.

Research methods, results an impacts

A. *Research methods*

We evaluated 900 kg of tubers belonging to different farmers from Chamizo and Monteverde. Then, we collected moth larvae with baculovirus infection symptoms, which were sent for evaluation in the CIP-Lima.

B. *Research Results and Discussions*

According to the CIP's results, the moth larvae collected in el Chamizo and Monteverde were infected with Nucleopolyedrosis baculovirus, its pathogenicity was reported by Niño (1997). We believe that the natural control observed in this pest of recent introduction in Ecuador is due to the presence of other moths in the area, which act as lodging virus. It explained also why this pest has not reached the population levels presented in Venezuela and Colombia.

C: *Experiment's conclusions*

Based on the results obtained, we present the following conclusions:

1. The resistant Fripapa variety, with minimum fungicide protection allowed an efficient and profitable LB control.
2. The alternated application of Mancozeb and Rhodax, provided and efficient and profitable LB control with the Gabriela susceptible variety, despite the rainy season.
3. The strategy to elimination AW with traps, from the moment the soil was prepared up to cropping, plus two acephate applications to the foliage, was the most efficient and profitable to control this pest.
4. The *Tecia solanivora* low population level registered in the field during the experiment development (34 adults per week compared to 100 adults per week reported in Colombia) allowed visualizing differences between field treatments. It was determined that the pheromone traps captured a significant number of PTM, the farmer also applied unnecessary fipronil doses to control this pest.
5. The major AW adult population was present after soil preparation, the minimum at planting, and none at emergence. The same level was maintained with the rotative cropping cycle.
6. There was no PTM adult population at planting, then at emergence presented an small increase, and finally a high increase. During the remaining time, the population was constant up to harvest time. In pea rotation crop the population keep a similar level, probably because the traps captured adults from the surrounding lots.
7. The PTM adult low population level (16 adults/month) registered with the pheromone control traps, and located in a nearby storage where the experiment was taking place, did not allowed to observe major difference in response to the treatments during storage. The treatment with Baculovirus was the most profitable with 220% MRR.
8. The *Tecia solanivora* larvae collected in Chamizo and Monteverde, were infected with Nucleopolyedrosis of baculovirus.
9. The components: LB (resistant varieties or susceptible + rational chemical control), AW (ethological control + two acephate applications), PTM (tramps with pheromones) and the knowledge of dynamic population for AW and PTM, allowed an efficient control of the three pests and reduced the amount of chemical pesticides. For the reasons stated above we accepted the stated hypothesis.

Recommendations

1. The integrated components to control LB, AW and PTM are in its order: Fripapa resistant variety planted with minimum fungicide protection. In case of susceptible varieties, the protection should be with alternated applications of Mancozeb and Rhodax. The AW adult population should be eliminated with traps, from soil preparation until crop germination, plus two acephate applications to the foliage. The PTM adult population should be eliminated with pheromone traps, from crop emergence until harvest time.
2. To repeat the PTM experiment control in the field and storage.
3. To consider the Nucleopolyedrosis of baculovirus strains for PTM biological control.

Networking Activities

A. Workshops

B. Research Investigator Interchanges

- On June, August, September and October, AGRIPAC, ECUADAL-FRITOLAY, Japan and UVTT-Carchi technicians, visited the field test located at Monteverde, Carchi to know about the late blight, *P. vorax* and *T. Solanivora* integrated system control.

Publications and Presentations

- On June 14, in Santa Catalina Experimental Station, we presented the methodology and the research results.

Training output

- Since May-1998, to february-1999, at field test located on Monteverde, 20 farmers were capacitated on *P. infestans*, *P. vorax* and *T. Solanivora* integrate control system.

Project Highlight

An inter-departamental meeting was held at Santa Catalina Experimental Station to plan the andean fruits research activities like the present project research activities.

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Development of Potato Varieties with Long Lasting Horizontal or Multigenic Resistance to Late Blight (*Phytophthora infestans*)

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Collaborating Scientists: Carmen Castillo[1], Arturo Taipe[2], Flor Cardenas[3], Efren Carrera[4], Pedro Oyarzun[5]

Abstract

Twenty-seven and 7 IPC1 clones (with horizontal resistance to late blight) were evaluated at Santa Marta de Cuba and Huacona Santa Isabel, respectively. Seven and 5 IPC2 clones (with horizontal resistance) and 6 and 2 IPC 3 clones (with vertical resistance) were also evaluated at each location, respectively. Evaluations of the IPC 1 clones is currently in progress. In Chimborazo the IPC 2 clone 95-9-1 with horizontal resistance was selected by local growers as the most promising selection. The IPC 3 clone P-84-1 was selected as the clone with vertical resistance that had the highest probability of acceptance by local growers. In Carchi clones 95-68-3 and 95-8-2 were selected as the best clones with horizontal resistance and CHP-3 was the best clone selected by growers with vertical resistance.

Training in gender analysis was initiated for technical personnel and agricultural cooperators in the PNRT-potato program. Local growers are being trained in participatory manner of the importance of horizontal resistance for sustainable late blight management.

Objectives

- To improve the welfare of potato-farm families in Ecuador through the rapid dissemination of late blight resistant clones.
- To document selection criteria farmers use for selection of planting material.

Introduction

The National Program for Roots and Tubers-Potato (PNRT), as part of its genetic improvement program for potatoes has developed a participatory research program with potato growers to evaluate and select advanced potato clones with horizontal or multigenic resistance to potato late blight, caused by *Phytophthora infestans*. Participatory evaluations were conducted in Carchi and Chimborazo in cooperation with local potato growers during the planting cycle 1998-99.

Methodology

Evaluation of potato clones with local growers is being conducted at three locations. One in the community of Santa Martha de Cuba (parish of the same name) at an altitude of 2800 m, and in La Palestina, at an altitude of 3150 m, (Julio Andrade parish), in the canton of Tulcán, Province of Carchi. A third location is the community of Huacona Santa Isabel, at an altitude of 3400 m in the province of Chimborazo.

Twenty-seven and 7 IPC1 clones (with horizontal resistance) were evaluated at Santa Marta de Cuba and Huacona Santa Isabel, respectively. Seven and 5 IPC2 clones (with horizontal resistance), and 6 and 2 IPC3 clones with vertical resistance were also evaluated at each location, respectively during 1998-99. Table 1 provides a list of the clones evaluated at each location.

[1] INIAP-PNRT-papa Participatipe plant breeding project
[2] INIAP-PNRT-papa IPM CRSP Project
[3] INIAP-NATC
[4] INIAP-PNRT-papa
[5] INIAP-CIP-FORTIPAPA

Table 1. Locations of planting and participatory evaluations, and clones evaluated at each location.

Location:

	Locality1	Locality 2	Locality 3
Province	Carchi	Carchi	Chimborazo
County			Colta
Community	Sta. Marta de Cuba	La Palestina	Huacona Sta. Isabel
Height (masl)	2800	3150	3400

Clones:

Selection cycle	Locality 1	Locality 2	Locality 3
First selection cycle (IPC1)	B1C4 015.10 B1C4 017.14 B1C4 056.7 B1C4 060.5 B1C4 087.6 B1C4 110.21 B1C4 110.23 B1C4 110.3 B1C4 110.9 B1C4 120.11 B1C4 125.10 B2C2 027.33 B2C3 018.13 B2C3 036.4 B2C3 076.4 B2C3 084.2 D56 LB3 007-13 LB3 022-03 LB3 022-16 N515 N551 N597 N775 U533 X106 X98		LB3029-50 LB3003-06 D-56 X-141 N-551 U-633 LB3022-16
Second selection cycle (IPC2)	95-59-5 95-35-1 95-8-2 95-68-3 95-61-1 95-68-1 95-85-4		95-86-2 95-9-1 B-50 B-51
Third selection cycle (IPC3)	CHP-94 CHP-70 CHP-141 CHP-154 CHP-40 CHP-3		CHP-65 CHP-97
Multiplication cycle	P-41-5 P-101-2 P-21-1 P-40-3 O-10 O-5 C-341 C-114 C-92	P-41-5 P-101-2 P-21-1 P-40-3 O-10 O-5	P-84-1 O-5 O-10 O-17-5

All evaluations were conducted on participating growers' farms, a total of three evaluations were conducted at each site.

Clones were planted in rows 3.0 m long during the first evaluation. During the second evaluation closes were planted in rows 4.5 m long. In the third evaluation and for clones in multiplication plots, clones were planted in rows 7.5 m long with a distance of 1.1 m between rows. The distance between plants was 0.3 m.

Participatory research methodology described by Ashby (CIAT, 1991) was adapted to our specific conditions, and was used for all studies. Evaluation sessions with the growers consisted of open-ended evaluation formats.

Evaluations were conducted as previously described (1997-98) at flowering and during harvest. After harvest, culinary quality preferences were also evaluated.

Methods such as personal interviews were used in the participatory rural appraisal. This appraisal was based on the process of perception and communication through dialog to enter into the world of the grower (informant) to determine ideas, current knowledge, and experiences, which would facilitate a rapid rural appraisal in the region of the study.

The format for initial meetings held in the communities was based on a flow chart that included the expectations of the study, an explanation of the methodology, and the dynamic social processes involved. Potato clone evaluating groups consisting of local growers were organized in both communities. Grower training was initiated with the development of a program focused on late blight, and was supported by visual aids such as comparative drawings.

Results

Evaluations were conducted in all three communities in an environment of trust and security between the participating growers and the technical support crew. This facilitated communication between both sides. Participatory evaluations during flowering and harvest constituted an essential component of the program, allowing growers to become directly involved in the evaluation process. The growers contributed information on several important agronomic, economic and sociocultural aspects of potato production that need to be considered, as well as their personal criteria regarding potato cultivation.

Participatory Appraisal

The participatory appraisal is on-going an integral part of this project that permits the research team to understand the environment and lifestyle of the community, from the perspective of the grower.

Of all farmers interviewed thus far, 3690 are women and 6490 men. In the province of Carchi 92% of all farmers interviewed were men; while in Chimborazo 56% were women. These results reflect the differences in ideologies concerning the participation of women in farming activities between the two areas. Fifty percent of the interviewers were from 29 to 39 years old; 27% were between 18 and 28; 11% were between 50 and 60; 9% were between 40 and 50; and 3% were between 13 and 18. Most of the interviewers had completed school (equivalent to high school), but 14% of them were illiterate.

The appraisal continues to be considered small-scale farmer (resource-poor) that had between 3 and 10 ha of land, use mainly family labor, and whose main agricultural activities were potato cultivation and livestock grazing. Depending on climatic conditions, they cultivate potatoes year-round. The rotational system consists of continuous potatoes for 2 to 4 years followed by a fallow period; or a potato-corn-bean rotation. The potato varieties typically used are Superchola and INIAP-Gabriela, and to a lesser degree Uvilla, Roja Nativa and Yema de Huevo. Part of the production is sold, another part is used for subsistence, and another part, for the production of seed.

The material used for seed is of third class quality tubers (generally poor quality) saved from the previous harvest. Some growers obtain seed from the market at Sn Gabriel or Julio Andrade; however, seed in the market is frequently difficult to find. Potato tubers used for seed are stored in sacks and kept in storage rooms.

Typical inputs for potato production are insecticides and fungicides. Half of the fertilizer is applied at planting, and the other half at flowering. The major disease affecting this crop is late blight, caused by *Phytophthora infestans.* Depending on the weather conditions, fungicides are applied between 8 and 14 times to control this disease. Other major problems are the Andean weevil *Premnotrypes vorax* and the marketing problems due to the fluctuating prices.

Varietal characteristics that farmers consider desirable include: potato with dense foliage; wide leaves; resistance to late blight; short growing season; and high yields (15-20 kg per kg of seed). In addition, tubers should be round to oval with superficial eyes, pinkish skin (similar to that of the variety Superchola 0 INIAP-Gabriela), and yellow or cream-colored pulp with a 'floury' consistency. Farmers believe that a variety with all these characteristics would enable them to market the crop without any problems.

Potatoes are grown typically year-round (depending on the rainfall), although several farmers prefer to start the season in October. The potato varieties mostly used are Superchola and INIAP Gabriela; and to a lesser degree Capiro, Roja Nativa and María. Management practices such as seed storage, fertilization, chemical control, and perceived

problems and expectations of a new variety are very similar to the findings in Santa Martha.

Formation of Participatory Groups Continue Evaluation in 1998-99

Meetings with farmers were continued in both communities in order to facilitate the formation of groups of farmers to evaluate potato clones. In this process, potato growers identified by the community as creative, critically innovative, and well experienced in the potato production were encouraged to participate in the groups to evaluate the potato clones.

The role of the technicians of the PNRT and of the Validation and Transfer of Technology Unit (UVTT) in Carchi was that of facilitating the meetings. Various methods such as the use of group dynamics were used to communicate the expectations of the study and to emphasize the importance of organization. In each community the group elected its own president, secretary and a promoter. Seventeen farmers participated in the group at Santa Martha, and 16 farmers participated in La Palestina.

Clone Selection

Data from evaluations of the IPC1 clones is currently being collected and evaluated. Tables 2-8 provide data from clonal evaluation for the IPC2 and IPC3 clones at Huacona Sta Isabel, Chimborazo and Santa Marta de Cuba, Carchi, Huacona Sta Isabel, Chimborazo.

Table 2. Analysis of variance to yield variables to IPC2 clones in en H. Sta Isabel, Chimborazo, 1999

		MS			
Source	***DF***	***# of plants at yield***	***Tubers/plant***	***Yield/plant***	***Yield t/ha***
Repetitions	2	1.11 ns	21.84 ns	0.85 ns	36.91 ns
Clones	4	17.79 **	67.04 ns	0.52 ns	184.05 *
Error	7	1.13	43.17	0.24	27.39
Average		14.32	24.69	1.94	22.81
CV (%)		7.25	26.61	25.05	22.27

Table 3. Analysis of variance to yield variables to IPC3 clones in en H. Sta Isabel, Chimborazo, 1999

		MS			
Source	***DF***	***# of plants at yield***	***Tubers/plant***	***Yield/plant***	***Yield t/ha***
Repetitions	2	4.30 ns	10.62 ns	0.07 ns	109.94 *
Clones	4	5.19 ns	83.88 ns	0.12 ns	168.51 *
Error	7	3.34	26.94	0.05	19.87
Average		15.55	23.23	1.41	20.49
CV (%)		11.76	22.34	15.88	21.76

Table 4. Tukey test at 5% and averages to yield variables of IPC2 in H. Sta Isabel, Chimborazo, 1999

Clones	***# of plants at yield***	***Tubers/plant***	***Yield/plant***	***Yield t/ha***
95-86-2	17.00 a	32.23	2.07	28.50 a
95-9-1	16.17 ab	24.83	2.43	19.25 ab
B-50	13.67 bc	22.80	2.17	26.08 a
B-51	14.00 ab	19.33	1.63	10.75 b
Gabriela	10.77 c	24.25	1.41	29.46 a

Table 5. Tukey test at 5% and averages to yield variables of IPC3 in H. Sta Isabel, Chimborazo, 1999

Clones	*# of plants at yield*	*Tubers/plant*	*Yield/plant*	*Yield t/ha*
CHP-65	16.53	25.99	1.47	21.49 ab
CHP-97	13.67	22.37	1.17	10.11 b
Fripapa	15.00	21.33	1.37	16.50 ab
Gabriela	15.57	30.33	1.33	29.50 a
P-84-1	17.00	16.17	1.70	24.83 a

Table 6. Analysis of the variance for yield variables of IPC2 clones in Santa Martha de Cuba, Carchi, 1999

		MS			
Source	*DF*	*# of plants at yield*	*Tubers/plant*	*Yield/plant*	*Yield t/ha*
Repetitions	2	294.97**	14.67ns	0.05ns	504.47**
Clones	7	10.20ns	86.82*	0.22**	130.97**
Error	14	5.85	22.32	0.04	19.99
Average		9.6	9.22	0.42	11.21
CV (%)		25.16	51.24	47.50	39.85

Table 7. Analysis of the variance for yield variables of IPC·3 in Santa Martha de Cuba, Carchi, 1999

		MS			
Source	*DF*	*# of plants at yield*	*Tubers/plant*	*Yield/plant*	*Yield t/ha*
Repetitions	2	263.67**	90.42**	0.26*	10.29*
Clones	7	24.56**	27.30ns	0.10ns	34.1**
Error	14	3.36	12.92	0.05	2.35
Average		7.50	5.16	0.30	3.56
CV (%)		24.46	69.70	78.40	43.01

Table 8. Averages and Tukey test at 5% to yield variables of IPC2 clones in Santa Martha de Cuba, Carchi, 1999

Clones	*# of plants at yield*	*Tubers/plant*	*Yield/plant*	*Yield t/ha*	*AUDPC*
95-68-3	11.8	18.5a	0.9[a]	22.2a	1980.3
95-8-2	12.3	12.8ab	0.7ab	20.2ab	-
95-68-1	10.2	12.0ab	0.5abc	11.9abc	5243.6
95-61-1	9.7	6.8ab	0.3bc	9.7abc	4433.3
95-85-4	9.3	11.4ab	0.4abc	9.3bc	3826.3
95-59-5	8.5	5.9ab	0.3bc	6.1c	4294.0
95-35-1	8.3	2.1b	0.1c	5.3c	3650.2
CATALINA	6.8	4.3b	0.2bc	5.1c	4298.0

Conclusions

In Chimborazo the IPC2 clone 95-9-1 with horizontal resistance was selected by local growers as the most promising selection. The IPC3 clone P-84-1 was selected as the clone with vertical resistance that had the highest probability of acceptance by local growers. In Carchi clones 95-68-3 and 95-8-2 were selected as the best clones with horizontal resistance and CHP-3 was the best clone selected by growers with vertical resistance.

Training in gender analysis was initiated for technical personnel and agricultural cooperators in the PNRT-potato program. Local growers are being trained in a participatory manner of the importance of horizontal resistance for sustainable late blight management.

Verification and Evaluation of Efficiency and Profitability of Chemical Control Strategies of Late Blight (*Phytophthora infestans*) in Susceptible Potato Varieties at Two Areas of the Ecuadorian Highand

Investigators: Jorge Revelo, Cesar Asaquibay, Sandra Garcés[1]

Abstract

To establish a rational late blight chemical control on susceptible varieties on wintertime, we are carrying out one field test at Chaupi, Cotopaxi and two at Huaca, Carchi to determinate the efficiency an profitability of nine chemical control strategies. Also we well determinate the metalaxyl M. anti-resistant characteristics to *P. infestans* of strategies. The strategies are structured by alternate applications of systemic and protectantes fungicides:1. Ridomil +Dithane; 2. Patafol + Dithane; 3. Rhodax + Dithane; 4. Ridomil + Daconil; 5. Ridomil + Daconil + Brestan; 6. Patafol + Daconil; 7. Patafol + Daconil + Brestan; 8. Rhodax + Daconil; 9. Rhodax + Daconil + Brestan; 10 Farmer control system; 11 Without control (check).

As preliminary results we can say that the isolation proportion 10/90 resistant/sensible to metalaxyl M in *P. infestans* population of Chaupi, was different in isolation proportion 100/0 R/S to that observed in the same area at end crop of the last year (1998). The reason could be that nowadays farmers do not use phenilamides for disease control.

The nine strategies proposed for late blight control keep the tree varieties at low level of *P. infestans* infection (10%) in both areas.

One of the main biotic factors affecting the potato crop yield in Ecuador is Late blight; disease caused by the *Phytophthora infestans*. This disease cause losses of 30 to 100% (Morales, 1994), and it is present in all the potato areas, every year. The problem aggravates because 76% of the varieties are susceptible and they are cultivated during the rainy season (Revelo *et al.* 1995). In order to protect the crops, the farmers apply high doses of mixed pesticides (up to 20 controls), generally these applications are carried out ignoring their action. This system implemented to control the disease increases the production costs, causes damages to the farmers' health as well as to the consumers, and contaminates the environment. (Hibon *et al.*, 1995; Chamorro *et al.*, 1996; Revelo *et al.*, 1997).

This situation forced to develop a strategy for the chemical control of late blight: to reduce the risks, to learn how to use pesticides appropriately, and to avoid resistance problems, mainly with phenilamides. These strategies will enable farmers to obtain a successful and profitable cropping of susceptible varieties during the rainy season, until the resistant varieties are available.

The Gabriela variety (susceptible) crops located in Chaupi-Cotopaxi, were of great help to determine that eight alternated applications of Ridomil Gold and Dithane, Patafol and Dithane, Rhodax and Dithane, during winter time, was possible to obtain an efficient epidemic control of Late blight caused by *P. infestans* 50/50 resistant/sensible and 100/0 resistant/sensible to metalaxyl M. The strategy Rhodax and Dithane, where the most efficient and profitable with antiresistant characteristics, according to Garcés et.al. (1998). The strategies containing Ridomil and Patafol (phenilamidas), registered strains 100% resistant at the end of the crop. In conclusion they did not presented antiresistant characteristics. These results enable us to state a hypothesis: the strategies using Ridomil and Patafol during the second cycle and in the same area, will not control the disease because of the resistance developed by the fungus.

We are verifying the efficiency of the strategies stated by Garcés et.al (1998) to accept or reject the hypothesis. Also we are evaluating the efficiency and profitability of six additional strategies. This information will allow us to establish an adequate strategy for the use of systemic pesticides, especially phenilamidas alternated with protectantes, to control late blight in susceptible varieties, during wintertime.

In this opportunity we present partial results of the investigation. The trials will conclude during the last week of October.

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- To evaluate the efficiency and profitability of six strategies for chemical control of late blight in susceptible varieties.
- To determine the strategies anti-resistant characteristics to *P. infestans*.

The first three strategies do not control late blight cause by *P. infestans* resistant to metalaxyl M in an efficient way, when is used in a second cycle, and in the same area.

None of the six-remainder strategies allowed control of late blight with fewer applications, than those applied by the farmers to susceptible varieties during wintertime.

Research Methods

To achieve the proposed objectives, we installed trials in Chaupi-Cotopaxi and in Huaca- Carchi.

Proportional determination of resistant and sensible isolations (R/S) on initial and final population of *P. infestans*. Up to date (02-09-99) we determined in Chaupi the proportion of isolations R/S in the initial population, with 10 samples of leafs infected and collected, in a radio of 500 m. We registered also data such as: altitude of the varieties of potato, and most used pesticides. The study in Huaca will finish soon.

The proportion of isolations R/S at the end of each test, and on each zone remains unfinished. We will take three samples of infected leafs from each plot, one month before harvest.

The isolation of *P. infestans* is being done with collected samples and according to the CIP reported techniques (1995).

We prepared solutions of metalaxyl M in concentrations of 0 ug/ml and 10 ug/ml, according to Matuszack, *et al.* (1994), and CIP (1995), to determinate isolations sensitivity. After inoculation of each isolation in petri dishes containing rye agar culture medium with the different solutions, were left in incubation and later evaluated the colony growth diameter at 7, 14 and 21 days of incubation and qualify them according to Davidse, *et al.* (1998) criteria, as sensitives (S), intermediate resistance (IR), and resistance (R).

The anti-resistant characteristics of *P. infestans* to the control of strategies proposed will be established at the end of the cycle; relating the isolation R/S proportion of population at the beginning of the test with those to be determined one month before harvest. If the relationship of resistant isolations is higher than the second evaluation, we will consider that the strategy does not present appropriate anti-resistant characteristics.

Determination of strategy control efficiency. On April 20th 1999, we established a field test to evaluate ten treatments with the variety Gabriela (Table 2), in Chaupi (3200 masl), Cotopaxi, (in this area this investigation took place in the 1998 cycle). This test was carrying out under a completed block design with four repetitions. Also we carried out two field tests in Huaca (3000 masl) in Carchi, on April 22nd of the same year to evaluate 11 treatments with the varieties Esperanza and Superchola (Tables 3 and 4), under a complete block design with four repetitions.

We established plots of 4.8 x 4.0m (19.2 m^2) formed by four furrows of 4.0 m long by 1.2 m deep. We planted one tuber by space at 0.30 m (13 tubers by furrow. The plots were fertilized with levels: 250, 300, 150 and 46 kg/ha of N, P, K, S, mixing the soil with chemical fertilizers at 10-30-10 and Sulfate de Amino.

The pesticides in commercial doses of: 0.5 kg/200L Dithane M-45 (mancozeb), 0.5 kg/200L Patafol (ofurace + mancozeb), 0.5 kg/200L Ridomil Gold (ximoxanyl + mancozeb), 0.5 kg/200L Rhodax (fosetil aluminio + mancozeb), 0.25kg/200L Daconil 76PW (clorotalonil) and 0.1kg/200L Brestan (trifenil acetate of tin), are applied with a back pack sprayer every 10 to 14 days for systemic pesticides, and 6 to 8 days for protectantes. To avoid the effect between plots, and products dragging to the neighbor plots caused by the wind, we planted a line of barley of 40 cm between plots. The fungicide application started at 54 days of emergence.

We controlled Andean weevil (AW) *Premnotrypes vorax* by using traps after soil preparation and at planting time, plus three applications of acephato to the foliage. (Gallegos, *et al.* 1997). The Potato tuber moth (PTM) *Tecia solanivora*, was controlled using 12 traps with sexual pheromone per ha, placed at emergence time and maintained until harvest. We considered the severity variable in AUDPC values (area under development curve of disease) according to Berger (1988). In each plot we registered percentage readings of foliage area affected, every 15 days, using an arbitrary scale of 0 to 100, where 0 = healthy plant and 100 = dead plant. The yield will be established at harvest time to determine total weight of tubers and expressed it in t/ha.

Profitably of strategies and farmer control system will be determined with a partial budget analysis for CIMMYT (1998). On each strategy we will determine cost variation, number of aspersions with or without fungicides and its cost. To measure the increase of net benefits in the strategies, we will calculate the return marginal rate.

Research Results

P. infestans resistant susceptible strains proportion

Table 1, show that the initial population of *P. infestans* in Chaupi, presented an isolation proportion of 10/90 intermediate resistance/sensibility to metalaxyl M, different to a proportion of 100/0 resistance/sensibility determined at

the 1998' cycle end in the same area (Garcés *et al.* 1998). The pesticides used by the farmers were Curzate, Rhodax and Mancozeb. This campaign did not record the use of phenilamidas. The varieties Gabriela, Esperanza and Yema de Huevo, are susceptible.

Table 1. Proportion of resistan susceptible isolations in the initial population of *Phytophthora infestans* in Chaupi, Cotopaxi. 1999.

Zone	Altitude (masl)		Varieties	Pesticides	Sample No.	Reaction
Chaupi	3200	1	Gabriela	Curzate, Rhodax	2	S
			Gabriela	Curzate, Rhodax	3	S
			Gabriela	Curzate, Rhodax	4	S
		2	Gabriela	Curzate, Rhodax	5	S
			Gabriela	Curzate, Rhodax	6	I
		3	Gabriela	Curzate, Rhodax	7	S
			Gabriela	Curzate, Rhodax	8	S
			Esperanza	Curzate, Mancozeb	9	S
			Esperanza	Curzate, Mancozeb	10	S
			Yema de huevo	Curzate, Mancozeb	11	S

S = susceptible; I = intermediate resistance

Table 2. Products and application frequency to control late blight in the variety Gabriela. Chaupi, Cotopaxi. 1999.

TREATMENTS	April	May		June			July			August
	Planting	Emergence		Development			Flowering start			Flowering end
DATES:	20	19	28	2	8	22	5	15	29	21
T1. Ridomil +Dithane		R	D	R	D	R	D	R	D	D
T2. Patafol + Dithane		P	D	P	D	P	D	P	D	D
T3. Rhodax + Dithane		Ro	D	Ro	D	Ro	D	Ro	D	D
T4. Ridomil + Daconil		R	Da	R	Da	R	Da	R	Da	Da
T5. Ridomil + Daconil + Brestan		R	Da	R	Da	R	Da	R	Da	B
T6. Patafol + Daconil		P	Da	P	Da	P	Da	P	Da	Da
T7. Patafol + Daconil + Brestan		P	Da	P	Da	P	Da	P	Da	B
T8. Rhodax + Daconil		Ro	Da	Ro	Da	Ro	Da	Ro	Da	Da
T9. Rhodax + Daconil + Brestan		Ro	Da	Ro	Da	Ro	Da	Ro	Da	B
T10. Without control (check)		--	--	--	--	--	--	--	--	--

D = Dithane, R = Ridomil, P = Patafol, Ro = Rhodax, Da = Daconil, B = Brestan.

Table 3. Products and application frequency to control late blight in the variety Esperanza. Huaca, Carchi. 1999.

TREATMENTS	April	May	June			July			August	
	Planting	Emergence	Development			Flowering start			Flowering end	
DATES:	22	22	1	10	17	1		21		19
T1. Ridomil +Dithane		D+C*	R	D	R	D		R		D
T2. Patafol + Dithane		D+C	P	D	P	D		P		D
T3. Rhodax + Dithane		D+C	Ro	D	Ro	D		Ro		D
T4. Ridomil + Daconil		D+C	R	Da	R	Da		R		Da
T5. Ridomil + Daconil + Brestan		D+C	R	Da	R	Da		R		B
T6. Patafol + Daconil		D+C	P	Da	P	Da		P		Da
T7. Patafol + Daconil + Brestan		D+C	P	Da	P	Da		P		B
T8. Rhodax + Daconil		D+C	Ro	Da	Ro	Da		Ro		Da
T9. Rhodax + Daconil + Brestan		D+C	Ro	Da	Ro	Da		Ro		B
T10 Farmer control system		D+C	D+C+ Co	D+C+ Cu+Co	D+C+ Cu+Co		D+C+ Cu+Co		D+C+ Cu+Co	
T11 Without control (check)		D+C	--	--	--	--		--		--

* Productos aplicados por el productor

C = Curathane (ximoxanil + mancozeb) 2.5g/l, Cu = Curzate (xymoxanil + mancozeb) 2.5g/L, Co = Cosan (Azufre) 2.5g/l, D = Dithane, R = Ridomil, P = Patafol, Ro = Rhodax, Da = Daconil

Table 4. Products and application frequency to control late light in the variety Superchola. Huaca, Carchi. 1999.

TREATMENTS	April	June			July			August		
	Planting	Development			Flowering start			Flowering end		
DATES:	**22**	**1**	**10**	**17**	**1**	**17**	**21**	**2**	**19**	**31**
T1. Ridomil +Dithane		R	D	R	D		R		D	D
T2. Patafol + Dithane		P	D	P	D		P		D	D
T3. Rhodax + Dithane		Ro	D	Ro	D		Ro		D	D
T4. Ridomil + Daconil		R	Da	R	Da		R		Da	Da
T5. Ridomil + Daconil + Brestan		R	Da	R	Da		R		B	B
T6. Patafol + Daconil		P	Da	P	Da		P		Da	Da
T7. Patafol + Daconil + Brestan		P	Da	P	Da		P		B	B
T8. Rhodax + Daconil		Ro	Da	Ro	Da		Ro		Da	Da
T9. Rhodax + Daconil + Brestan		Ro	Da	Ro	Da		Ro		B	B
T10. Farmer control system		C+D+Co	D+C+Cu +Co	D+C+Cu +Co		D+C+ Cu+Co		D+C+ Cu+Co		
T11. Without control (check)		--	--	--	--		--		--	--

C = Curathane (ximoxanil + mancozeb) 2.5g/l, Cu = Curzate (xymoxanil + mancozeb) 2.5g/L, Co = Cosan (Azufre) 2.5g/l, D = Dithane, R = Ridomil, P = Patafol, Ro = Rhodax, Da = Daconil.

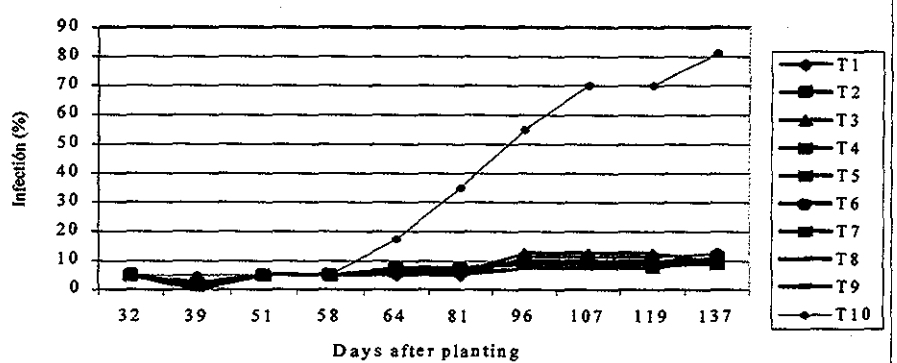
Strategy control efficiency. Figures 1, 2 and 3 show the alternated application of systemic and protectant pesticides response, which allowed maintain *P. infestans* severity at low level in all varieties at both areas.

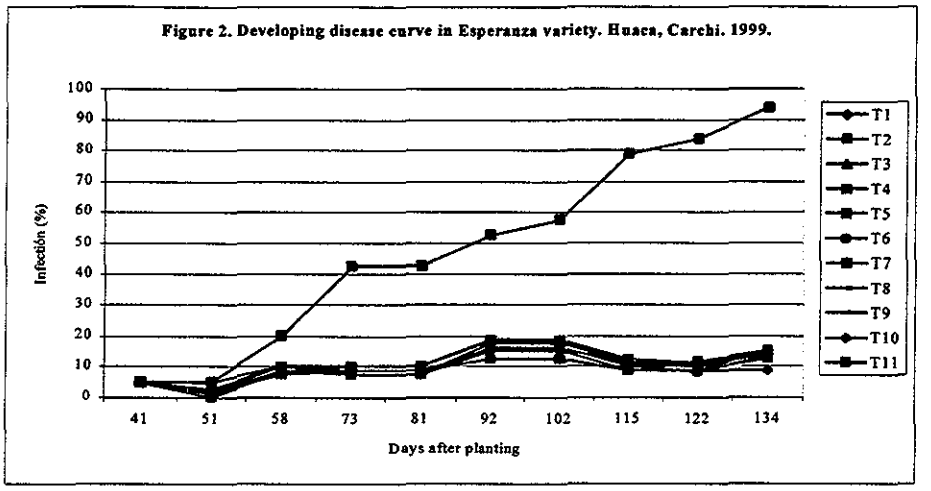
These results are the same as those obtained by Garcés *et al.* (1998) in Chaupi, and Navia *et al.* (1996), according to efficient disease control, with alternative applications of systemic and protectantes fungicides.

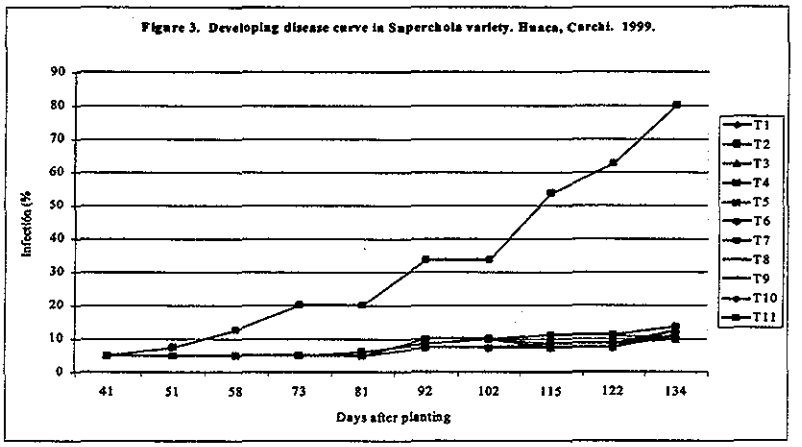
The infection percentage registered in the checks (without control) was 81.3% in Gabriela, 83.8% in Esperanza, and 83.8% in Superchola, which showed that disease pressure was high, and confirmed the efficiency of the evaluated strategies.

Tables 2, 3 and 4 show fungicides name, doses and number of controls complied up to October 2nd: 9 controls for Gabriela in Chaupi, 6 for Esperanza, and 7 for Superchola in Huaca. The farmer's last zone, applied according to his system 6 controls for Esperanza, and 5 for Superchola, mixing up four fungicides.

Figure 1. Developing disease Curve in Gabriela variety. Chaupi, Cotopaxi. 1999.







Conclusions

The isolation proportion 10/90 resistant/sensible to metalaxyl M in *P infestans* population of Chaupi, is different in isolation proportion 100/0 R/S to that one observed in the same area at the end of the crop last year (1998). The reason could be that nowadays farmers do not use phenilamides for disease control. The nine strategies proposed for late blight control keep the crop with low level of *P. infestans* infection, in both areas.

Networking Activities

A. Workshops

- On June 14, in Santa Catalina Experimental Station, we presented Partial Research Results, to show the project advances.

B. Research Investigator Interchanges

- On June 24, an Agriculture Ministry technician visited the field test located at Chaupi to know about the late blight control.

Training output

- At Chaupi, 20 farmers were capacitated on late blight integrated control.
- On September, Cesar Asaquibay gave a presentation of late blight integrated control system to the farmers from San Gabriel, Carchi.

Project Highlight

An informal meeting was held to establish a method to validate and transfer the late blight control results to the farmers.

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Biorational control of the Andean potato weevil, *Premnotrypes vorax* (Hustache)

Investigators: Patricio Gallegos G., Sandra Garcés C., Franklin Maiguashca T.[1], Roger Williams[2] and Jesús Alcazar[3]

Abstract

To protect potato tubers from the damage caused by the Andean potato weevil, *Premnotrypes vorax* (Hustache), potato producers employ a great quantity of pesticides and risk the consequences of affecting the environment. In some studies, as in Chamorro *et al.* 1996, they report adverse effects to human health due to pesticide use. The present project purports to find biological alternatives (micoinsecticidas), derived botanical, or chitin inhibitors, that are of lower risk for human beings. Laboratory and field trials were conducted to examine efficacy of safer compounds. We know the susceptibility of the *P. vorax* adults to Spinosad and etofenprox insecticides. The insect susceptibility to Spinosad was different, with foliage originating from upper stratum of the plant (30 % of mortality) in comparison with the lower stratum (100 % of mortality), (t, P =0.05). Spinosad utilization in weevil traps gave good control. In the laboratory 0.03 y 0.005 % Etofenprox produced 100 % of mortality, after 7 days on potato leaves. Furthermore, we have isolated *Metharrizium* from *P. vorax*. Field trials are presently in process.

The Andean potato weevil, *Premnotrypes vorax* is the main pest of potatoes in Ecuador. If we do not use an adequate practical control, the damage can totally ruin the crop (Gallegos *et al* 1996).

In order to protect the crop farmers use a lot of pesticides; which represents a risk to human health. According to a survey made in Carchi province, 47% of those interviewed knew people who experienced chronic intoxication who use pesticides, also they were aware of persons who had suffered from headaches, dizziness, vision loss (Chamorro, *et al.* 1996).

With the preliminary data showed and in order to find biological products to substitute pesticides, which represent big risks such for both producers as consumers health, this project called Bioracional control, tries to find products of low toxicity for mammals.

Objectives

- To search for control alternatives for the potato weevil with biologicals or products of low mammalian toxicity to expand integrated management systems for potato insect pests.
- To identify biological insecticides of lower mammalian toxicity efficacious in controlling the potato weevil.

The present project contains the following experimental trials:

1. Effect of Spinosad on the mortality of *P. vorax* adults.
2. Validation of Spinosad as a foliar application to control *P. vorax* on potato.
3. Effect of <etofenprox> in the mortality of *P. vorax* adults in laboratory.
4. Study of the efficacy of 8 insecticides for the control of the Andean potato weevil, *P. vorax* of potato control, which have low toxicity for mammals.

Trial 1. Effect of Spinosad on the mortality of *P. vorax* adults

Methodology

Tests made last year (1998) in this IPM CRSP project let us know that *P. vorax* is susceptible to Spinosad (Gallegos *et al.* 1998 and Gallegos *et al.* 1999). The advantage of this product is its low LD50 (5000 mg/k) Thus, the risk to humans is quite low.

In order to know the susceptibility of *P. vorax* adults to Spinosad (fungus toxin of *Saccharopolypora spinosa*), some applications were made to potato plant foliage in the field.

The methodology was the following :

The potatoes utilized for this experiment were the variety INIAP-Gabriela, of 60 days of age. We applied Spinosad to an area of 20m2 at a concentration of 0.09 %. Six

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plants from this area were selected. Three and 6 days after treatment, the leaves were taken from the upper, middle and lower strata of the plants.

We put the leaves from each stratum in petri dishes with 5 adults for a period of 12 hours, then they were replaced by potato leaves without any pesticide. After 14 days we registered insect mortality.

In order to compare we included a check treatment, in which no insecticide was applied.

Results and discussion

Table 1 presents the results of mortality of the adult insects which were fed potato foliage 3 and 6 days after Spinosad treatment.

Table 1. Mortality of *P. vorax* adults fed potato leaves treated with Spinosad 0.09 %. EESC. INIAP. Pichincha. 1999.

	With 3 days foliage	With 6 days foliage
Stratums	**mortality %**	**mortality %**
Upper	40	20
Middle	80	100
Lower	100	100
Check	0	0

Even without an experimental design, we were able to observe higher mortality in the middle and lower strata over the upper stratum. The "t" test used in order to compare the mortality between upper and lower stratum was meaningful (p=0.05) with a value of - 3.1623.

The difference between strata is probably due to the fact that the upper stratum was growing and as it is expanded, it reduced its concentration of foliar pesticide. Furthermore; the foliage from the top received more direct sun which aided in the breakdown of pesticide.

The highest mortality the *P. vorax* adults, appeared in the first four days after eating the foliage with insecticide, indicating rather short residual activity. The capacity of Spinosad to eliminate *P. vorax* was not very different from the 3rd to the 6th day after treatment.

Conclusions

- Insect mortality tends to be higher when they are fed with the lower foliage of the plant.
- The highest mortality occurs on the first few days after feeding on treated foliage.
- These results can serve as a basis for future research works.

Trial 2. Evaluation of foliage applications of Spinosad for the control of *Premnotrypes vorax* on potato

Methodology

In previous work *P. vorax* adults, demonstrated susceptibility to Spinosad when treated foliage was utilized in traps and on potato plants in the field (Gallegos 1998). As a followup the following trial was established in the field. The work was conducted in two communities of Chimborazo province: Rayoloma and Pushñag. Five treatments were evaluated from the factorial A x B + 1, under a randomized complete block design with four repetitions. The factors were: two concentrations of Spinosad (0.09 % and 0.05 %) and two sequences of application (40- 60- 80 days and 40- 60 days, after sowing), and an untreated check.

In order to evaluate the treatments, areas of 5.0 x 6.0 m (30 m2) consisting of 5 furrows of 5.0 m of length by 1.2 m of width were established.

INIAP-Rosita variety of potatoes was used.

In each locality, 15 days before the sowing, 20 traps were placed, according to Gallegos's recommendation, 1996. The traps consisted of foliage of potato, sprayed with a 0.09 % Spinosad solution. The foliage which was used in the trap was then covered with cardboard. At planting the same number of traps were utilized. The foliage in the traps was replaced each 15 days until the plants were 60 days old. At each survey the number of dead weevils was counted.

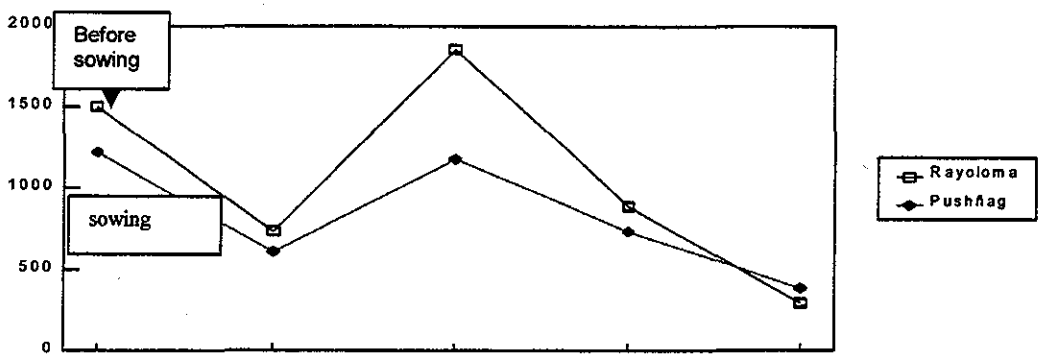
During the crop development we applied pesticide with knapsack (Spinosad to the 0.09 % and 0.05 %) according to the treatments. In addition, we mixed in the adjuvant "Carrier".
At harvest the percentage of tubercles with *P. vorax* damage and the degree of incidence of the damage will be evaluated.

Results and discusion

The adult population captured by traps during the trial, before and after sowing, (Figure 1), shows that adults *P. vorax* kept a similar behavior as the study of Gallegos

1993. Before sowing the adult populations increase and later it is reduced by the effect of trapping. In this case we found, before sowing, a population of 1500 and 1220 adult insects by area, in Rayoloma and Pushñag, respectively. They were decreased to 300 and 390 due to the effect of continued application of Spinosad in the traps, for 45 days after crop emergence.

Figure 1. Mortality of *P. vorax* adults in Spinosad traps. Chimborazo, 1999



Seventy-five days after crop emergence, the crop suffered because the temperature dropped to 0°C. The plant gave new germ of vines for which reason the cycle of crop will be longer than normal. Due to these circumstances the present report is preliminary.

Conclusions

- Adult *P. vorax* populations were decreased for 45 days in two localities.
- Effectiveness in Spinosad applications in traps was effective, as populations were reduced at 300 and 390 insects per area.

Trial 3. Effect of <etofenprox> in the mortality of adults *P. vorax* in the Laboratory

Methodology

In a laboratory trial, Etofenprox insecticide showed capacity to eliminate *P. vorax* adults. Therefore the present study was conducted to evaluate dose effectiveness. The toxicity of this product for human beings is very low (LD50 = 5000mg / k), it offers security when farmers manage it properly.

Studied treatments are listed in Table 2.

Table 2. Etofenprox treatments for the control of *P. vorax* in the laboratory. EESC-Pichincha 1999.

Treatment	Concentration%
1	0.03
2	0.01
3	0.005
4	0.003
5	0.001
6	0.0005
7	Check

The test consisted of supplying *P. vorax* adults with potato foliage which had been dipped for

three minutes in one of indicated concentrations; allowed to dry and then placed with the weevils for 12 hours. After this exposure the weevils were offered untreated foliage.

The statistic design was randomized complete blocks with three replications per treatment.

Evaluations were done after 1, 3, 5, and 7 days. The figures in table 3 are given in percent of mortality. An insect was considered dead if it could not walk.

The experimental unit consisted of a petri dish containing 5 adult insects and the proper potato foliage.

Results and discussion

During the evaluations made at 1, 3, 5 and 7 days, the analysis of the percentage of affected insects, showed a high statistic significance for treatments, (P = 0.01). The variation coefficients were lower than 10.5 %.

Tukey test was conducted to find statistical significance for treatments, see Table 3.

Table 3. Tukey test for the percentage of affected insects with etofenprox to 1, 3, 5, 7 evaluation days. EESC. INIAP. Pichincha. 1999.

Treatments	Evaluation days			
Concentrations%	1	3	5	7
0.03	100.0 a	100.0 a	100.0 a	100.0 a
0.01	100.0 a	100.0 a	94.0 a	100.0 a
0.005	100.0 a	94.0 a	94.0 a	100.0 a
0.003	100.0 a	94.0 a	80.0 a	100.0 a
0.001	86.0 ab	80.0 a	80.0 a	100.0 a
0.0005	74.0 b	66.0 a	74.0 a	100.0 a
Check	0 .0 c	0.0 b	6.0 b	6.0 b

In the first day evaluation, all the concentrations produced differences in insect mortality of 74 % or more reflecting the rapid action of Etofenprox.

On the third day all concentration were statistically equal and furthermore they presented a clear differentiation with the check which was located in another range of significance. In the evaluation seven days after treatment all insects were dead in those treated with Etofenprox.

The concentrations of 0.0005 and 0.001 % showed a similar reaction to the recommended concentration to be used in the field - 0.03 % (BASF 1998). This can be explained in part by the closed ambiance of the containers where the tests were conducted. Etofenprox's mode of action is generally by contact, however it is possible that in a close container their may be some fumigation action.

Conclusions

- The laboratory test allowed us to immediately identify the susceptibility of adults of *P. vorax* to Etofenprox.
- Even low dosages were highly toxic to the weevils.
- Starting on the third day, there were no statistical differences between the treatments.
- Etofenprox needs to be studied using other techniques in order to determine its best utility in controling *P. vorax* in potatoes.

Trial 4. Study of the efficacy of 8 insecticides of low mammalian toxicity to control the adults of the Andean potato weevil in the field.

Methodology

This study will be carried out two steps. The first one was in the laboratory and the second will be in the laboratory and field.

Stage 1. Laboratory evaluation of biological insecticides (micoinsecticidas) and insecticides of low toxicity for mammals against the adults of the Andean potato weevil.

Treatments were as follows:
1. *Beauveria bassiana*
2. *Metarhizium anisoplae*
3. Azadirachtina
4. Buprofezin
5. Etofenprox
6. Diflubenzuron
7. Clorfurazuron
8. Trifllumuron
9. Check, untreated control
10. Check chemical control with, acephate.

The first eight treatments were divided into three separate applications.

An experimental unit consists of potato foliage plus 30 adult insects (15 females and 15 males) in a plastic container.

The variables will be following: Mortality, number of eggs and percentage of egg eclosion.

The experimental design is randomized complete blocks, with three observations per treatment, with a factorial of 8 x 3 + 2.

It is important to notice that we count on *P. vorax* infected with Metharhizium.

Stage 2. Biological and lower toxicity insecticide evaluation (micoinsecticidas), which passed stage 1 are further tested in stage 2.

The treatments that succeded the former stage will be used in a potato crop in order to know the persistence in the field. The foliage from these plants will be supplied to adult insects to evaluated their efficacy.

The insecticide persistence in the field will be evaluated for a period of 15 days.

The variables will be the same used in Stage 1. They are: mortality of adults, number of eggs and percentage of egg eclosion. At the moment (August 99), the first stage is installed and the first evaluations have been initiated.

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Biological Control of the Central American Tuber Moth, *Tecia solanivora* Povolny with *Baculovirus* and *Bacillus thuringiensis* in Storage for Seed

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Abstract

The potato moth *Tecia solanivora*, in the province of Carchi produces high losses in stored tubers. To control it, producers use highly toxic pesticides without taking protective measures. The use of biological control may represent an appropriate alternative to the highly toxic compounds presently used. The present study was developed in two phases; one in laboratory and another in field. The difference between the two virus strains (the granulosis virus and the nucleopolyhedrosis virus) was studied in the first phase.

For this trial potato tubers were submirged in viral solutions from 10 to 60 larval equivalents. First-instar larval were placed on these tuber and the evaluations were performed in the last larval instar based on the number of infected larvae. Both strains were pathogenic for the moth, although with a similar behavior. The concentration of 60 larval equivalents produced a mortality of at least 88.9% for both viruses. The LC_{50} was of 2.77 larvae/liter for the granulosis virus and of 3.75 larvae/liter for the nucleopolyhedrosis virus.

The second phase was made with nucleopolyhedrosis virus (with 60 larval equivalents), in addition to *Bacillus thuringiensis*, carbaryl, talc along with anuntreated check. The control treatments were statistically similar, but different from the check. The low insect population development, for handling effects did not permit to get higher differences among treatments. The damage level in the check only reached 12.7%. The nucleopolyhedrosis virus provided a greater effect; only 1.37% of tubers were damaged. The infestation procedure of the stored tubers, by means of adults of *Tecia* will have to be reviewed in order to obtain a better development of the insect population. The use of biological control for *Tecia* will allow potato farmers in Ecuador to avoid intoxication problems and to obtain economical insect control during storage of seed pieces.

Introduction

The Central American potato tuber moth, *Tecia solanivora* Polvony is a recent arrival in Ecuador (1996), coming from Colombia (MAG-SESA-INIAP-ICA 1996), therefore famers do not count on appropriate technology for its control, which at the moment is based only on the use of toxic broad-spectrum pesticides.

The area of major incidence of the insect is located in the Province of Carchi which shares a common border with Colombia.

The pest causes damage to the tuber in the field, up to 40% and in storage the loss can be total. Therefore, it is important to investigate various control strategies within integrated pest management.

Since this insect has greater importance in storage, the control is centered around those conditions. The proposed control is a biological one, through the use of the Baculovirus and *Bacillus thuringiensis*. In Venezuela and Colombia *Baculovirus phthorimaea* (which corresponds to granulosis virus VG) provides efficient control of *T. solanivora*. On the other hand, in Ecuador, Alcázar and Gallegos (1997) found *Tecia* larvae with virus symptoms in El Chamizo, Carchi. It was tested at CIP, Lima and determined that it is a new entomopathogenous virus of *Tecia*, and classified as a nucleopolyhedrosis virus (NPV) (Personal information). Therefore, the present study compares these two types/strains of viruses.

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Regarding *B. thuringiensis,* it is known that it is successfully used in the control of various moths, consequently, it will also be part of this study.

Objectives

- To determine the efficiency of biological control of *Tecia* in stored seed potatoes.
- To evaluate the pathogenecity of two strains of Baculovirus (VG and NPV) in larvae of *Tecia solanivora,* under laboratory conditions.
- To compare the efficacy of *Bacillus thuringiensis* with the better strain of Baculovirus, in potato tubers stored for seed.

The control of *Tecia solanivora* through the use of Baculovirus and *Bacillus thuringiensis* in potato tubers for seed is efficient.

Methodology

The present study was developed in two phases. The first, was to test pathogenicity of the two virus strains (VG and NPV) and the second, to evaluate a combination of *Bacillus thuringiensis* and the better strain of baculovirus, for the prevention and control of *Tecia* in stored seed.

A. Phase I: Pathogenicity test for virus strains in laboratory.

1. Location

The study was conducted under laboratory conditions at the Validation an Technology Transfer Unit (UVTT), Carchi, INIAP, located in San Gabriel, Province of Carchi, at an altitude of 2,860 meters above sea level.

2. Study material sources

Breeding of *Tecia solanivora*: Several tests were conducted to determine the best rearing method and to determine the necessary materials to establish a massive breeding program for *Tecia solanivora.*

The work began with the collection of moths, from potato seed storage from farms in El Chamizo. The adults were place in 3 breeding cages with 80 adults per cage.

Eggs were collected over a period of 3 days. Then daily observations were made until the eggs had hatched and larvae emerged. First instar larvae were utilized to infest the potato tubers "superchola" variety in order to evaluate the viral strains (VG and NPV).

Multiplication of the granulosis virus and nucleopolyhedrosis virus in the larvae of *Tecia solanivora*: Strains of the VG and NPV viruses were purified in the International Potato Center and multiplied in larvae of *Phthorimea operculella.* Prior to the begining of the work, the larva of *Tecia solanivora* were infected with the methodology recommended by Alcazar *et al* (1992).

Thirty five days later, sick larvae of *Tecia* were collected which showed the characteristic symptoms of infection by the virus. This work was perfomed independently for the two strains in such a way that infected larvae of VG and NPV were obtained to uilized for this trial.

3. Development of the trial

The methodology of Alcázar *et al.* 1992, Angeles 1994; and Niño de Gualdron 1997 were employed this trial.

The infected larvae served to prepare a viral solution. The concentration of this solution was expressed as larval equivalents (LE), which corresponds to the number of larvae per liter of solution.

Treated potato tubers were submerged in the virus solution for five minutes. The tubers were dried indoors and then placed in a plastic recipient before being infested with 10 recently emerged larvae.

The treatments were 10, 20, 30, 40, 50 and 60 larval equivalents per virus. Additionally a check treatment was employed, which was treated only with destilled water and 0.2% Agral.

The effect of the virus was evaluated by counting the number of dead larvae after 35 days. This time coincides with the appearance of the first pupae, as described by Niño Gualdron (1997).

The test was implemented under Randomized Complete Block Design with four repetitions. The experimental unit was of 3 tubers, the average analysis of the test in which statistical significance was found was realized through the Tukey 5% test.

The mortality observed in each one of the treaments was corrected by means of the mortality of the check using Abbott's formula (Gualdron, L 1997). The analysis of the dose-mortality relations to determine the medium lethal concentration (LC_{50}) as well as the liability limits at 95%, were realised by means of the Probit Analysis (Infante 1986).

B. Phase II. Biological control of *Tecia* in stored potatoes.

The tuber storage trial was located in the town El Chamizo, Mortúfar, Carchi, in a storehouse with diffuse light, under

controlled infestation. The experimental unit corresponded to 10 kg. of "superchola" potatoes deposited in dense plastic fiber sacks in which 5 pairs of *Tecia* adults were liberated.

The treatments in study were the following:
T1. Baculovirus NPV 2.5 g/ kg of potato tubers
T2. Baculovirus NPV 5.0 g/ kg of potato tubers
T3. Baculovirus NPV 7.5 g/kg of potato tubers
T4. *Bacillus thuringiensis* (5%) 2.5 g/kg of potato tubers
T5. *Bacillus thuringiensis* (5%) 5.0 g/kg of potato tubers
T6. *Bacillus thuringiensis* (5%) 7.5 g/kg of potato tubers
T7. Carbaryl (10%) 5.0 g/kg of potato tubers.
T8. Talc 5 g/kg of potato tubers
T9. Check. (Untreated control).

The treatments with Baculovirus and *Bacillus* were named products and Carbaryl and talc, as additional treatments. All the treatments were applied as dusts.

The treatments with Baculovirus were prepared at a concentration of 60 larval equivalents and for *Bacillus*, a commercial formulation was used and it's concentration was reduced by adding corn floor.

The statistical design was a totally random in factorial arrangement 2x3+3. A total of ofour bservations were made.

The evaluation was conduced at the end of the storage period of 115 days and the percentage of tubers with damage was registered.

V. Results and Discussion.

Phase I

The analysis of the variance of larval mortality is presented as percentage in Table 1. The real values were corrected by means of the Abbott's formula (Gualdron 1997).

Table 1. Analysis of variance of larval mortality in percentages. San Gabriel. Carchi. 1999.

Variation source.	Degrees of freedom.	Mean Square
Total	51	
Treatments	(12)	58.54 **
Strains (C)	1	5.33 n.s.
Larval Equivalent larval (LE)	5	19.15 *
C x E	5	4.88 n.s.
Factors vs. Check	1	576.92 **
Experimental error	39	6.11

** P= 0.01; * P=0.05; n.s.= non significant.
0 *Variation coefficient = 9.58%*

Table 1 shows the statistic significance for treatments. It indicates that significant larval mortality was realized. The comparison among strains was not significant.

The larval equivalents were significant which tells us that the larvae are sensitive to the variation of the viral particle concentrations defined as larval equivalent.

The highly significant comparison between factors and check shows that the resulting mortality in the treatments is due to the application of the strains of baculovirus.

Table 2 shows the Tukey tests (5%) for the percentage of larval mortality cause by the granulosis virus (VG) and nucleopolyhiedrosis virus (NPV). For purpose of comparison the values for each strain was regrouped although the statistical test was only one.

Table 2. Tukey test 5%, for the percentage of larval mortality of *Tecia solanivora* for granulosis virus (VG), and nucleopolyhiedrosis virus (NPV). San Gabriel. Carchi. 1999.

Treatments	**Strain VG**		**NPV strain**	
E.L (larvae/liter)	**Observed mortality (%)**	**Corrected mortality (%)**	**Observed mortality (%)**	**Corrected mortality (%)**
60	96.7	93.7 a	94.2	88.9 a
50	90.0	81.0 bc	94.2	88.9 a
40	91.7	84.1 b	95.8	92.1 a
30	88.3	77.8 c	82.5	66.7 bc
20	87.5	76.2 c	80.0	61.9 c
10	87.5	76.2 c	81.7	65.1 c
Check (untreated)	47.5	0.0 d	47.5	0.0 d

Dosages of 10 to 60 larval equivalents in the case of VG produced a corrected mortality of from 76.2% to 93.7%, and the NPV strain of from 65.1% to 88.9%. In both cases, these larval equivalents were above the 50% level of mortality. The comparison between the two strains shows a range difference only in the dosage range of 40 and 50 larval equivalents. The rest of values share equal ranges. Despite the presence of several levels, the comparison between strains permit us to confirm that there were no important differences between the two.

The check was in a different level from the other treatments. After application of Abbott's formula, the checks value was zero.

The mortality observed in the two checks of 47.5% reflexes a high larval mortality, which may due to a natural mortality, or it could represent handling effects.

The values of dose-mortality for each one of the virus strains permitted calculation of a medium lethal concentration value (LC 50) Table 3.

Table 3. Medium lethal concentration (LC50) and liability limits for the strains of the granulosis and the nucleopoliedrosis virus in larvae of *Tecia solanivora*. San Gabriel. Carchi. 1999.

Viral strains	LC 50 (larvae /liter)	Reliability limits
Granulosis virus	2.77	0.5208-5.7372
Nucleopolyhedrosis virus	3.76	1.0770-6.7140

The LC 50 for the granulosis virus was of 2.77 larval equivalents, and for the nucleopolihydrosis virus was 3.76. It means that the first strain requires less concentration to produce the same effect than the second. However, in the variance test, there was no statistical difference between strains.

The equation of regression for the granulosis virus was the following: Y=4.57+0.97X. On the other hand, for the nucleopoliedrosis virus it was: Y=4.40+1.04X.

Phase II

The analysis of variance for the percentage of damaged tubers was highly significant for the products factor; highly significant for the interaction between factors in study and additional treatments; highly significant for the interactions with talc, carbaryl and the untreated check; significant differences for the dosage factor; and non significant for the interaction of product per dosage.

Table 4 presents Tukey test (5%), for the average of the treatments in study for the variability of tubers with damage.

Table 4. Tukey test 5% for the variable percentage of tubers with damage of *Tecia solanivora*. San Gabriel. Carchi. 1999.

Treatments	Tubers with damage (%)
T9	12.7 a
T4	4.2 b
T6	3.5 b
T8	2.6 b
T1	1.5 b
T5	1.3 b
T7	0.8 b
T3	0.8 b
T2	0.6 b

Treatment 9 which corresponds to the check or untreated control presents the highest percentage of tubers with damage, 12.7%. It is in a different level of injury from the other treatments. This result shows that treatments controlled *Tecia* larvae, even the use of only talc (T8).

The Tukey test 5% for the comparison between Baculovirus NPV and *Bacillus thuringiensis* demonstrated the presence of two levels of control. The Baculovirus presented a better control than the B. thuringiensis, due, possibly to it's higher specificity for *Tecia* (Table 5).

Table 5. Tukey test (5%) for the comparison between *B. thuringiensis* and Baculovirus NPV to prevent damage to potato tubers from *Tecia solanivora*. San Gabriel. Carchi. 1999.

Produts	% tubers with damage
B. thuringiensis	2.96 a
Baculovirus	0.97 b

In spite of the fact that the analysis of variance indicated high statistical significance for the same factors, the low level of insect damage did not permit a better manifestation of the control as the checks only reached a level of 12.7% damage.

Conclusions

- The larvae of *Tecia solanivora* demonstrated susceptibility to both the granulosis virus (VG) and the nucleopoliedrosis virus (NPV)
- Statistical differences were not found between the granulosis virus (VG) and nucleopolihydrosis virus (NPV).
- The medium lethal concentration (LC 50), for the VG was 2.77 LE and for the NPV it was 3.76 LE.
- The 60 LE presented a mortality of at least 88.9% for the two viruses.
- In the trial to prevent damage to stored potato tubers the check (untreated control) had higher damage than the other treatments.
- The low damage level of the pest did not permit better action of the treatments.
- The baculovirus NPV offered a better control than *B. thuringiensis*.
- The management of the experiment in storage needs to be improved.

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Diagnosis and Etiology of Babaco Diseases in Ecuador

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Abstract

In Ecuador, Babaco Vascular Wilt caused by *Fusarium oxisporum* is the most important disease of babaco. Plants are systemically colonized and the disease results in plant death. Incidences up to 100% have been observed. Seed piece rot is associated with *Pythium mamilatum* and *Pythium ultimun.* Disease incidence can reach 20%, and the disease is thought to be associated with low vigor of seed piece. Root rot is caused by *Erwinia* sp. and *Pseudomonas* sp., and results in similar wilt symptoms. Powdery mildew (*Oidium* sp.) is an important disease of babaco in greenhouses. If disease control is neglected, plant defoliation can occur. Foliar diseases caused by *Micosphaerella* sp., *Colletrichum sp.* and *Phyllosticta* sp. are similar in appearence, together they are important in field plantings in humid areas. "Peca" caused by *Aperosporium caricae* is distributed contrywide. Mainly due to the small lesion size, peca alone is not so important. In Azuay, it did cause defoliation and fruit infection. "Lancha" is caused by *Alternaria sp.* and although it is frequently found, it is considered an unimportant disease. Fruit rot caused by *Colletotrichum sp.* is associated with poor harvest practices. Some virus like symptoms are apparently caused by nutrient deficiencies.

Babaco, *Carica heilbornii* nothovar *pentagona* is a species derived from a spontaneous cross between *Carica pubescens* "chamburo" and *Carica stipulata* "toronche" (2). This species is one of the most promising native exotic fruits of Ecuador mainly due to its aroma, taste, absence of seeds, low sugar content, good level of vitamins and minerals, and long storage capacity. Increase in local market demand and export perspectives have created interest in babaco cultivation, especially in plastic greenhouses (13). However, among other problems, diseases are serious limiting factors of babaco cultivation. Disease management is at the moment precarious and improvised, mainly due to a lack of etiological knowledge.

Babaco diseases have been described in some babaco production areas (6,7,9,11,16,17, 18,19,20,21,22). However, etiology of soil born diseases has not been well characterized and symptoms, and etiology of foliar diseases is poorly described. This study was conducted to clarify the etiology of some diseases and to characterize diseases of unknown etiology.

Research Methods

Etiological and diagnostic studies of the main babaco diseases were conducted in the main babaco production areas of the provinces of Pichincha, Tungurahua, Azuay and Loja. At least five babaco orchards were analyzed in each location, using a diagnosis form. The form contained questions about cropping system, incidence, distribution, plant origin, irrigation system and irrigation frequency, fertilization and disease management. Type and characteristics of the disease symptoms were also described in detail on the form. Diseased plants or parts of diseased plants were brought from various orchards to the laboratory at the Plant Protection Department of Sta. Catalina Experimental Station, INIAP in Quito-Ecuador.

Fungal isolations were done on Potato Dextrosa Agar (PDA), Malt Extract Agar (MEA), V8 Juice Agar (V8), Corn Meal Agar (CMA) and Corn Meal Agar Pimaricina, Ampicilina, Rifampicina PCNB (P_5 ARP). For bacterial isolation, Nutritive Agar (NA), Crystal Violet Pectate (CVP) and B of King Agar (KB) mediums were used. Culture media were prepared as described by Singleton *et al*, 1992 (15) and Schaad, 1980 (14) for fungi and bacteria, respectively. Fungal identification was conducted by comparing their reproductive structures with those of taxonomic keys (3, 4,5,8,10,23) Bacterial identification was conducted according to colony type on the different culture media.

Pathogenicity tests were conducted according to pathogen requirements. For soil borne pathogens inoculum was uniformly distributed in the pots. For foliar diseases, pathogen spores were uniformly sprayed on the leaves and plants were incubated in a chamber with 100% of relative humidity. Controls without inoculum were always included in the tests. Inoculated plants were carefully observed for symptom appearance. Symptoms were described and if possible disease scales were developed. Re-inoculations were also conducted to complete Koch postulates.

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Research Results

Babaco Vascular Wilt

Babaco Vascular Wilt (BVW) is also called Fusariosis. Symptoms begin with chlorosis of the lowest leaf followed by a progressive upward chlorosis and defoliation of the plant. Chlorosis of the lowest leaves is frequently characterized by a lengthwise pattern on half of the leaf. Fruits ripen prematurely and fall. In some cases, symptoms appear longitudinally along a part of the stem, but in the majority of cases the whole plant becomes affected. On stem tissues surrounding the zone of leaf and fruit abscission, slightly depressed olive spots develop. These spots are most obvious on the stem apex when the plant is defoliated. During final stages of the disease, spots take the shape of lengthened bands. Finally, infected tissue becomes soft and a progressive necrosis proceeds down from the apex covering the entire plant. When relative humidity is high, a wet rot with a fetid odor is the final disease symptom. The crown and principal roots are not decomposed until the final stages of the disease. Longitudinal and transver selections of a diseased stem shows olive green to light brown spots in the vascular tissue. When the observed plant is completely colonized by the pathogen, an orange sporulation is visible on necrotic tissue.

Due to the rot like symptoms, the causal organism was initially thought to be a bacterium and the disease was named "Bacteriosis". This disease is caused by *Fusarium oxisporum*. The pathogen was isolated from fine roots, principal roots, collar, stem, stem apex and fruits. The fungus was systemic in the plant. The disease was present in all provinces studied and disease incidence reached 100%. However, some orchards from all region are free of the disease. Although the disease was present in exposed fields as well as greenhouses, disease incidence was much higher in greenhouses. Similarly, orchards irrigated with surface irrigation and overhead irrigation showed higher levels of disease than those irrigated with trickle or seasonal rainfall. Effective control measures do not exist. However, several growers attempt control by using mancoceb and cooper fungicides, and the antibiotics Enrofloxacina, and Oxitetraciclinas, Sulfadiazina and Trimetoprim. None of these chemicals provide effective control.

Rot of the seed piece

Seed piece rot is also an important soil borne disease of babaco. Symptoms start with a semi wet, soft and brown rot of the base of the seed piece. Rot eventually covers the entire seed piece. Bark frequently does not rot and the seed piece develops a hollow appearance. Disease incidence varied from 1 to 50%, but average incidence was about 22%. Padilla, 1992 (11), identified *Pythium sp.* as the causal organism of seed piece rot. In this study *Pythium mamilatum* and *Pythium ultimun* were associated with the disease. Seed or soil disinfestation and rooting hormone applications did not reduce seed piece rot incidence. Apparently damage to the stem predisposes the seed piece to rot, Pythium species are weak pathogens in this case (1,12).

Root rot

Babaco root rot was first observed in Zigzig-Azuay and Baños-Tungurahua. The disease was recently observed at a very high incidence in Tumbaco-Pichincha. The disease is associated with *Erwinia sp.* and *Pseudomonas sp.*, both cause similar symptoms and are sometimes isolated together from the same plant. The entire plant suddenly wilts. Leaves get flaccid and hang on petioles. Leaf color between veins turns yellow-silver. Leaves remain on the plant until plant death. If the root system is observed fine and principal roots are rotted. Diseased plants are often isolated in the orchard, perhaps because the inoculum is soil or seed piece- borne. When inoculum is water- borne, the entire orchard can be affected. Disease incidence varied from very low, less than 1% in the majority of orchards to 100% in one orchard. Babaco root rot is generally found at low incidences, but it can become serious if irrigation disseminates the pathogen, which apparently happens in some valleys of Ecuador. Disease control has been tried with kasugamycin aplications, apparently with success.

Powdery Mildew (PM)

Symptoms of PM are initially observed on the lower leaf surface as small, diffuse and translucent spots, which become chlorotic. Spots enlarge covering, in majority of cases, the entire leaf. A powdery sporulation covers spots.

Sporulation is more frequently observed on the lower surface of the leaf. In very aggressive infections, both sides of the leaf, petioles and flowers can be covered by sporulation. Eventually sporulation covers the entire leaf and the leaves become twisted and fall. Fallen leaves are the main source of inoculum for future infections. PM develops from the lower to upper part of the plant. *Oidium sp.* is the causal organism of this disease and it is found countrywide. PM is a serious disease in greenhouses. Disease severities vary from 0 to 70%. In the majority of orchards, absence or low disease severity was due to efficient control with pyrazophos and penconazole fungicides.

Blight

Blight is mainly observed in mature leaf tissue. Irregular necrotic spots (3 to 5 cm) develop. Lesions at first are light brown and become dark brown when mature. The border of the lesions is well defined and is surrounded by a slight chlorotic ring. Concentric rings are usually formed successively inside the lesion. The causal organism of babaco blight is *Alternaria sp.* In pathogenicity tests, *Alternaria sp.* required an incubation period of 20 days. Disease severity varied from 0 to 10%. "Blight" was more

frequent when the crop was densely cultivated and relative humidity was high.

Anthracnoses

On leaves, irregular necrotic spots develop. Lesions have a brown border and are pale in the center. Spots have a well-defined dark border, some times surrounded by a diffuse chlorotic ring. Lesions reach 3 cm individually, but when they coalesce, a significant area of the leaf can be covered. On the center and upper side of the lesion many fruiting bodies grouped in circular patterns can be observed. Lesions regularly enlarge in direction of the leaf border, and veins do not limit lesion growth. *Mychosphaerella sp.* is the pathogen associated with anthracnose, ascocarps are easily found in the center of the lesion, and conidia of *Cercospora sp.* can be found growing in the border of the lesion. Therefore, the telomorph and anamorph stages of the fungus are apparently growing in the same lesion (27,45). Anthracnose severity was low in all orchards studied, perhaps due to control practices currently conducted by farmers. To control anthracnose, farmers spray chlorothalonil, copper, and copper hydroxide, metalaxil, propideb, mancoceb and benomyl fungicides.

Phyllosticta

Phyllosticta and anthracnose symptoms are very similar in appearance. Lesions are also brown at the border and pale in the center. Borders are irregularly defined and rarely surrounded by chlorotic rings. Lesion size varies from 0.5 to 2 cm. However, when they coalesce, they can reach 7 cm. Within the lesion black picnidia are clearly visible. These lesions are often found on the same leaf with lesions caused by other pathogens, but rarely join together. The causal organism of this disease is *Phyllosticta sp.*, which had an incubation period of 13 days. This disease is most common in exposed fields with humid and relatively cold environments. Disease severity did not exceed 4% probably due to fungicide sprays conducted by farmers to control foliar spots.

Foliar spot or Colletotrichum

Lesions of foliar spot are similar in appearance to anthracnose and *Phyllosticta* spots. Lesions are dark brown with a defined, regular and often darker border. Chlorotic rings rarely surround lesions.

Lesion size regularly reaches 2 cm, but when they coalesce, they can cover extensive leaf areas. Internally in the lesion dark brow acervuli develop in a circular pattern. In old lesions acervuli become orange. Foliar spots often grow together with other leaf spots. The causal organism of this disease is *Colletotrichum sp.*, which has an incubation period of 12 days.

Foliar spot was frequently observed in exposed fields under humid and relatively warm conditions. Disease severity did not reach more than 10%. Perhaps foliar sprays done regularly by farmers as described for anthracnose could have reduced foliar spot severity.

Peca or Asperosporium

"Peca" is characterized by small cream to light brown leaf spots with a dark ring surrounding the lesion. Lesions are mainly circular to irregular with 0.5 to 0.8 cm size. On the lower side of the lesion, abundant black acervuli develop. Observation of acervuli reveals the presence of abundant conidia. Lesions usually develop individually, but lesions can coalesce covering a significant area of the leaf. Lesions usually develop together with other lesions. *Asperosporium sp.* is the causal organism of the disease. Although it was present in every region, disease severity did not exceed 2 %. The low disease severity can, in some cases, be explained by fungicides applied by farmers for control of leaf spots. Peca is more frequently observed in exposed fields. Disease levels can reach 10%.

Asperosporium-like symptoms were observed in Azuay, but in this case fruit infection was also present. Slight depressions about one centimeter in diameter limited by a crack were observed on fruits. On these depressions, black acervuli developed, which contained slightly different conidia than those produced by *Asperosporium caricae*. Apparently, this pathogen is a different strain of the fungus.

Fruit rot

"Fruit rot" was very rare and it was only present when fruit were poorly handled. An extensive light brow rotting of the fruit starts near the fruit peduncle, where natural injuries allow the pathogen to penetrate. Fruit rot can cover more than 50% of the fruit. Fruit rot is caused by *Colletotrichum* sp.

Nutritional unvalances

Leaf deformations, mosaic patterns and over-growths have been observed in babaco. These symptoms often have virus-like disease appearance. However, plants recover after fertilization, suggesting that these symptoms are associated with nutritional deficiencies. In nutritional analysis, calcium, iron and manganese deficiencies were observed. Furthermore, seed pieces do not disseminate these symptoms.

Foliar deformations have been described as genetic disorders in close babaco relatives. In addition some babaco clones have fruit deformations. Consequently, some of these symptoms could be due to genetic disorders.

In general presence of plant deformations, mosaics and overgrowths are of low incidence and in the majority of cases plants recover under good cultural management.

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Babaco Vascular Wilt: diagnosis, etiology and its association with *Meloidogyne incognita* in Ecuador

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Abstract

Babaco Vascular Wilt (BVW) or Fusariosis is the most important disease of the babaco in Ecuador. It was found distributed countrywide and disease incidences up to 100% have been observed. Symptoms BVW begin with chlorosis of the lowest leaf, followed by a progressive chlorosis and defoliation of the plant. Final stages of the disease are characterized by plant rot. Due to the final rot like sympthoms, the cause of the disease was attributed to bacteria and the disease was named "bacteriosis". But, in pathogenicity tests *Fusarium oxysporum* was identified as the causal organism of this disease. Studies of *F. oxysporum-Meloidogyne incognita* interactions revealed than *F. oxysporum* along can cause the disease, however the nematode speeds up establishment of the fungus. An efficient way of the fungus transmission is through piece seed. Within the orchard surface and overhead irrigation systems efficiently disseminate the pathogen. An early detection of initial symptoms (level 1 and level 2) can allow recovery of infected plants with applications of carbendazim and propiconazole. When disease is already established a combination of plant eradication and disease control is recommended.

Incidence of babaco soilborne diseases has recently reached important levels, significant yield losses are reported for these diseases (14). In Ecuador, *Fusarium* sp. (4), *Pythium* sp. (11) and several bacteria (14) are reported as babaco soil borne diseases, but some etiological aspects are not well defined.

In 1996, a very serious babaco wilt appeared in Ecuador. Disease incidence reached up to 100%, the disease is at the moment countrywide. Chlorosis, defoliation, ending with plant rot are the most notorious symptoms of this disease. At the beginning the causal organism was attributed to a bacterium due to the final rotting symptoms and the disease was named "bacteriosis". Attempts for disease control have been done with antibiotics and copper fungicides without any success and disease has been so far out of control. Lack of disease control suggested that disease diagnosis had been wrongly done and therefore etiological studies were necessary. This study was carried out to diagnose the disease, to characterize its etiology, and to study the disease association with *Meloidogyne incognita.*

During the research, due to the evident vascular wilt symptoms, the initial disease name "bacteriosis" was changed by Babaco Vascular Wilt, name that is used in this article.

Research Methods

Babaco Vascular Wilt (BVW) diagnosis was carried out in at least five orchards of provinces of Imbabura, Pichincha. Tungurahua, Azuay and Loja. Characterization of the etiology and the study of disease association with *M. Incognita* were done in the laboratories and greenhouses of The Plant Protection Department of Sta. Catalina Experimental Station of INIAP in Quito-Ecuador.

At each orchard a diagnosis form was fill out. The form contained questions about crop system, incidence, distribution, plant origin, irrigation system, and irrigation frequency, fertilization and disease management. Type and characteristics of disease symptoms were also described in detail in the form. Diseased plants with different disease level were sampled and carried to the laboratory.

Pathogen isolation was done from fine roots, principal roots, caller, stem, stem apex and fruits. For fungi isolation, Potato Dextrosa Agar (PDA), Malt Extract Agar (MEA), V8 Juice Agar (V8), Corn Meal Agar (CMA) and Corn Meal Agar Pimaricina, Ampicilina, Rifampicina and PCNB (P_5 ARP) were used. Nutritive Agar (NA), Crystal Violet Pectate (CVP) and B of King Agar (KB). were used for bacteria isolation. Culture mediums were prepared as described by Singleton *et al*, 1992 (13) and Schaad, 1980(12) for fungi and bacteria respectively.

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Fungi isolation from fine roots was done by disinfecting for three minutes diseased root of 2 cm long in a solution of 0.05% sodium hicoclorite. For fungi isolation, from principal roots, collar, stem, stem apex and fruits, pieces of 2 cm side were disinfected for three minutes in a solution of 3% of sodium hipoclorite. Immediately after disinfection, tissue was rinsed for three times with sterile water. In aseptic conditions tissue was sectioned into smaller pieces of approximately 0.125 cm^3. These pieces were then placed in petri dishes containing different culture mediums. Petry dishes were incubated at 20 °C until fungus growth and then exposed to daylight to induce fungus sporulation. Fungi were identified by comparing their reproductive structures with those of taxonomic keys (1,2,3,6,10,15).

For bacteria isolation, pieces of 0.125 cm^3 of affected tissue were disinfected for one minute in a solution of 0.05% sodium hipoclorite. These pieces were then suspended in 2 ml of sterile water for half-hour to obtain bacterial suspension. From this bacterial suspension, dilutions of 10^{-1}, 10^{-2} and 10^{-3} were done. One ml of each of these three dilutions was uniformly distributed in petri dishes containing the culture mediums described previously. Petri dishes were then incubated at 28 °C until bacteria development.

Fungus pathogenicity test was carried out with *Fusarium oxisporum*, which was the most consistently and pathogenic isolated fungus. The test was done with seven month old plants grown in plastic sheaths of 3 kg of potting soil capacity. Potting soil consisted of 1/3 organic soil, 1/3 compost and 1/3 sand. 10^6 conidia of *Fusarium oxysporum* suspended in 40 ml of sterile water were let to reach plant roots through four plastic straws disposed equidistantly around the plant 5 cm from the stem. Three colonies of bacteria grown in NA differing in color, form an appearance were tested for pathogenicity. Inoculation of bacteria was done by taking a bacterial colony with the tip of a sterile wood toothpick and introducing it into the cortex of babaco detached stocks and into principal roots, caller and stem of healthy plants. In both cases, checks without inoculum but treated in the same way of inoculated plants were also included in the tests. Detached stocks were incubated in a growth chamber at 100% of relative humidity and inoculated plants were transferred to a room chamber with the same relative humidity. After inoculation plants were watered daily with 400 ml of sterilized water. After symptoms recovery re-aisolation of the pathogen was done in the same way of isolation. Identification of Fusarium specie was done using Nelson *et al*, 1981(10) criteria, based on monosporic isolates grown on PDA and leaf carnation agar (LCA).

Degree of association between *F. oxysporum* and *M.incognita* was studied evaluating plant reaction of all pathogen combinations: *F. oxysporum* (F), *M. incognita* (M) and *F. oxysporum* + *M. incognita* (F+M). A check (c), without any inoculation was also included. Each treatment was evaluated in four replications (plants). *M. incognita* was inoculated applying 10^4 larvae L_3 per plant. Nematode inoculum was obtained from galls of infected roots of tomato tree plants. Nematode eggs were extracted from the roots using the sodium hipoclorite method. Extracted eggs were then incubated in a exuded solution of naranjilla (*Solanum quitoense*) roots until larvae eclotion. Inoculations of *F. oxysporum* were done applying 10^6 conidia per plant eight days after *M incognita* inoculations. In this experiment inoculation of *M. incognita* and *F. oxysporum* was done in the same way as *F. oxysporum* in pathogenecity test. Time in days of four levels of BVW appearance according to the 0-9 scale (Table 1) and the final population of *M. incognita* were evaluated in this experiment.

Table 1. Schematic scale of Babaco Vascular Wilt development obtained from pathogenicity tests. Quito-Ecuador, 1998.

Level	Symptoms
0	Healthy plant
1	Chlorosis of the first leaf of the plant
3	Chlorosis of 50% of leaves
5	Chlorosis of whole leaves
7	Defoliation of whole plant, initial necrosis of the stem apex
9	Necrosis of more than 50% of the plant (dead plant)

Research Results

Symptoms of Babaco Vascular Wilt (BVW) begin with chlorosis of the lowest leaf, followed by a progressive chlorosis and defoliation of the plant. Chlorosis of lowest leaves is frequently characterized by a lengthwise pattern of one halve of the leaf. When disease develops during fruiting stage, fruits ripe prematurely and falls down. In some cases, symptoms appear longitudinally along a part of the stem or in some stems when the plant is branched, but in the majority of cases the whole plant becomes affected. Surrounding the zone of leaf and fruit abscission, slightly depressed olive spots are developed. These spots are more notorious in the apex, when the

plant becomes defoliated. About disease final stages, spots become stressed and take the shape of lengthened bands. Finally, the infected tissue becomes soft and a progressive necrosis goes down from the apex covering the whole plant. When relative humidity is high, a wet rot with a fetid smell is the final disease symptom. Caller and principal roots decompose at the very end of the disease. Longitudinal and transversal analysis of the vascular tissue reveals olive green to light brown spots. Only when the plant is completely colonized by the pathogen a vast orange esporulation is present along the necrotic tissue.

Due to the rot like symptoms at the end of the disease, the causal organism was initially attributed to a bacterium and the disease took the name of "Bacteriosis".

F. oxysporum, *Pythium* sp. *Gliocladium* sp. and three colonies of bacteria were isolated from fine and principal roots. Only *F. oxysporum* was isolated from collar, stem, stem apex and fruits (Table 1). From these results systemicy of *F. oxysporum* was evident and therefore this fungus appeared already to be the causal organism of the BVW. Later, pathogenicity tests demonstrated that *F. oxysporum* was the causal organism of this disease. Symptoms of BVW were only recovered with inoculations of. *F. oxysporum.* Bacterial inoculations did not show any disease symptom.

Colony appearance and morphology of Fusarium on PDA and CLA corresponded to those described for *Fusarium oxisporum* by Nelson *et al* 1981(10). In addition, symptoms and systemic colonization of the plant correspond to *F. oxisporum* patterns on many plants worldwide.

Uniform inoculations and conducive conditions for disease development allowed clear and uniform BVW symptom expression. These symptoms were classified into a schematic 0-9 scale (Table 2). This scale describes disease developmental stages during time.

Table 2. Frequency of fungi isolated from different parts of babaco plants with Babaco Vascular Wilt. Quito.Ecuador, 1998.

Plant part	Fungus	Number of isolates	Isolation frequency (%)
Fine roots	*Fusarium oxysporum*	189	93.2
	Pythium sp.*	14	6.8
Main roots	*Fusarium oxysporum*	210	81.1
	Pythium sp.*	35	13.5
	Gliocladium sp.*	14	5.4
Collar	*Fusarium oxysporum*	195	100.0
Stem	*Fusarium oxysporum*	244	100.0
Plant apex	*Fusarium oxysporum*	93	100.0
Fruits	*Fusarium oxysporum*	47	100.0

Some association between *F. oxysporum* and *M. incognita* was observed in this study. In table 3, time of four levels of BVW symptom appearance is shown. Level 3 appeared 44.5 days after F inoculation and 35,2 days after F+M inoculations, which was 9.3 days of difference between each other. Similar differences were found for levels 5, 7 and 9 respectively (Table 3). Time spans between level 3 and level 9 were 27.7 and 25.9 days for F and FM inoculations respectively (Table 3). Plants from *M. incognita* inoculations and plants without any inoculation (check) did not show any BVW symptoms.

Table 3. Time in days from inoculation to the appearance of four B V W levels during the study of the interaction between *F. oxysporum* with *M. incognita*. Quito-Ecuador, 1998.

Treatment	Time (days) to BVW levels appearance			
	Level 1	Level 2	Level 3	Level 4
F	44.5*	55.2	61.2	72.2
M	-	-	-	-
M+F	35.2	47.5	54.1	61.1
T	-	-	-	-

* Average of four plants.

BVW was found in all babaco production areas of the provinces of Pichincha, Tungurahua, Azuay and Loja. Incidences of 100% have been observed in Tumbaco-Pichincha, Baños-Tungurahua and Saraguro-Loja. In the same way orchards without disease were also found in all provinces studied. Although BVW was present in exposed fields as well as greenhouses, disease incidence was much higher in green houses. Orchards with surface and overhead irrigation systems shower higher levels of disease than trickle or seasonal rainfall Control of BVW was generally neglected mainly due to lack of etiological knowledge. However some control attempts have been doing with mancoceb, and cooper fungicides and with the antibiotics Enrofloxacina, Oxitetraciclinas, Sulfadiazina and Trimetoprim. These treatments were oriented to bacterial control without any success.

Discussion

Symptoms of BVW follow the typical patter of any vascular wilt, progressive chlorosis together with defoliation ending with plant dead. Due to the succulent babaco stem strructure, infected stems become rotted at the end of disease cycle. Due to stem rot cause of disease was attributed to a bacterium and it was named "Bacteriosis". However, pathogenicity tests demonstrated that *Fusarium oxysporum* is the causal organism of BVW. Bacteria causing rot symptoms are most likely saprophying dead tissue. Initially BVW was also called root rot (4) or basal rot (14), probably due to a confusion with the real root rot caused *Pseudomonas sp* and *Erwinia sp.* (5) Due to symptoms and systemicy of the pathogen, the disease is suggested to be called Vascular wilt or Fusariosis (7,9) names which have been used in this article.

Fusarium oxysporum is a systemic pathogen that infects the plant by roots, colonize the vascular system and become distributed systemically in the whole plant, including fruits. Fungus sporulation does not start unless the plant is completely colonized, which demonstrates the high levels of adaptation and pathogenicity of this fungus. Incubation period, time between infection to symptom appearance was 45 days in conditions of this study. Interaction between *M incognita* and *F oxysporum* reduced the incubation period to 35 days. Therefore, presence of *M incognita* only speeds up the colonization of the fungus, but *F oxysporum* along is able to infect the plant.

At the moment BVW is the first limiting factor of babaco cultivation in Ecuador. Its only presence means a serious risk due to the high levels of pathogenicity, high sporulation capacity and for the effective transmission through asexual seed. However, due to the easy disease diagnosis and efficient chemical control, disease management is relatively easy if disease is detected early in the orchard. At the moment disease is countrywide distributed, but some places and orchards are still free of disease. The first step to have a healthy orchard is to identify carefully healthy orchards for plant propagation. In healthy orchards measures to avoid contamination is priority, Shoes should be disinfected before entering the orchards and tool use should not be shared between orchards. When the disease is present in the orchard, infected plants can be recovered only at symptoms level 1 and 2, which means chlorosis of less than 50% of leaves. In this cases drench applications of carbendazim and propiconazole at 10 ppm and 100 ppm respectively can control the pathogen (8). When disease reach level 3 or more the plant can not be recovered and sporulation of the pathogen should be avoided, by taking out and incinerating diseased plants. Places, where a diseased plant was located should be disinfected and isolated from culture practices.

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Chemical control of *Fusarium oxysporum* in Babaco in Ecuador

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Abstract

A series of experiments in-vitro and on infected plants in the field were carried out to identify the most efficient fungicides to control babaco vascular wilt caused by Fusarium oxysporium. Procloraz, carbendazim, benomyl, imazalil and propiconazole were the most effective fungicides in in-vitro evaluations, and were selected to be tested on infected plants in the field. Carbendazim at 10 ppm, propiconazol at 100 ppm and imazalil at 1000 ppm were the most effective treatments to control the disease on plants with level 1 and 2 of disease development Diseased plants at level 3 or more did not recover with any treatment evaluated. Carbendazim at 10 ppm was the cheapest treatment, and; therefore, is recommended for *F. oxysporum* control. To avoid fungicide resistance development in the fungus a rotation program with propiconazole is suggested.

Objectives

(1)To develop basic information on the occurrence and severity of the major diseases, weeds and insect pests associated with the four Andean fruit crops in Ecuador.
(2)To develop baseline information on current pesticide usage patterns for these crops.
(3)To study etiological and important epidemiological aspects of the most important diseases and insect pests of four Andean fruits.
(4)To conduct research to develop practical alternatives to current pesticide uses.

Babaco, *Carica heilbornii* nothovar *pentagona* is a species derived from a spontaneous cross between *Carica pubescens* "chamburo" and *Carica stipulata* "toronche" (1). In Ecuador, the main limiting factor of babaco production (*Carica heilbornii* nothovar *pentagona*) is the Babaco Vascular Wilt (BVW) or Fusariosis caused by *Fusarium oxysporum*. The disease is presently distributed countrywide and in some orchards disease incidence up to 100% has been observed (2). Due to asexual propagation of babaco, the primary means of dissemenation of *F. oxysporum* is through seed pieces. Therefore, clean seed is the principl procedure in managing BVW. However, for orchards that are already infected, eradication and chemical control are the only alternatives for control. In this study, the in-vitro efficacy of fungicides was evaluated for control of F. oxysporum. The most effective fungicides on in-vitro tests were selected for further evaluation under field conditions.

Research Methods

First experiment: Fungicide in-vitro evaluations to control *F. oxysporum*.

The study was conducted at the laboratories of The Plant Protection Department of Sta. Catalina Experimental Station INIAP, Quito-Ecuador. The systemic fungicides: benomyl, carbendazim, thiophanate-methyl, tridemorph, bitertanol, difenoconazole, penconazole, propiconazole, imazalil, hexaconazole, bupirimate, cyproconazole, kresoxim-methyl and procloraz were used.

Fungicides were initially evaluated at three concentrations. The intermediate concentration was the EC50 found in other studies for similar pathogens. The other two concentrations were arbitrary defined. After the first test additional concentrations where added for the most effective fungicides to calculate accurately the EC50. Five petri dishes per fungicide were evaluated, and five petri dishes without fungicide were included as a check.

Fungicide concentrations were prepared from a stock solution. Ten cc of each fungicide con- centration were mixed uniformly in 100 cc of Potato Dextrose Agar (PDA). PDA was prepared by suspending 38 gm of synthetic Difco PDA in one liter of suspension.

A 5 mm diameter plug of mycelium from a seven-day-old monosporic isolate grown on PDA of *F. oxysporum* was transferred to the center of each petri dish containing the treatments.

Mycelium growth was measured in mm at four days after exposure to treatments.

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Second experiment: Fungicide efficiency to control *F oxysporum* in infected plants.

The five most effective fungicides in-vitro were procloraz (Sportak), carbendazim (Bavistin), imazalil (Fungaflor), propiconazole (Tilt) and benomyl (Pillarben). These fungicides were selected for use in greenhouse studies.

Fungicides were evaluated at three doses: dose 1 was defined as the lowest in-vitro concentration in which there was no fungal growth. Dose 2 was 10 times dose 1 and dose 3 was 100 times dose 1. Fungicide concentrations were defined as $v_1(w)/v_2$, which means volume(v_1) or weight (w) of the fungicide per volume of potting soil v_2). In the experiment volume of potting soil was 4 dm^3. Potting soil was a mixture of 1/3 organic soil, 1/3 compost and 1/3 sand.

Fungicides were evaluated on plants at disease level 1, 2, and 3 according to a 0-9 scale (Table 1). Different disease levels were obtained by inoculating plants of the same age at different times and then selecting the same disease levels. Interactions between fungicides, doses and disease level resulted in a 5x3x3 factorial design, which was evaluated in a randomized design with five replications.

Fungicide applications were conducted by diluting the amount of fungicide necessary for each dose in 500 cc of tap water. Fungicide dilutions were applied as a drench covering the entire root system of 210-day-old plants at various levels. Percentage of plant recovery after treatment was the main variable evaluated.

Table 1. Scale of Babaco Vascular Wilt disease severity obtained from pathogenicity tests Quito-Ecuador, 1998.

Severity Level	Visible Symptoms
0	Healthy plant
1	Chlorosis of the first leaf of the plant
3	Chlorosis of 50% of leaves
5	Chlorosis of whole leaves
7	Defoliation of whole plant, initial necrosis of the stem apex
9	Necrosis of more than 50% of the plant (dead plant)

Results

First experiment: Fungicide in-vitro evaluations on *F. oxysporum* in BVW.

In table 2, the analysis of variance of the EC50 values for the most efficient fungicides is shown. High statistical significance for treatments was found, which means that fungicides evaluated have different effects on *F. oxysporum* mycelium development

Table 2. Analysis of variance of the EC50 for systemic fungicides on *Fusarium oxysporum* 1999.

Source	DF	SS	MS
Total	49	26400.72	
Treatments	9	26387.37	2931.93**
Error	40	13.344	0.33

Tukey test (5%) for fungicides (Table 3) shows 6 different statistical ranges. Procloraz, carbendazim and benomyl grouped in range **a** and have very low EC50 values. Imazalil and propiconazole grouped in range **b** and have relatively low EC50 values. Penconazole and hexaconazole grouped in range **c** and have acceptable EC50 values and the EC50 values of the rest of systemic fungicides are considerebly high, if compared to the fungicides in range **a**.

Table 3. Tukey test (5 %) for the E50 values of systemic fungicides on *Fusarium oxysporum* in Quito-Ecuador, 1998.

Common name	Trade name	EC 50 (ppm.a.i.)	Statistical ranges
Procloraz	Spotak	0.68	A
Carbendazim	Bavistin	0.82	A
Benomyl	Pillarben	1.48	A
Imazalil	Fungaflor	2.78	B
Propiconazol	Tilt	3.38	B
Penconazol	Topas	6.76	C
Hexaconazol	Anvil	6.92	C
Difenoconazol	Score	37.78	D
Iprodione	Rovral	54.02	E
Cyproconazol	Alto	63.02	F

*** EC50 was calculated with five fungicide doses**

Second experiment: Efficacy of Fungicides for control of *F. oxysporum* in infected plants.

In table 4, plant recovery (percentage) after fungicide applications to infected plants is shown. Carbendazim at 10 and 100 ppm., and propiconazole at 100 and 1000 ppm resulted in 100% recovery of all treated plants with level 1 and 2 disease severity. Carbendazim at 1pp resulted in 60% recovery of plants when applied at BVW level 1. Procloraz at 10 and 100 ppm resulted in 20% recovery of the plants when applied either at BVW level 1 or 2. Imazalil at 10 ppm and 100 ppm resulted in 20% recovery of plants when applied at BVW level 1. Propiconazole at 10 ppm resulted in 60% recovery of plants only applied at BVW level 1. Benomyl at 1, 10 and 100 ppm resulted in 40%, 60% and 80% recovery of plants when applied at BVW level 1. Benomyl at 100 ppm resulted in only 20% recovery of plants when applied at BVW level 2. No treatment was effective in curing infected plants at disease level 3 or higher. One of the most efficient treatments to control *F. oxysporum* was propiconazole, however some levels of phytotoxicity were observed in plants treated with the doses of 100 ppm and 1000 ppm.

Table 5 shows an economical analysis of the treatments. Plant recovery from *F. oxysporum* infections with the lowest efficient concentration of carbendazim (10 ppm), propiconazole (100 pp) and Imazalil (1000 ppm) costs $ 0.0029. $ 0.094 and $ 0.94 American dollars. Carbendazim applications at 10 ppm were the most economical treatment, which is 32 times cheaper than propiconazole and around 390 times cheaper than Imazalil. _

Table 4. Plant recovery (percentage) from Symptoms of Babaco Vascular Wilt, Quito-Ecuador. 1999.

Fungicides	Doses (ppm. a.i.)	Disease Severity Level 1	Disease Severity Level 2
Procloraz	1	0.0	0.0
	10	20.0	20.0
	100	20.0	20.0
Carbendazim	1	60.0	0.0
	10	100.0	100.0
	100	100.0	100.0
Imazalil	10	20.0	0.0
	100	25.0	0.0
	1000	100.0	100.0
Propiconazole	10	60.0	0.0
	100	100.0	100.0
	1000	100.0	100.0
Benomyl	1	40.0	0.0
	10	60.0	0.0
	100	75.0	25.0
Check		0.0	0.0

* Disease level (scale 0-9, Ochoa, fonseca) in which the fungicide was applied.

Table 5. Economical analysis of Fungicides for control of Babaco Vascular Wilt, Quito-Ecuador, 1999.

Common name	Efficient doses ppm. a.i	a.i applied per* plant. in cc	Price 1 cc/a.i $ Dollar U.S.	Control cost per plant. $Dollar U.S.
Carbendazim	10	0.04	0.074	0.0029
	100	0.4		0.029
Propiconazole	100	0.4	0.234	0.094
	1000	4.0		0.94
Imazalil	1000	4.0	0.214	0.86

This calculation was done for the soil volume used in this study (4dm3). For smaller or larger amounts of soil, fungicide calculation can be easily adapted.

Discussion

Systemic fungicides evaluated in-vitro showed a wide range of reaction. Procloraz and Carbendazim showed a very low EC50; therefore they apparently are very efficient for control of *F. oxysporum*. In-vitro, benomyl was expected to have a similar efficacy to carbendazim being chemically similar, but in this evaluation benomyl was less efficient than carbendazim. Imazalil and propiconazole were less effective than procloraz and carbendazin; however, their EC50 was still acceptable.

Penconazole and exoconazole were relatively effective, but they were not as effective as procloraz and carbendazim. Difeconazole, iprodione and cyproconazole were not effective.

The five most effective fungicides: procloraz, carbendazim, benomyl, imazalil and propiconazole were evaluated on infected plants to test their efficacy in practical conditions. Only carbendazim had a direct relationship between in-vitro and in -vivo efficacy. Propiconazole which was the least effective in-vitro of the five fungicides, was the second most effective in controlling the fungus in infected plants. Propiconazole showed some levels of phytotoxicity. Imazalil controlled the disease, but due to the high doses necessary, is not of practical interest. Benomyl had some levels of efficiency at 100 ppm and perhaps could be efficient at 1000 ppm, but due to the efficacy of carbendazim, benomyl is not of practical interest. Procloraz being the most effective fungicide in-vitro resulted in less effective control on infected plants, perhaps due to poor systemicy.

Carbendazim at 10 ppm is a very inexpensive treatment and therefore should be recommended for control of BVW. However to avoid the development of fungicide resistance, a rotation program with propiconazole at 100 ppm should be considered. The amount of fungicide used should depend on the amount of soil in which roots are distributed to be treated.

If the disease is detected early, a single application of propiconazol alternated with carbendazim could eradicate the disease. It is suggested that the fungicide be applied to apparently healthy plants in the vicinity of diseased plants. Where the disease is established, a combination of eradication of infected plants and fungicide application is recommended. Plants with a disease severity level of 3 or higher should be removed and destroyed. Plants with a disease severity level of 1 or 2 should be treated with fungicide.

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Control strategies for the Two Spotted Spider Mite, *Tetranychus urticae* Kork, in babaco, *Carica pentagona* Heilbornni, in Pichincha- Ecuador

Investigators: Patricio Gallegos[1], Milton Arroyo[1]
Collaborating Scientists: Roger Williams[2] and George Norton[3]

Abstract

At present, babaco shows a significant increase in production, especially in the greenhouse. Increased production is due to a strong export potential for the fruit. At present a high incidence of mites is a major production problem, against which farmers have no adequate control recommendations. Mite infestations result in poor quality fruit. The present work was conducted with the purpose of finding the best chemical control products for each stage of the biological cycle of the mite. The miticides that best controlled eggs were hexiathiazox, tetradifon, diafhenthirun, "prieto soap" and potassium salts. The best efficiency values were higher than 85.8%. Miticides that best controlled nymphs and eggs were abamectin, diafhenthiuron, "prieto soap", and potassium salts. The best efficiency values were higher than 88.5%. It is important for us to understand the mode of action of the "prieto soap" which is a handmade product and competes well with synthetic products yet is not toxic to mammals. Potassium salts showed good control and low toxicity for mammals as well. These two products have promise to be included in integrated management programs for mites. The persistence of mite control by products in this study (at 50% of control) oscilated between 13 and 20 days. The least effective products were amitraz, pyraben and nicotine.

Babaco, *Carica pentagona* Heilbornni originated in Ecuador. It resulted from a natural cross between *Carica pubescens* (Chihualcan) and *Carica stipulata* (Toronche), Fabara, 1985.

At present, babaco has become important in Ecuador due to the potential for export. Babaco is a very profitable crop. A babaco orchard in a greenhouse of less than 1000 m2 provides strong economical income (Fonseca 1997).

Greenhouses provide good climatic conditions for babaco production. However mites are also favored by greenhouse environments (Tigreros. 1998).

Fabara 1985, reports that severe mite attacks can produce marks on the fruit, which can cover up to 50% of the surface.

In 1988, The Ecuadorian Service of Agricultural Sanitation (SESA), reported the incineration of two shipments of babaco destined for export, due to the presence of mites.

Research on babaco mites is rare. Therefore producers do not have adequate control recommendations. Consequently, farmers use pesticides irrationally.

Objectives

1) To determine the efficacy and persistence of miticides with different mechanisms of action; and

2) To define correct miticides rotations which keep population levels low and do not affect fruit quality; and

3) To develop basic information for use in Integrated Pest Management programs.

Research Methods

The study was conducted in two experiments. In the first experiment, which is reported in this article, the best miticides were selected based on their effects on the different biological stages of the mite.

The second experiment (which is currently being conducted) is focussed on defining the best miticide combinations. The combinations should follow the sequence: adult, egg and botanical miticides.

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Treatments

First experiment.
Ovicidal miticides:
t1: Hexythiazox (Nissorun) 0.4 g/ l
t2: Amitraz (Mitac) 2cc/ l
t3: Tetradifon (Tedion) 4cc/ l

Adult miticides:
t4: Abamectina (Vertimec) 0.25 [cc]/ l
t5: Diafhenthiuron (Pole) 1.00cc/ l
t6: Pyridaben (San [mite]) 0.28 g/ l

Botanical miticides
t7: Prieto soap (Jatropa curca) 15 g/ l
t8: Potassium salt (Impide) 12 [cc]/ l
t9: Nicotine 25% plus Nicocianina 15% (Nicotine extract) 12cc/ l
t10 Check (untreated control)

Experimental unit

The experimental unit consisted of a babaco plant, in which three leaves were selected. Three samples were taken from each leaf. The sample consisted of an area 0.5 cm2 located in the base of the leaf near the principal vein.

Variables

- Miticide efficiency at 48, 96, 120, 168 hours and also at 10, 13, 20 and 27 days after application. The effect of miticides was evaluated on eggs, nymphs and adults. Differences between initial and final populations were calculated in each treatment and for each time of evaluation. These values were transformed into percentages.
- Changes in treatment populations were corrected according to check variations using the Hendersson & Tilton formula.
- Persistence. Time in days between mite applications and time of 50% mite control.
- Persistence values were graphically defined by plotting evaluation dates with efficacy dates.
- Phytotoxicity was evaluated at seven days after miticide applications, according to a 1-5 scale, in which 1 was considered a healthy plant, and 5 a dead plant.

Second experiment: The following variables are being assessed:

Fruit yield per plant, expressed in Kg.
Number of fruits per plant.
Quality of fruits

Experimental design

A completely randomized block design with four replications was used.

Research Results and Discussion

1 Egg control

Efficacy of egg control was statistically significant for treatments (p=0.01) and for every time of evaluation. The coefficient of variance was less than 17.7% for all evaluations.

Table 1 shows the Tukey 5% test for miticide efficacy in the control of mite eggs during eight evaluation periods.

Table 1. Tukey test (5%) for miticide efficacy to control eggs during eight evaluation periods. Yaruqui Pichincha. 1999.

Treat	Evaluation time / % of control							
	48 hours	96 hours	120 hours	168 hours	10 days	13 days	20 days	27 days
T1	50.9 b*	81.2 a	93.0 a	98.7 a	97.1 a	96.2 a	37.8 a	11.2 c
T2	38.8 c	61.9 cd	84.6 ab	82.2 b	69.2 de	62.0 cd	13.0 b	4.6 de
T3	74.8 a	78.6 ab	90.3 a	95.2 a	89.6 ab	85.0 b	29.3 a	10.8 c
T4	60.4 b	66.3 bc	84.8 ab	86.3 ab	77.2 cd	69.7 c	38.4 a	30.1 ab
T5	61.2 b	68.7 ab	83.4 ab	85.8 ab	80.6 bc	66.6 c	31.5 a	26.9 ab
T6	59.1 b	60.3 cd	78.4 ab	79.4 b	77.0 bcd	58.2 de	11.7 b	3.4 de
T7	52.5 b	81.0 a	94.5 a	89.4 ab	92.5 ab	87.4 ab	34.0 a	33.1 a
T8	75.5 a	78.5 ab	93.7 a	90.3 ab	85.0 bc	71.4 c	28.1 a	18.7 bc
T9	51.6 b	51.5 d	69.2 b	66.0 c	62.9 e	53.2 e	15.2 b	9.5 cd
T10	0.0 d	0.0 e	0.0 c	0.0 d	0.0 f	0.0 f	0.0 c	0.0 e

* Different letters, statistically different.

Hexythiazox (treatment 1) showed good mite control from 96 hours to 13 days after application, with 81.2% and 96.2% of control, respectively. Increased efficiency from 96 hours to 13 days could be due to chitin inhibition, the mode of action of hexythiazox. Curkovic, *et al.* (1994) reported that, the miticide requires time to act in the embryo and in the

mother's body. In addition to good control, this product is moderately toxic on the beneficial fauna (Brown *et al.* 1992).

Tetradifon (treatment 3) showed effective control from the first evaluation (48 hours) until 10 days later. The highest control level was observed at 168 hours with 95.2% control. Tetradifon is recommended for mites and its efficiency is specific for eggs, (Ecuaquímica, 1998).

Diafentiuron (treatment t5) was effective on eggs. This miticide showed a good level of control from 96 to 168 hours after application. The highest level of control was at 168 hours with 85.8% control. Diafentiuron is recommended for mobil stages of mites. Effects on egg numbers could be due to control of adult mites.

"Prieto soap" (treatment t7) had acceptable control, but miticide efficacy increased from 96 hours after spray until the final evaluation. The most effective treatment had 94.5% control, which was recorded 120 hours after spray. "Prieto soap" obstructs the respiratory process through blocking gas exchange in eggs.

Potassium salts (treatment t8) showed good initial control, which remained stable until 168 hours after application. Control reached 90.3% at 168 hours. After which, control values decreased significantly. Potassium salts have a contact mechanism of action on the cuticle, which explains the effective control of eggs.

Treatment t7and t8 were also very effective.

The remaining treatments showed lower levels of control or erratic control.

Table 1, shows that control decreased more than 50% after 13 days for all miticides. Therefore, egg control evaluations should not be conducted after 20 days.

Control of nymphs and adults

Control efficiency for nymphs and adults is shown in tables 2 and 3, respectively. Values correspond to the difference in percentage between initial populations and after treatment.

Table 2. Tukey test (5%) for nymph control (%) by miticide treatments. Yaruqui. Pichincha. 1999.

	Evaluation time / % control							
Treat.	48 hours	96 hours	120 hours	168 hours	10 days	13 days	20 days	27 days
t1	28.4cd	32.0d	86.2 a	88.8 a	65.8 bc	50.8 bc	27.7 bc	3.5 b
t2	20.7 d	12.2 e	49.0 d	64.3 bc	44.9 d	42.2 c	3.5 ef	0.0 b
t3	43.0 bc	42.9 cd	65.4 bc	79.2 ab	64.8 bc	50.5 bc	11.5 cde	4.1 b
t4	59.6 ab	59.0 ab	93.0 a	96.5 a	95.5 a	85.3 a	38.8 ab	33.3 a
t5	60.3 ab	60.5 ab	80.1 ab	91.9 a	94.3 a	65.6 ab	39.0 ab	30.7 a
t6	59.7 ab	68.8 a	80.5ab	67.1 bc	58.0 cd	48.3 bc	23.0 bcd	21.4 a
t7	70.7 a	72.9 a	91.9 a	95.8 a	96.0 a	69.2 ab	54.5 a	32.7 a
t8	65.9 a	64.6 a	86.0 a	88.5 a	78.1 ab	59.4 bc	11.0 de	3.1 b
t9	44.4 bc	46.1 bc	65.0 c	60.4 c	73.6 bc	64.2 ab	26.0 bc	1.5 b
t10	0.0 e	0.0 f	0.0 e	0.0 d	0.0 e	0.0 d	0.0 f	0.0 b

Table 3. Tukey test (5%) for adult control (%) by miticide treatments. Yaruqui. Pichincha. 1999.

	Evaluation time/ % control							
Treat.	48 hours	96 hours	120 hours	168 hours	10 days	13 days	20 days	27 days
t1	22.1 bc	11.6 c	28.3 d	35.2 de	27.4 b	22.7 c	22.3 bc	0.0 c
t2	4.1 de	10.6 c	20.0 d	20.0 e	10.0 c	3.5 d	0.0 d	0.0 c
t3	8.3 cde	13.7 c	28.3 d	44.7 cd	28.3 b	24.1 c	18.6 bc	0.0 c
t4	68.4 a	75.0 a	96.2 ab	97.2 a	91.3 a	91.1 a	53.0 a	36.1 a
t5	68.7 a	70.0 a	91.2 ab	98.2 a	90.9 a	86.8 a	37.5 ab	31.5 a
t6	51.3 ab	54.1 ab	76.6 bc	77.0 ab	79.2 a	46.0 b	25.8 bc	3.1 c
t7	74.9 a	78.9 a	100.0 a	95.0 a	90.1 a	92.2 a	39.1 ab	30.0 a
t8	58.9 a	74.6 a	95.3 ab	84.4 ab	85.0 a	61.5 ab	22.6 bc	12.4 b
t9	45.8 ab	36.0 b	62.9 c	58.6 bc	71.4 a	55.8 b	13.5 c	0.0 c
t10	0.0 e	0.0 b	0.0 e	0.0 f	0.0 c	0.0 d	0.0 d	0.0 c

Treatments abamectina (t4)], diafentiuron (t5) "prieto soap" (t7) and potassium salts (t8) were most effective for control of nymphs and adults. These treatments were effective up to 13 days after application, except for treatment t8, which was only effective for nymph control until 10 days after application. In all cases, mite control efficiency reduced significantly after 13 days.

In this experiment, abamectina resulted in 96.5% and 97.2% control for nymphs and adults, respectively. An ovicide should be used with this strong adulticide.

Diafentiuron was also an adulticide. Nymph control of 94.3% was recorded 10 days after application, and 98.2% control of adults was recorded 168 hours after application. Diafentiuron is recommended specifically for adult mite control.

"Prieto soap" was the most effective treatment in all evaluations. The highest miticide effect on nymph and adults was 10 days and 120 hours after applications, respectively. The effect of "prieto soap" is most likely due to the efficient covering of the mites.

Potassium salts controlled 88.5% of nymphs and 95.3% of adults, at 168 and 120 hours after application. Potassium salts have a dehydrating effect on mites and therefore sequential rotation with other miticides would not induce cross-resistance.

Persistence

Chart 4 shows values for miticide persistence, which was defined as number of days until control efficiency reached less than 50%.

Table 4. Miticide persistence for control of eggs, nymphs and adults. Days until control efficiency reached less than 50%.Yaruqui. Pichincha. 1999.

Treat.	N°. Days		
	Egg control	Nymph control	Adult control
T1	18.2	13.2	0.0
T2	16.7	9.2	0.0
T3	14.5	13.1	0.0
T4	17.2	18.5	21.2
T5	16.5	17.1	17.7
T6	14.3	12.7	12.7
T7	17.8	21.3	18.5
T8	16.4	14.3	14.7
T9	13.5	15.6	13.7
T10	0.0	0.0	0.0

Persistence determination is important, because it allow us to identify the time for the next application.

Hexythiazox, "prieto soap" and abamectina have an egg control persistence of 18.2, 17.8, and 17.2 days, respectively. These were the highest values recorded in this experiment.

"Prieto soap", abamectina and diafentiuron were the most effective treatments for nymphs, with persistence of 21.3, 18.5 and 17.1 days, respectively.

Effective adult control was obtained with abacmectina, "prieto soap" and diafentiuron. Persistence values between 17.7 and 21.2 days were recorded for these treatments.

We should point at that "prieto soap" was as effective as synthetic products. It has a botanical origin and is handmade.

Phytotoxicity

Amitraz and tetradifon produced slightly burned leaves in one of the replications. Pyridaben and potassium salts treatments showed 50% foliar chlorosis in one of the replications.

Although phytotoxicity effects were not high in this experiment, some phytotoxicity problems could be expected with increased doses or under adverse climatic conditions.

Impacts

Hexythiazox and tetradifon were the most effective synthetic ovicides in this experiment.

Abamectina and diafentiuron provided the best nymph and adult control.

The botanical miticides "prieto soap" and potassium salts showed good control efficiency for all biological stages of the mite.

Nymphs and adults showed similar response to all treatments.

Persistence of all treatments varied from 13 to 20 days.

Amitraz, pyridaben and nicotine were not effective in controlling mites or the control was very erratic in control.

Networking Activities

- In June 14th, 99 there was a workshop at Sta. Catalina Experimental Station to show the advances of the project " " with the participation of some researchers from different provinces of Ecuador.
- Milton Arroyo and Patricio Gallegos discussed the research plan with the committee of teachers of central university. Also, Ing. Mario Lalama statistician of the central university visited the field trial to evaluate the Mr. Arroyo work.

Project Highlight

- The results of this trial were used by the researchers of the Fruticulture program of INIAP to control mites in babaco and other fruit species. These results were also used by babaco growers located in the area of the research nursery.

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Plantain/Coffee Agroforestry Systems in Northwestern Ecuador: A Landuse Alternative to Low Quality Pasture

Investigators: C. R. Carroll[1], R. Ontaneda[2], Fernando Echeverría[2], Carmen Suárez-Capello[3], and Danilo Vera[3]
Collaborating scientists: Carmen Triviño[3], Roger Williams[4] and Mike Ellis[4]

Abstract

Beneficial predatory nematodes were rare in all pre-treatment sites and root knot nematodes were common. Root zone soil beneath plantains treated with fresh bagasse, bagasse + ash or ash alone had greater numbers of nematodes than soil samples from plantains given normal applications of chemical fertilizers. However, sample variances were too high to make valid comparisons. Beneficial nematode populations are expected to grow slowly and the experiment is still in a very early stage. Pest weevils have high numbers in this region and we need to understand how these numbers are influenced by in-migration. Boring lepidoptera can have major effects on plantains at very low numbers. Because adults are attracted to fresh bagasse it may be possible to impact the population by applying a microbial agent such as Bt to the fresh bagasse. Incidence of black sigatoka is relatively high in the region although it does not seem to have marked effects on yields. Treatments appear to have no lasting effect on disease incidence.

The work is being conducted on five farms with intensive work being done on two farms. On the Orongo site, we have established a citrus, coffee, plantain polyculture on which we have superimposed a completely randomized treatment design.

Objectives

I. Determine incidence, seasonalty and relative abundance of pests, primarily root-damaging nematodes, of upland banana, plantain and coffee grown in monoculture and in banana/plantain x coffee agroforestry; 2. Determine the significance of sheet application of sugarcane bagasse to retard soil erosion in this agroforestry system; 3. Determine the potential production benefits of applying ash mineral byproducts from sugarcane processing to this agroforestry system; 4. Determine the effect of bagasse and ash amendments to root-damaging and predator nematode populations; and 5. Establish the incidence of aerial plant pathogens, mainly *M. fijensis*, the causal agent of black sigatoka disease, in monoculture plantain plantations and within a polyculture agroforestry system.

This Andean region, highly vulnerable to erosion, requires production systems that offer attractive economic activities to farmers that do not suffer severe pest damage or cause erosion. Low quality pastures, based on Setaria grass, are common throughout the region. Sugarcane is a major land use activity in the region, but bagasse and ash byproducts constitute a source of contamination; none or few attempts have been made to find alternative uses for them. On the other hand, farmers do not have many alternatives to sugarcane for an economically productive activity. One alternative is a mixture of coffee, plantain, and citrus. Coffee, plantain and citrus are currently found scattered in farms but have low yields from pests and diseases. The region has good potential to produce high quality coffee and citrus. The common plantain variety is the Musa cultivar, "Maqueño", sold as a cooking banana for local, Quito and Northern provinces markets, however, despite the market demand, it is disappearing from farms due to pest attacks to the corm and roots. The potential for this agroforestry system is good, provided farmers can get a solution for their ecological (mainly soil erosion) and pest/desease constraints.

Research Methods

The main research sites are the Maquipucuna farm, "Orongo" and "La Perla", a farm belonging to Mr. Guido Rivadeneira. Both are located in northwestern Ecuador 1300 meters above sea level, with an annual average rainfall of 182 mm/month, a maximum of 343 mm in April and a minimum of 52 mm in August. The average annual temperature is 18 degrees centigrade. Large portions of both farms, as with most of them in the zone, have steep slopes

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(as much as 45°) on which "Maqueño" plantain-coffee-citrus and *Setaria* pastures are planted. In Orongo the experimental area has a plantain/coffee/Setaria system, while in La Perla there is only plantain.

Sampling was conducted in a total of five farms, including the Orongo and La Perla sites, to assess populations of root damaging and predator nematodes. Samples were taken with a standard soil sampler at the drip line of five plantain plants in each farm. In Orongo and La Perla 10 plants were sampled. Counting and identification of nematodes was done by INIAP's nematologist. Six months later a new sample was collected on the experimental plot in Orongo and La Perla to evaluate the effect of treatments.

A fully randomized design with five treatments and 10 evaluation units (plants) per treatment on plantain and, 5 for coffee was used in Orongo and La Perla. Treatments were (1) fresh bagasse (from newly ground sugarcane); (2) ashes from burnt bagasse; (3) bagasse + ash; (4) control without any amendment and (5) fertilizer application. 212.4 kg of bagasse and 31.6 kg of ashes were spread in a half circle under every plant-treatment, using the plantain plant it as a barrier to avoid rain washing of bagasse. This was not possible to avoid with ash which was readily washed away, therefore weekly application of ash were continued to ensure its presence on the treatment plant. Fertilizer application consisted of 46 g of super phosphate, 162 g of urea and 1856 g of potassium muriate based on previous soil analysis performed on INIAP-PICHILINGUE soil laboratory. Mineral content of sugarcane bagasse and ash was also determined in the same laboratory. In coffee 40 kg of bagasse and 16.6 Kg of ashes. Fertilizer application consisted on 11.3 g of super phosphate, 110 g of urea and 84 g of potassium muriate

Weekly monitoring of the experimental plots recorded pest and diseases as they appear. "V" traps were used to capture weevils attacking plantain. When necessary, samples were sent to INIAP'S laboratories for identification.

Research Results

Table 1 shows mineral content of bagasse and ash. The composting beds established for observation, however, do not show any sign of decomposition so far. Bagasse was not meant to be a primary source of nutrients, but rather a source of labile carbon to increase saprophytic bacterial populations as a food base for predatory nematodes. Thus, the mineral content of bagasse is not critical to the study and the apparent slow rate of decomposition should gradually lead to higher levels of soil labile carbon.

Table 1. PH and mineral content (percentage of dry weight), of sugarcane ash and bagasse. MAQUIPUCUNA-INIAP-IPMCRSP. 1999.

	pH	N	P	K
Bagasse	6.7	0.6	0.09	0.63
Ash	11.5	0.3	0.78	3.52

Precipitation was unusually high from January to April during 1999 (Table 2) and, as stated above, may have washed away most of the ash treatments.

Table 2. Rainfall in four months of 1999 as compared to same period annual average in northwestern Ecuador. MAQUIPUCUNA-INIAP-IPMCRSP. 1999.

Months	1999	Annual Average (cm)
January	280	241
February	325	288
March	580	339
April	680	343

Ants and mosquitoes were the first arthropods to visit the bagasse treatment. After approximately a week, rain seems to remove soluble sugars from the bagasse and insects disappeared until the following application.

The pattern of black sigatoka showed a typical seasonal increase during 1999, on two commercial Musa sp. (Banana and plantain). On plantain, the disease index goes from 36% in the peak of the rainy season down to 20% in the dry season. Bananas are more susceptible, reaching levels up to 45 % but, the general seasonality of the disease is similar to that on plantain.

The plantain "Maqueño" cultivar cultivated in Maquipucuna area. "Maqueño" is more susceptible than the other commercial varieties, with sigatoka affecting nearly 55% of leaves, and during most of the evaluation period is over 30%. Treatments do not seem to have much influence on sigatoka, as expected, but during the first 8 weeks, plants receiving the bagasse treatment have a lower disease index. The bagasse treatment effect disappears after 8 weeks.

The black weevil (*Cosmopolites sordidus* Germar-Coleoptera: Curculionidae), is the major arthropod pest found in the area. 5 to 8 weevils/trap is generally considered to be an acceptable upper threshold in banana and plantain before yields are depressed. In the farms around Maquipucuna, 16 and 17 weevils/trap are common. On fifteen sampling dates between May 7 and August 13 on the Orongo and La Perla farms, 22 out of 23 samples contained more than 8 weevils per trap. Levels of infestation look rather similar for both farms, but although they are separated only 9 Km from each other, variation in peaks of incidence are an interesting fact to explore further. We plan to increase our focus on this pest. More information is required about the population dynamics of the weevils because as shown on plantain research (Activity III-plantain IPM), *C.*

sordidus may fly long distances and the numbers caught in traps represent an unknown mixture of locally produced weevils and migrants.

Farmers say that the main problem is another borer or "tornillo", that destroys the pseudostem and corm. This lepidopteran pest is *Castniomera humboldti* Maubl Ashby – Lepidoptera: Castnidae. However, during the time of monitoring the degree of incidence seemed rather low (Table 3) and no patterns can yet be determined. It should be noted that a single larva can destroy a mature plant in a short period. Farmers have no methods for controling this pest. We observed adults visiting the fresh bagasse and this suggests that adding a microbial agent such as Bt to the bagasse might provide some measure of control. We plan to investigate this approach.

Table 3. Incidence of minor pest and diseases in Orongo and La Perla farm on Maqueño plantain. MAQUIPUCUNA-INIAP-IPMCRSP. 1999.

TREATMENTS	ORONGO			LA PERLA		
	Tornillo	Hairy-worm (NI)	Unknown disease	**Tornillo**	Hairy-worm (NI)	Unknown disease
Bagasse	1	-	1	3	-	1
Ash	2	-	-	3	-	-
Bagasse + Ash	1	4	-	2	-	-
Control	-	2	2	-	-	2
Fertiliz	-	-	1	-	-	-

As expected, main effect of treatments was shown at the rhizosphere and soil level. The amount and type of nematodes found increased over time with all treatments. In early March, before the treatments were applied, the average number of nematodes found in ten100cc samples of rhizosphere soil beneath Maqueño plantains at the Orongo farm was 22 Meloidogyne and 55 Helicotilenchus. In August, after the treatments had been in place for six months, populations of nematodes generally increased. However, because the number of nematodes in the control sites also increased, it is not possible to completely separate the effects of the treatment from normal seasonal patterns of nematode abundance. By comparing the abundance and type of nematode in the control sites with treatment sites we see a strong treatment effect (Table 4). The largest increase is seen with the bagasse treatment. When the type of nematodes present is considered, Meloidogyne sp. accounts for the bulk of nematodes present in samples and beneficial nematodes (*Dorilaymus* sp and *Rabditis* sp.) are very rare in the pre-treatment and post-treatment and control sites. The significance of this rather high incidence of root knot nematodes, normally not very serious in plantain, should be elucidated. *Helicotilenchus* was found causing a type of damage or symptom (deep root lesions and necrosis) that is normally caused by *Radopholus similis*. However this genus was not found in any of the samples analyzed from Northwestern Ecuador. Despite the differences in numbers that can be seen, a first comparison of before and after treatment, done with the Mc.Nemar non parametrical test, did not show significance because sample variances were very high. Populations of the beneficial predatory nematodes (*Dorilaymus* sp and *Rabditis* sp.) are expected to grow slowly and we will be tracking populations of these two genera. We will be placing more emphasis on bactivorous nematodes because the labile carbon released by bagasse is expected to stimulate large bacterial populations. The significance for plantain production is that nematodes feeding on bacteria release large amounts of available nitrogen that can be utilized by plantain.

Table 4. Average number of ematodes in 100cc rhizosphere soil samples (N=10) beneath Maqueño plantains, Orongo farm site, in early August 1999.

11	Treatments	Meloidogyne	Helicotilenchus	Dorylaimus	Rhabditis
12	Bagasse	137	30	20	15
13	Ash	60	60	20	15
14	Bagasse + Ash	120	36	17	14
15	Chem. Fertilizer	45	25	45	17
16	Control	80	30	30	5

Networking Activities

Although we are just beginning to collect data from the experimental design and from on-farm studies, the project has already attracted interest. This summer a graduate student and a new faculty member from the University of Georgia will visit the site and begin companion studies to investigate microbial dynamics.

Project Highlight

• The addition of sugarcane bagasse and bagasse + ash may increase soil nematode populations, especially root knot nematodes. However, the experiment is still in a very early stage and population numerical responses have not yet occurred. Beneficial nematodes (predators and bactivores) are increasing in the system but their numbers are still small.
• Because some lepidopteran pests are attracted to fresh bagasse it may be possible to apply microbial control agents to the bagasse and thereby achieve some measure of control.
• Black weevils often occur in densities that may affect plantain yields. We will be monitoring these populations.

Modeling Impacts of Changes in Pest Management Technologies

Investigators: Victor Barrera[1], Charles Crissman[2], and George Norton[3]
Collaborating Scientists: P. Espinosa[2], S. Sherwood[2], L. Basantes[2], M. Perez[2], L. Escudero[2], J. Suquillo[1], S. Hamilton[3], J. Antle, P. Pardey[4], and S. Wood[4]

Abstract

The IPM-CRSP impact activity for potatoes in Ecuador is being implemented as a joint activity with the SM-CRSP Tradeoffs Project and the IDRC Eco-Health Project. The three projects held a joint planning meeting in Quito in March during which progress to date and plans for the 1999-2000 year were developed. With the exception of the IFPRI collaborators, all of the above indicated scientists were present.

The work to date has focused on objectives 1 and 3. For objective 3 work has consisted of the establishment of the field research team, the design of data collection instruments, recruitment of farmer collaborators, and initiation of field data collection. The field team is based in the San

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Gabriel office of INIAP. Sixty farm families from three communities, La Libertad, Santa Martha de Cuba, and San Pedro de Piatal, have been recruited to participate in the project data collection and training activities.

Upon recruitment, a diagnostic survey on pesticide knowledge, attitudes and practices was given to both men and women household heads. This survey is immediately processed and the results given back to the community in a group meeting. All three communities have been surveyed and the results given back to two of them (La Libertad and Santa Martha de Cuba). The results show a marked ignorance of efficient pesticide use and safe management. The group meeting is used to motivate farm family participation in a discovery-based learning experience in Farmer Field Schools, where farmers follow the production cycle of potatoes while designing simple experiments to test and develop more efficient and sustainable potato production, emphasizing integrated crop management. To develop local capacities in this methodology and to enable effective linkages between research and farming practice, two extension professionals from Carchi, one from each the Ministry of Agriculture (Fernando Chulde) and INIAP (Jovanny Suquillo), participated in an intensive three month Training of Trainers with 35 representatives from throughout the Andes that was sponsored by the FAO/Global IPM Facility.

Additionally, a baseline examination of nutritional and neuro-psychological status is given to the family members. This has been completed for La Libertad and is presently underway in Santa Martha de Cuba. Field level production information was started in September and will be collected during a complete crop cycle on at least two parcels of all participating farmers.

With an eye towards assuring the continuation and sustainability of IPM efforts and linkages between lessons from tradeoff modeling and farming practice, collaborators INIAP and CIP together with the University of Guelph developed a complementary project proposal entitled "Eco-suelos", designed to strenghten research capacity and to measure the impact of practices on soil regenerative capacity to further understand production externalities. The project will specifically examine the impact of diverse IPM and general crop management practices (pesticides, tillage, and rotation schemes) on long term soil biota and associated chemical and physical effects. The World Bank-sponsored Agricultural Modernization Program (PROMSA) has agreed to fund Eco-Suelos for cerca $80,000. Furthermore, a second project entitled Eco-Papas is being developed to strengthen university and farmer experimenter research capacity in IPM for more biological/ecological crop production.

For Objective 1, a preliminary version of The Tradeoff Model, a decision support system for policy makers, was completed. This software integrates field-scale GIS-based soils and climate data with the DSSAT suite of crop growth simulation models, econometric-based economic simulation models of land use and management decisions, and environmental process models (leaching and erosion). The software provides the basis to draw a statistically representative sample of fields in a region such as a watershed, conduct integrated analysis, and statistically aggregate the results to a scale relevant to policy decision making. The software displays tradeoffs between competing or complementary policy objectives in simple two-dimensional graphs, and shows how these tradeoffs change under alternative policy and technology scenarios.

The Tradeoff Model provides the framework in which the Soil Management CRSP constraints will be assessed in this project. Tradeoff indicators include value of crop and livestock production, soil productivity and water quality, and human health. Constraints addressed in this project include reductions in soil productivity associated with mechanical and water erosion and soil compaction, losses in nutrients, impacts of management practices (erosion and chemical use) on water quality, and impacts of pesticide use on human health. Scenarios for enhancing the long-term sustainability of Andean production systems include improved soil and pest management practices, improved crop varieties (specifically, adoption of late-blight resistant varieties), pasture management, and farmer training to improve the safety of pesticide use.

The Tradeoff Model provides a framework in which to structure input from stakeholders, such as farmers, research administrators, and local and national policy makers. This information is used to define the indicators that are quantified as tradeoffs, and to define policy and technology scenarios to be evaluated.

Objectives

1. Assess the impacts of IPM technologies on land use and management, farmer income, and pesticide use.

2. Assess the aggregate economic impacts of the IPM technologies developed on the IPM CRSP, including spillovers across regional and national boundaries.

3. Assess the health and economic impacts of IPM CRSP technologies by gender.

Research methods

A bio-economic simulation model will be used to address objective one. This model is currently being developed on

the SOILS CRSP to explore the effects of factors such as changes in technologies and prices on land use and management, revenues, income stability, erosion, contamination of water tables, etc. This model is being developed for the same geographic region where the potato IPM work is underway on the IPM CRSP. It is proposed that reductions in pesticide use be measured or projected due to generation and adoption of IPM technologies on potatoes and that these pesticide use changes be fed into the bio-economic model as a scenario, with modifications made to the model as needed. To address objective two, it is proposed that the per unit cost reductions measured or projected due to IPM CRSP technologies be combined with measured or projected information on adoption and included in an economic surplus model to generate aggregate benefits. All changes in input use, outputs, and prices are being measured for each of the CRSP experiments. This information will be used to help generate per unit cost changes. Information on agro-ecological zones assembled by IFPRI and included in a GIS model will be used in the economic surplus model to help define the potential spillovers of the technologies. For objective three, survey information on household labor allocation and income distribution within the household will be used to project gross gender-differentiated economic impacts. Health impacts by gender will be examined by collecting information on activities by gender that might directly (e.g. applying pesticides) or indirectly (e.g. washing clothes of pesticide applicators) lead to pesticide exposure.

Networking Activities

Workshops

- On May 26, INIAP and CIP convened 30 provincial stakeholders from governmental and non-governmental agencies, private industry, and farmer representatives to discuss issues relevant to sustainable potato production, including seed, soils, fertilizers, and pest management. Participants constructed matrices of information and training demands and established a short term action plan for addressing these concerns. Planned activities include field trips to IPM test sites as well as a provincial conference to inform the public and policy makers of provincial pesticides concerns.

- In July, researchers from INIAP, CIP, Wageningen Agricultural University, the University of Guelph and Cornell University met to design the eco-soil proposal that will investigate the impact of pest management and other practices on soil regenerative capacity. By design, the research will be fully integrated with the IPMCRSP field activities.

Publications and Presentations

- Project investigators Lilian Basantes and Stephen Sherwood gave a presentation entitled "Papas, pests, pesticides, and power" to the March conference of the Global Late Blight Initiative (GILB) that took place in Quito. The talk centered on constraints to enhancing sustainable and productive potato production in Carchi, as revealed by early Tradeoff studies, as well as opportunties of overcoming those obstacles, such as through IPM training and political action.

- In March, Jovanny Suquillo presented the IPM research and training initiative to over 60 members of the Consortium Carchi, representing a broad range of stakeholders.

- Stephen Sherwood gave a presentation on collaborative natural resource management at the July Sustainable Natural Resource Management (SANREM) meeting in Quito. While drawing heavily on experience in Central America, the talk discussed challenges to sustainable agriculture, and in particular the achievement of IPM, provided by the changing institutional environment of Ecuador due to recent economic and political restructuring policies. Understanding the health, economic, and environmental tradeoffs between alternative policies was emphasized.

Training output

- Two institutions, MAG and INIAP, developed capacities in participatory methodologies for implementing farmer-centered IPM training, representing the first application of farmer field school methodologies in the Andes.

- Weekly Farmer Field School sessions in two locations have begun. During a six-month cropping cycle, the Field Schools will enhance abilities in productive and integrated crop management, emphasizing IPM of the Andean Weevil and Late Blight.

Project Highlight

- An inter-institutional meeting was held and the early framework for a provincial-level network for IPM in potato production was established.

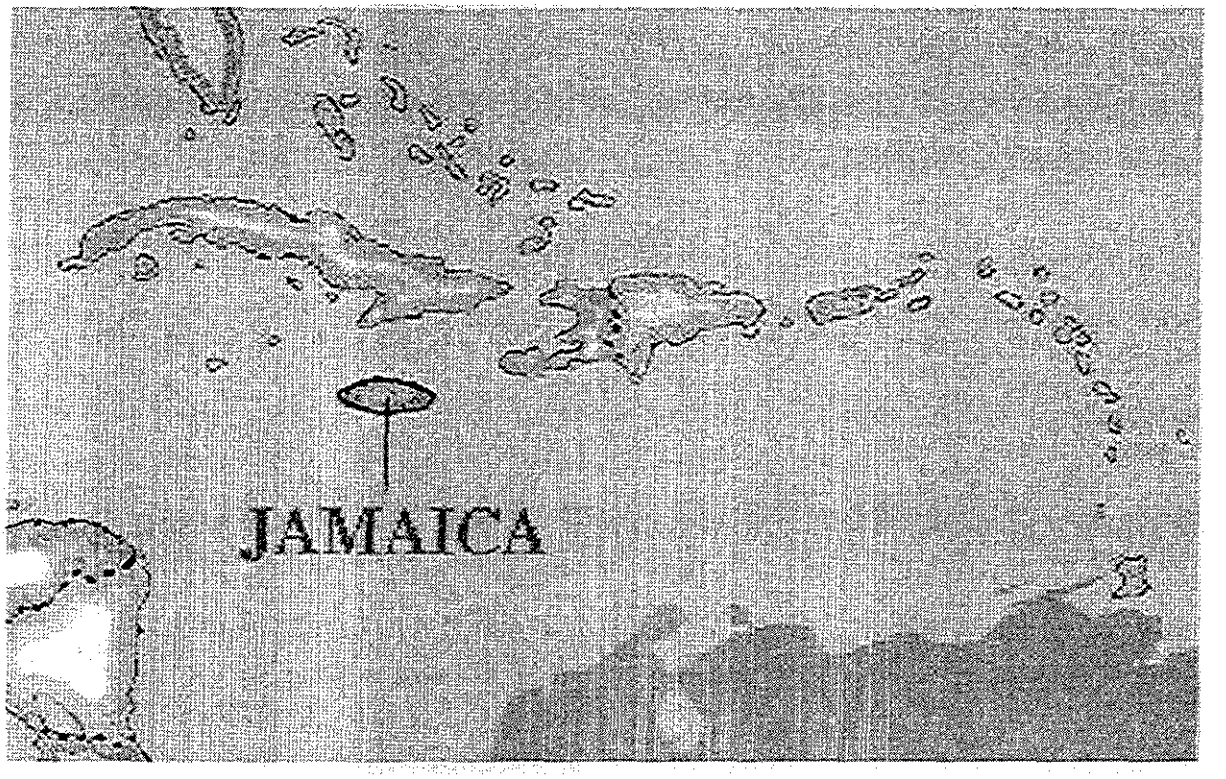
- Two extensionists from each of MAG and INIAP received intensive three-month training in Farmer Field School methodologies for IPM in potato.

- Baseline research on local knowledge and health effects of pesticides was completed in two of the three project locations. Community training activities have begun in two of those locations.

- Farmer Field Schools on IPM-Potato were established in two locations.

- An inter-institutional working group on potato was established.

- Eco-suelos, a complementary project to examine the impact of pest management on soil regenerative capacity was developed and funded.
- Eco-papas, a complementary project to strengthen research capacities in IPM areas was developed and submitted to PROMSA and is pending evaluation..



CARIBBEAN

Overview for Caribbean Site in Jamaica

Authors: Janet Lawrence[1] and Sue Tolin[2]

The activities of the Caribbean site are conducted under four main research components: IPM Systems Development, Pesticide Use Residues and Resistance, Social-economic, Policy and Production Systems, Research Enhancement through Participatory Activities. For the 1998-1999 project year, the activities of the site were conducted mainly under the first three research components. Research activities presented herein are the collective efforts of scientists from Caribbean and US Institutions including the Caribbean Agricultural Research and Development Institute (CARDI), Ministry of Agriculture (MINAG), Rural Agricultural Development Authority (RADA), Pennsylvania State University (PSU), Virginia Polytechnic Institute and State University (VPI&SU), Ohio State University (OSU), United States Department of Agriculture - Vegetable Laboratory (USDA-VL) and Lincoln University (LU).

Summary

Key components have been identified to form the framework of an IPM model for the management of major pests on callaloo. Validation studies of the field chart designed in year five to guide pest management decisions have been completed and have shown the potential to reduce the frequency of pesticide application by up to 60% without significant increase in pest damage and economic loss due to lepidoptera species. The use of the sampling plan has been demonstrated to over 60 farmers within the major callaloo-growing parish of St Catherine. Some farmers had the opportunity to compare callaloo which had received 11 applications based on the calendar sprayed system with those sprayed six times using the sampling plan. Unanimously the farmers thought the sampling plan plot was either less damaged or had the same level of damage as the weekly sprayed plants. A follow up pesticide evaluation trial was conducted to assess three new biorational [Spintor® (spinosad), Confirm® (tebufenozide) and Ecozin® (azadirachtin)] chemistries and reassess Proclaim® (emamectin benzoate) for efficacy in controlling lepidopterous pests. Spintor® was found to give more effective control of defoliating pests resulting in markedly lower insect damaged losses (6.2%) than the grower standard, Karate® (lambda cyhalothrin, 27.7%). Emamectin benzoate (8.93%) and tebufenozide (14.2%) also gave superior protection against lepidoptera pests.

Pests Affecting Hot Pepper, *Capiscum chinense*

A breeding program to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into Habanero pepper was continued; the third backcross was completed and resistant plants from this backcross are being used to complete the fourth backcross. A breeding program was initiated to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into West Indies Red; the initial F_1 cross was completed and F_1 plants are currently being backcrossed to the West Indies Red parent. The resistance to the peanut root-knot nematode (*Meloidogyne arenaria* Race 1) in *C. chinense* was found to be conditioned by a single dominant gene; this finding confirms the results of the inheritance study conducted in 1998. The results of growth chamber tests confirmed earlier findings that resistance to southern root-knot nematodes (*M. incognita*) in *C. chinense* is partially compromised at high temperatures. However, the root galling response and nematode reproduction in the resistant Scotch Bonnet germplasm at high temperatures was significantly lower than in susceptible Habanero-type peppers. Root-knot resistant *C. chinense* cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates. The results of a second year of field tests conducted cooperatively with a CARDI investigator in St. Kitts confirmed that the recently released *C. chinense* germplasm lines PA-353, PA-398, and PA-426 are resistant to indigenous field populations of *Meloidogyne* spp. The results of greenhouse studies demonstrated that the southern root-knot nematode resistant *C. chinense* cultigens PA-353, PA-398, and PA-426 are also resistant to the peanut root-knot nematode (*M. arenaria* race 1). *Meloidogyne arenaria* race 2 was not highly pathogenic to any of the tested *C. chinense* cultigens.

Seven legumes (velvetbean, Iron-Clay cowpea, sunnhemp, soybean, Cahaba vetch, crimson clover, and hairy vetch) selected for their potential usefulness as cover-crop mulches for weed control in pepper plantings were evaluated for host suitability to southern root-knot nematodes; the velvetbean, Iron-clay cowpea, sunnhemp, and soybean entries were highly resistant and are

[1] CARDI
[2] Virginia Tech

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potentially useful for managing *M. incognita* if used as a cover-crop mulch for weed control.

Viruses are a major constraint to hot pepper production in Jamaica. During the past year, studies were conducted to determine the dynamics of the aphid vectors, the epidemiology and evaluate the potential of stylet oil and cultural practices to reduce virus incidence. Over twenty species of aphids were identified throughout the time of sampling, with the period of greatest species diversity occurring during December 1998 to April 1999. The spread of TEV was slower in plants sprayed with stylet oil than unsprayed plants.

As a stop gap to the virus problem which is crippling the hot pepper industry, West Indian Red hot pepper variety was introduced into four project areas inclusive of IPM CRSP target sites. Using IPM technologies, the West Indian red variety proved to be an economically viable crop for small farmers.
In 1998, high gall midge interceptions crippled the hot pepper industry in Jamaica, resulting in the enforcement of mandatory fumigation as a condition of entry of the product into US markets. This prompted several responses, many of which were lead by the IPM CRSP team. The development of a IPM strategy to reduce infestations was the focus of the activities and included both pre and post harvest investigations. During the past 12 months, a monitoring system that includes the assessment of larval infestation in fruits was developed. This methodology was used to assess populations in IPM studies that evaluated the potential of cultural practices and chemical insecticides to reduce gall midge infestations. The use of cultural practices in combination with selective chemicals fipronyl (Regent ®) and imidacloprid (Admire®) suppressed populations of the gall midge for over 3 weeks below a 5% threshold. These results are being used in technology transfer programmes being conducted by the task force. In addition, aluminum phosphide demonstrated its potential to kill >80% larvae within fruits without significant effect on the quality and shelf life of the peppers.

Pests Affecting Sweetpotato, *Ipomoea batatas*

A new insect pest attacking sweetpotatoes in Jamaica was identified as the sweetpotato leaf beetle (*Typophorus viridicyaneus* Crotch), and a scoring system for assessing the damage to sweetpotato roots caused by this insect was refined. Sweetpotato IPM component research focused on developing high yielding, red-skinned, cream-fleshed sweetpotato cultivars with resistances to root-knot nematodes, diseases, and insects. In addition, the integration of these varieties with a selective low toxic compound, fipronyl was initiated. Several USDA-developed sweetpotato clones and Caribbean varieties demonstrated good resistance to the sweetpotato leaf beetles, sweetpotato weevils, and/or the WDS soil insect complex in a replicated field test in Jamaica. Similar to 1997-1998 season, the promising lines appear to be White Regal and Picadito as well as the local varieties "Fire-on-land" and TI24-98. When compared to the grower standard - Sidges, combining White Regal with the selective pesticide fipronyl gave lower root damage. The regionalisation of the sweetpotato IPM was one of the highlights of the component. Researcher exchanges and visits to Jamaica, St Kitts and Nevis, St Vincent, Montserrat and St Lucia provided the medium to initiate sweetpotato research and has set the stage for future expansion of the IPM CRSP research activities.

Pesticide Use, Residues, and Resistance

The goal of this topic is to assess the extent to which pesticides are used on pepper, callaloo, and sweetpotato. We hypothesize that many of these pesticides remain on crops long after application even to the extent to which residues can be detected in local and export marketplaces. Thus, the activities described below attempt to quantify pesticide use and residues that can either cause human health problems or rejection in the marketplace. Resistance to pesticides may also be a result of excessive pesticide use or of those chemicals that degrade very slowly under field conditions. The second project described for this topic addresses the pesticide resistance question for callaloo and pepper arthropod pests.

Monitoring Pesiticide Residue Levels on Callaloo

Over the past three years, results of market basket surveys have demonstrated that pesticide residues are present on marketable produce. In an effort to address the problem. IPM technologies geared at reducing spay applications were developed. To further demonstrate the benefits of these technologies, samples of callaloo from a field experiment which compared routine farmer spraying with a limited pesticide spraying regime were analyzed for pesticide residues.

Social and Gender-Related Issues that Affect IPM Adoption

The primary activity of Year 6 was the analysis of data collected during Year 5's baseline socioeconomic survey in three communities, each affiliated with the IPM CRSP for one target crop and each located in a distinct ecological zone and geo-political region. The goals of this activity were to identify (1) socioeconomic constraints to IPM adoption and (2) beliefs and practices that contribute to health and environmental problems associated with pesticide use. Gary Schlosser and Tina Schlosser, graduate students in the Department of Geography at Virginia Tech, have published results in their Masters theses, which can be downloaded at http://www.vt.edu.

Key findings related to gender equity issues and socio-economic constraints to IPM adoption (see Objectives 1 – 3 below) are summarized in this report and are published in: G. Schlosser. *Gendered Production Roles and Integrated Pest Management in Three Jamaican Farming Communities.* M.S. thesis, Virginia Tech, 1999. Findings of the pesticide safety and health research are published in T. Schlosser, *Local Realities and Structural Constraints of Agricultural Health: Pesticide Poisoning of Jamaican Small-holders*. M.S. thesis, Virginia Tech, 1999.

Among the gender equity issues addressed is whether the adoption of IPM is likely to alter the gendered division of labor and resources within households in ways that would disadvantage women. Findings indicate that IPM adoption would not disadvantage women. However, the potential benefits of IPM adoption may not be as available to women as to men, as women are less likely to receive relevant technical assistance or to be involved in technology development. Gender bias in technology design and delivery may also constrain adoption by households. Women are producers of targeted crops who make pest management decisions. Even women who do not farm are likely to have considerable control over farm incomes; this control can impact decisions concerning purchase of pesticides. Women farmers may be more pesticide dependent than men. As women have less access to information and technology-development processes than men, they may be less likely to incorporate IPM alternatives. It is recommended that IPM CRSP collaborators increase on-going efforts to include women farmers in participatory research and disseminate gender-disaggregated social science research results to cooperating extension officers.

Farmers showed substantial awareness of safety procedures but often chose not to practice them. A general lack of knowledge among health-care providers concerning identification and treatment of poisoning was observed, although both medical and agricultural branches of the national government have made efforts to address pesticide poisoning. Pesticide poisoning is widespread in Jamaica. The subsample of cases available for analysis of pesticide health and safety issues was too small to draw conclusions concerning gender differences, but there did not appear to be gender differences in pesticide safety knowledge, attitudes, or practice. Although women were likely to resort to pesticides, they were less likely than men to spray. This pattern may help to explain why women are less likely to be treated for pesticide poisoning. Qualitative information confirmed the lack of gender differences in pesticide safety knowledge, attitudes, and practices.

Project Highlight

Results of a probability-sample household survey in three IPM CRSP research communities showed that women produce and market targeted crops, choose among pest management alternatives, and select and purchase pesticides; as women appear to have less access than men to IPM-related extension, it is recommended that the CRSP intensify efforts to incorporate women farmers in field research activities and to disseminate gender-disaggregated information to extension officers.

At the beginning of Year 6, information had been collected on government policies potentially affecting IPM adoption in Jamaica. Information had been collected on the effects of IPM on costs and returns for callaloo, sweet potato, and sweet pepper. General information had been collected for vegetable production costs and returns for farmers in Ebony Park, Clarendon Jamaica. A modeling framework was developed for evaluating returns from IPM adoption for producers of callaloo, hot pepper, and sweet potato in Jamaica.

In November 1998, Ogrodowczyk made a two-week return visit to Jamaica. During this visit economic returns and costs were evaluated for farmers at Bushy Park, St. Catherine. Potential policies affecting IPM adoption were reviewed with policy analysts and government officials in Jamaica. Technical coefficients for IPM production of sweet potato, callaloo, and hot pepper were reviewed with the collaborating scientists from CARDI. A seminar describing research objectives, procedures, and preliminary results was presented to scientists at CARDI.

From November through January, the analysis was completed, results written up in the thesis, and the thesis was successfully defended. A paper was written and presented by Ogrodowczyk at the Southern Agricultural Economics Association Annual Meeting, January 31—February 3, 1999 in Memphis, Tennessee.

Research findings indicated that the IPM systems developed for callaloo, hot pepper, and sweet potato are potentially profitable. The systems remain more profitable than conventional systems when 1) assumed chemical savings from IPM are eliminated; and 2) labor requirements for IPM are increased by 50%. When the assumed yield increase with IPM was reduced from 30% to 5% for the crops, IPM continued to be more profitable at Ebony Park but not at Bushy Park.

The policies evaluated included preclearance of vegetables for export, elimination of water subsidies, elimination of credit subsidies, a reduction in the real interest rate, elimination of the duty concession, a lowering of the Common External Tariff, and an appreciation of the real exchange rate. None of the policies had large effects on the returns to IPM adoption. Policies designed to liberalize the domestic economy are not likely to affect the potential for IPM adoption in sweet potato, callaloo, and hot pepper in Jamaica.

Caribbean Site in Jamaica
IPM CRSP YEAR 6 ANNUAL REPORT

The activities of the Caribbean site are conducted under four main research components: IPM Systems Development, Pesticide Use Residues and Resistance, Social-economic, Policy and Production Systems, Research Enhancement through Participatory Activities. For the 1998-1999 project year, the activities of the site were conducted mainly under the first three research components. Research activities presented herein are the collective efforts of scientists from Caribbean and US Institutions including the Caribbean Agricultural Research and Development Institute (CARDI), Ministry of Agriculture (MINAG), Rural Agricultural Development Authority (RADA), Pennsylvania State University (PSU), Virginia Polytechnic Institute and State University (VPI&SU), Ohio State University (OSU), United States Department of Agriculture - Vegetable Laboratory (USDA-VL) and Lincoln University (LU).

Caribbean Site Researchers

Institution	Researchers	
CARDI	Frank McDonald Janet Lawrence Dionne-Clarke-Harris	Joseph Lindsay Lilory McComie
MINAG	Don McGlashan	Lisa Myers
RADA	Phillip Chung	Trevor Morgan
VPI&SU	Sue Tolin Sally Hamilton Brain Nault	Sharon McDonald William Ravlin Larry Grossman
Penn State	Shelby Fleischer	
USDA - V L		
	Richard Fery D. Michael Jackson Howard Harrison	Janice Bohac Judy Thies
LU	Frieda Eivazi	
OSU	Clive Edwards	

IPM Systems Development

The goal of this topic is to develop IPM system components (i.e., sampling systems, decision support tools, and control tactics) and to combine these components into management systems for the three major crops (pepper, sweet potato, and vegetable *Amaranthus* [callaloo]). that are being addressed by the IPM CRSP Caribbean site research team working in Jamaica. In many cases, Jamaican farmers have adopted systems of intensive pesticide application using chemicals that pose high risks to human health and the environment. In these cases, the Caribbean research team is attempting to implement a phased approach to demonstrate the benefits of eliminating these toxic materials from Jamaican agriculture and eventually the Caribbean. The first phase is to demonstrate that less toxic pesticides can produce comparable crop yields with smaller environmental and human costs; whereas, the second and most important phase is to develop and implement IPM systems that are biologically intensive and environmentally benign.

Integrated Pest Management of Pests Affecting Callaloo, *Amaranthus* sp.

Investigators: Dionne Clarke-Harris[1], Frank McDoanld[1], Shelby J. Fleischer[2],
Collaborating Scientists: Clive Edwards[3] and Phillip Chung[4]

Abstract

Key components have been identified to form the framework of an IPM model for the management of major pests on callaloo. Validation studies of the field chart designed in year five to guide pest management decisions have been completed and have shown the potential to reduce the frequency of pesticide application by up to 60% without significant increase in pest damage and economic loss due to lepidoptera species. The use of the sampling plan has been demonstrated to over 60 farmers within the major callaloo-growing parish of St Catherine. Some farmers had the opportunity to compare callaloo which had received 11 applications based on the calendar sprayed system with those sprayed six times using the sampling plan. Unanimously the farmers thought the sampling plan plot was either less damaged or had the same level of damage as the weekly sprayed plants. A follow up pesticide evaluation trial was conducted to assess three new biorational [Spintor® (spinosad), Confirm® (tebufenozide) and Ecozin® (azadirachtin)] chemistries and reassess Proclaim® (emamectin benzoate) for efficacy in controlling lepidopterous pests. Spintor® was found to give more effective control of defoliating pests resulting in markedly lower insect damaged losses (6.2%) than the grower standard, Karate® (lambda cyhalothrin, 27.7%). Emamectin benzoate (8.93%) and tebufenozide (14.2%) also gave superior protection against lepidoptera pests.

Plant development is being monitored under three types of row covers which give 70%, 85% and 95% light transmittance, to determine the optimum light requirements for economic growth of callaloo in a protected agriculture production system.

The callaloo washer basket developed in year five was tested against the current procedure of manual washing to evaluate its effect on post harvest disinfestation of the produce. The same level of pest removal was obtained using both methods however, the ease of manipulation of each wash load was increased and mechanical damage to callaloo stalks was decreased using the washer basket.

Objectives

1. Initiate the design for integration of a scouting system in control programs for callaloo pests.
2. Define the phenological times of pest infestation in callaloo.
3. Initiate the design for integration of exclusion tactics in control programs in callaloo
4. Select and evaluate more effective, safer pesticides for controlling major pests of callaloo
5. Evaluate and enhance farmer knowledge of pests and crop management in major callaloo growing areas in St Catherine
6. Develop protocols that would ensure freedom from contamination due to arthropod pests and pesticide residue in callaloo produced in selected areas
7. Develop protocols to assist in putting callaloo back on the preclearance list

IPM Constraints

1. Taxonomic status of certain lepidopteran pests in their larval stage needs to be clarified. This is essential for development of management tactics more closely tied to the biology of the pest.
2. Current grower practice emphasizes prophylactic calendar sprays for control of lepidopteran larvae, resulting in high insecticide inputs. This results in high labor and material costs, minimizes the potential for integrating other management tactics, and creates environmental, health and export constraints. Developing action thresholds would begin to manage these insecticide inputs.
3. Pesticides currently used against callaloo pests fail to give effective control, possibly because of the lack of resistant management protocols for pesticide use. New effective chemistries need to be identified and introduced in conjunction with the implementation of stricter management procedures for pesticide use.
4. Ideally, IPM seeks to minimise pesticide use in production systems effective non chemical methods

[1] CARDI
[2] Penn State University
[3] Ohio State University
[4] RADA

need to be identified and adapted to this cropping system

5. Farmer empowerment through education and transfer of technology is paramount to the successful implementation of new methods of crop (pest) management.
6. Post harvest management of the crop needs to be developed to complement pre harvest efforts towards the supply of produce of high quality.

Research Methods

(1) Development of sampling protocols for pests in callaloo. *(D. Clarke-Harris, S. Fleischer).*

Objectives

- Estimate the seasonal dynamics of pests in callaloo, and statistical properties of insect sampling data for the development of sampling programmes (addressed in Year 5)
- Initiate the design for integration of precise scouting methods in control programmes for callaloo

Research Methods

On farm validation/ demonstration

A validation trial was conducted on four farms in Bushy Park to determine the efficacy of a developed sampling plan and decision making tool in reducing frequency of spray applications without significantly increasing insect damaged losses. Two plots of four hundred plants each were established on each farm.

Treatments

Two treatments were compared in the paired plots established on each farm:
1) Sampling Plan: Pesticide applications were made based on a decision making tool which uses a sequential sampling plan.
2) Farmer Practice: Pesticide applications were made once per week on a calendar cycle.

Data collection

Pest frequency. Once weekly, 25 plants per plot were randomly selected and six leaves per plant (3 inner whorl and 3 outer whorl) were examined for lepidoptera larvae. The number of larvae per plot was recorded. Data from two farms were analysed using a t-test to compare treatment means.

Damage severity. The level of lepidopteran feeding damage on each leaf was recorded as one of four indices : No damage, 1- < 30% damage, 2- 31-60% damage and 3- > 60% damage.

Crop loss Assessment. Stalks of harvestable length (30 cm and over) were cut from all plots every eight days. Stalks cut from each plot were kept separate and harvested stalks were then graded as marketable or reject. Rejected stalks were further sorted into loss categories: seeding (shoots becoming reproductive and thus not salable), fungus damaged, insect damaged, mite infested/damaged, and rough stalk (shoots developing bark tissue and thus not salable).

Results and Discussion

Results obtained from evaluation trials on four farms showed savings in pesticide input (ie number of spray applications) without increases in the severity of leaf damage and hence losses in marketable yield. On all farms pesticide input was reduced by greater than 33 percent. This potential for reducing pesticide inputs so greatly has major positive implications for economic (reduction in labor cost and cost of inputs) and environmental benefits (insecticide resistance management and reduced pesticide load).

The range of cumulative larval frequencies recorded per plot on each farm was Francis (1-145), Edwards (0-54), Johnson (0-260) and Woolery (0-97). Treatment differences on all farms were not significant ($P > 0.05$). Analysis of data showed there was no significant ($P > 0.05$) difference between the damage severity observed on plants sprayed weekly and those sprayed less frequently using the sampling plan (Table1).

The number of pesticide applications was reduced as follows by using the sampling plan: Francis (33.3%), Edwards (40.9%), Johnson (60%) and Woolery (33.3%). The mean number of larvae (standard deviation) in the farmer practice plots was 36.7 (38.5), 19.5 (14.8), 30.4 (66.0) and 24.4(23.5) at Francis, Edwards, Johnson and Woolery, respectively, compared to corresponding means of 38.8 (27.2), 24.2 (14.1), 30.6 (38.9) and 26.5 (24.1) recorded in the plots sprayed based on the sampling plan. The large variation in pest frequencies observed allowed for testing of the plan at low and high pest frequencies.

Table 1: Larval frequency and severity of damage to callaloo leaves treated with timed pesticide applications based on a sampling plan versus calendar spraying.

Farms	Sampling Plan						Calendar Spraying					
	Mean No. of larvae	No. of sprays	Percentage of leaves With damage index				Mean no. of larvae	No. of sprays	Percentage of leaves with damage index			
			0	1	2	3			0	1	2	3
Francis	38.8	8	11.7	23.1	39.5	25.9	36.7	12	12.9	26.5	38.7	21.3
Edwards	24.2	13	20.1	30.2	35.8	13.9	19.5	22	26.9	30.1	31.6	12.3
Johnson	30.6	6	30.1	26.7	29.3	13.3	30.4	15	26.6	27.1	29.3	16.7
Woolery	26.5	10	24.1	28.3	32.1	15.5	24.4	15	26.7	28.4	30.3	14.7

The results obtained from on farm evaluation trials showed up to 60% savings in pesticide inputs (Table 1). Figure 1 shows that spray applications using the sampling plan were made during periods of increased larval populations while in weekly-sprayed plots pesticides were applied even when pest populations were low.

Upon comparison of the proportion of leaves per damage category, callaloo leaves in both treatment plots showed no appreciable difference in level of damage (Table 1) despite the reduction of 33.3-60% in pesticide inputs using the sampling plan.

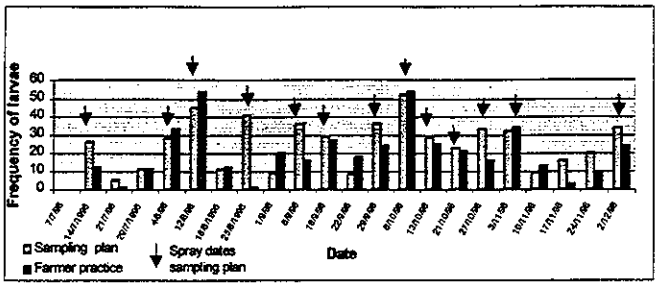
Insect damaged losses ranged from 10%- 46% (Table 2) on all farms but were not significantly (P>0.05) different between treatments indicating that the same levels of insect damage control may be obtained with less frequent applications of pesticide than current farmer practice of weekly sprays (Figure 2). However, the need for more effective chemistries to increase crop protection is evident.

Other factors contributing to loss were also recorded in treatment plots (Table 2) however lepidoptera pests were the main culprits therefore, savings in cost of pesticide inputs and increased management of these insects would result in increased earnings to callaloo farmers.

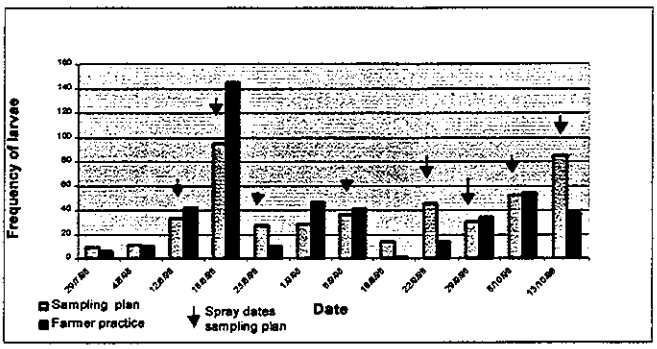
Table 2: Comparison of percentage yields in different yield grades harvested from weekly-sprayed plots versus plots with timed spray applications based on sampling

GRADE OF YIELD	Percent loss per yield grade per farm							
	Francis		Edwards		Johnson		Woolery	
	SP	FP	SP	FP	SP	FP	SP	FP
Marketable	21.22	17.63	60.82	63.54	57.35	51.08	60.50	59.30
Rejects								
Insect damaged	43.56	46.00	32.81	30.14	10.0	10.64	22.13	19.90
Mite damaged	0.00	0.00	0.27	0.29	0.40	0.20	0.00	0.00
Fungus damaged	9.24	11.24	0.29	0.59	16.30	16.43	4.22	4.76
Seeding	17.55	18.06	5.12	5.10	3.55	3.69	5.53	6.49
Rough stalk	8.42	7.31	0.66	0.49	4.08	3.67	7.50	9.64

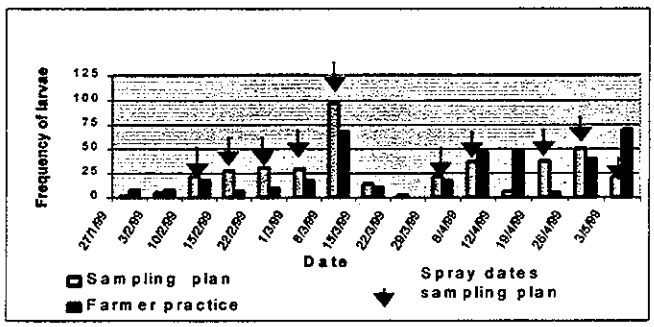
FP = farmer practice, SP = sampling plan



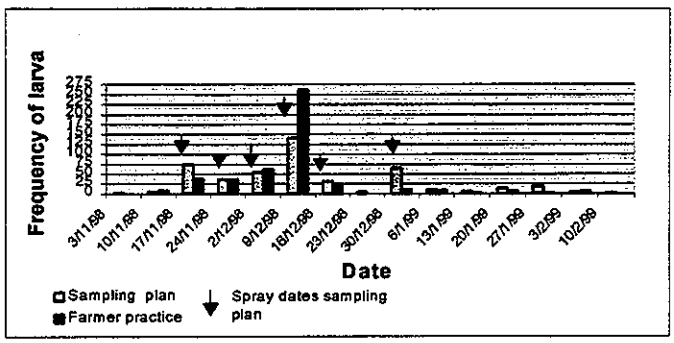
a. **Edwards Farm**



b. **Francis' Farm**



c. **Woolery's Farm**



d. **Johnson's Farm**

Figure 1 a-d: Relative incidence of lepidopteran larvae and spray applications in weekly-sprayed plots versus timed pesticide applications using a sampling plan

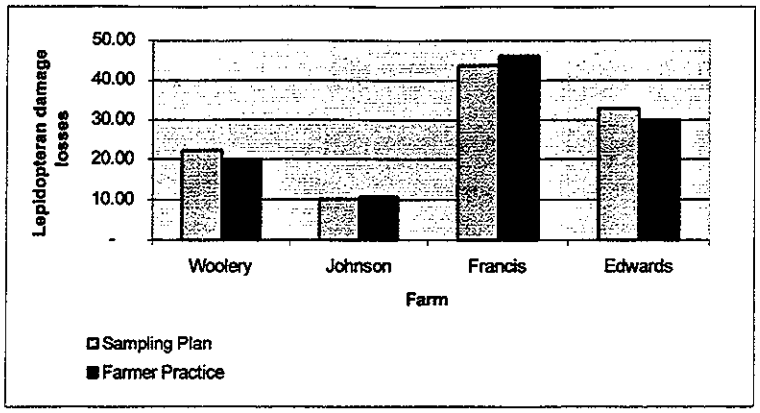


Figure 2: Mean lepidopteran damaged losses on four farms from weekly-sprayed plots versus plots sprayed based on the sampling plan

Impact

Callaloo farmers spray their crop once weekly mainly as a prophylactic treatment against lepidopterous pests. This practice is probably the major contributor to the eroded efficacy of most contemporary pesticides. The introduction of any new chemistry without the implementation of a resistance management program would only again result in insecticide resistance and the cycle would continue. This sampling plan shows the potential to indicate economic pest population levels and thereby guide farmers in timing spray applications.

The development and implementation of this sampling plan was a fundamental step to minimizing pesticide use in callaloo production systems and guiding the sustainable use of new biorational chemistries now available to control lepidopteran species on leafy vegetables.

(2) Assessment of exclusion as a control tactic for callaloo pests *(D. Clarke-Harris and S. Fleischer)*

Research Methods

Experimental design. A randomised complete block experiment (4 treatments x 5 replicates) was set up at CARDI, Mona Campus to evaluate plant development under row covers of varying levels of light transmittance. Crop development under three row covers Tufbell, Ag19 and AG30 (95%, 85% and 70% light transmittance, respectively) are being compared to the development of uncovered plants (100% light transmittance). Each treatment plot consists of 24 plants (2 x12 plants) planted at 30 cm spacing within row and 45 cm spacing between row.

Status

Trial was initiated in September 1999. Results will b reported in the 1999-2000 Annual report.

Impact

Callaloo production is currently heavily reliant on pesticides because its salability is dependent on the aesthetics of leaves, which are attacked by several voracious herbivorous arthropod species. With the growing concern among consumers globally about pesticide residues on food non-chemical methods of pest control would give a competitive advantage to this commodity.

Exclusion of major pests by using a mesh barrier was demonstrated in earlier trials to be very effective. Other horticultural considerations such as optimal light requirements and the selection of cost-effective screens will provide valuable information for the development of this technology in order to produce callaloo economically in a protected agriculture system.

(3) Evaluation of the efficacy of new chemistries in controlling major pests on callaloo*(D. Clarke-Harris and S. Fleischer)*

Research Methods

A randomized complete block (five treatments and four replicates) experimental trial was laid down to compare the efficacy of Proclaim® (emamectin benzoate), Confirm® (tebufenozide), Spintor® (spinosad) and Ecozin® (azadirachtin) with the farmer standard (control), Karate® (lambda cyhalothrin). Treatments were applied at manufacturer's rate once per week beginning two weeks after transplant.

Each treatment plot contained 56 plants (8x7 arrangement) in a 6.5 m2 area. The 20 central plants were the experimental plants and the surrounding 36 plants served as border rows. Five randomly selected experimental plants per plot were monitored once weekly to determine pest infestation and damage. Data on pest

frequency and damage severity were collected from the five plants as described in Section 1A.

Stalks of harvestable length (30 cm and over) were cut from all plots every eight days. Stalks cut from experimental plants were kept separate from border plants for each plot. Harvested stalks were then graded as marketable or reject. Rejected stalks were further sorted into loss categories: seeding (shoots becoming reproductive and thus not salable), fungus damaged, insect damaged, mite infested/damaged, and rough stalk (shoots developing bark tissue and thus not salable).

Results and Discussion

Pest frequency. On comparing incidence of lepidopteran larvae among treatment plots, the plots treated with spinosad had the lowest larval populations (0-1larvae/plant) (Figure 3). Plots treated with tebufenozide (0-5.2 larvae/plant) and emamectin benzoate (0-4.25 larvae/plant) also had good control of lepidoptera larvae while plots treated with azadirachtin (0-16.05 larvae/plant) had the highest larval frequencies.

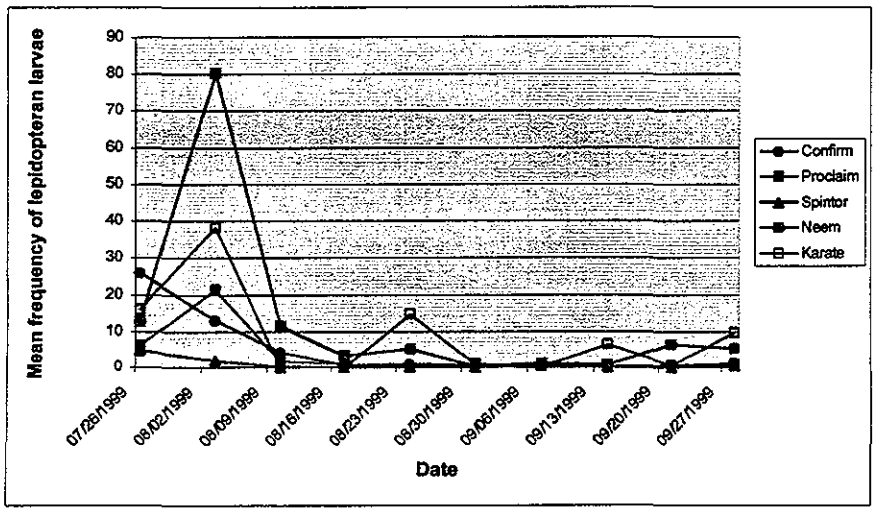


Figure 3: Effects of Proclaim® (emamectin benzoate), Confirm® (tebufenozide), Spintor® (spinosad), Ecozin® (azadirachtin) and the farmer standard, Karate® (lambda cyhalothrin) on lepidopteran populations on callaloo

Damage incidence and severity. Differences in the severity of damage to leaves collected from different treatment plots showed spinosad giving superior protection to the crop (Figure 4). The mean percentage of undamaged leaves (severity index 0) that were observed in plots treated with spinosad was 51% compared with 39% (control). Azadirachtin and lambda cyhalothrin offered the least protection against lepidoptera as 33% and 35% of leaves respectively had >30% feeding hole damage and 33% with damage index 1.

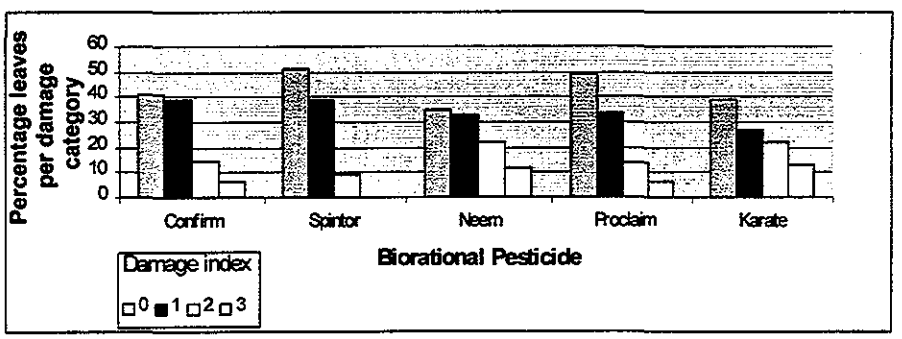


Figure 4: Severity of damage by lepidoptera on leaves sprayed with different insecticide treatments

Crop Loss. Levels of crop loss followed the same trends as pest frequency and damage (Figure 5). Plots treated with spinosad gave the highest volume of marketable yields (68.9%) and correspondingly the least losses due to lepidoptera damage which ranged from 2-19 percent (mean 6.18%) (Figures 5&6). Marketable yields in other treatments ranged from 64.7% (tebufenozide) to 39.1% (azadirachtin) and corresponding mean insect damaged losses were 14.18% and 22.6% respectively. The control lambda cyhalothrin had the highest insect damaged losses (4.25-72.25) per cent mean 27.66%.

The relatively high level of control of lepidopteran pests obtained with the new biorational chemistries (spinosad, tebufenozide and emamectin benzoate) gives credence to the perception that insecticide resistance is the main contributor to the ineffectiveness of current pesticides. These new chemistries can be introduced in tandem with strict resistance management protocols (the sampling plan/spray application guide and pesticide rotation) for the sustainable control of lepidoptera larvae.

The neem pesticide (Ecozin®) like the pure neem oil used in the trial in year 5 was not as effective as other treatments. The low persistence of the active ingredient could be one contributing factor and more frequent application may give greater control.

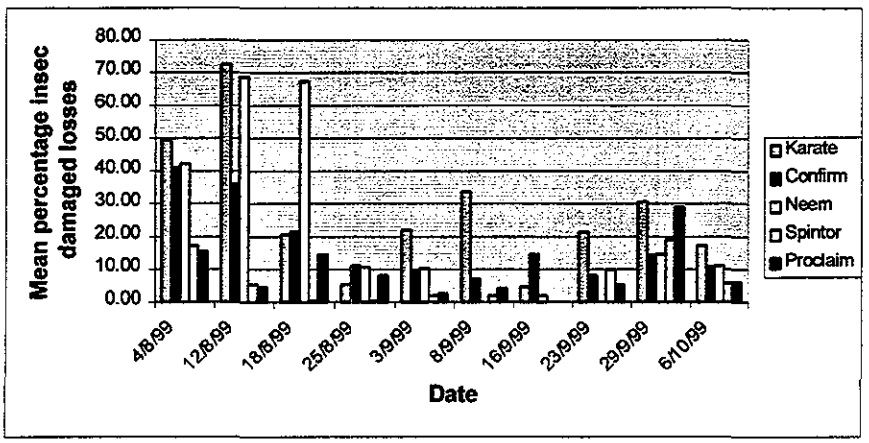


Figure 5: Effects of Proclaim® (emamectin benzoate), Confirm® (tebufenozide), Spintor® (spinosad), Ecozin® (azadirachtin) and the farmer standard, Karate® (lambda cyhalothrin) on yield grades of callaloo

Impact

Synthetic pesticides currently being used on callaloo in the management of major pests, mainly lepidopteran species fail to give adequate control despite frequent applications. It is unlikely that any developed IPM strategy would exclude the use of pesticides therefore the selection of more effective chemistries is critical to the successful implementation of IPM.

Two biorational pesticides used in this trial, viz. spinosad and tebufenozide are registered for use on leafy vegetables and are therefore ready candidates for use with the developed sampling plan.

(4) Technology transfer of callaloo IPM *(D. Clarke-Harris and P. Chung)*

Description

Two farmer field days were held in two major callaloo growing areas in St Catherine. The first training day was held in January in Bushy Park the theme being "Integrated Pest Management on callaloo- *Monitoring Populations of Major Pests on Callaloo*". The objectives were:

- to outline the components of callaloo IPM
- to demonstrate the use of pheromone traps as an early warning of lepidopteran outbreak
- to demonstrate the use of a sampling plan for lepidopteran larvae
- to give hands on training in identification of major pests on callaloo

A group of 30 agriculturists comprising callaloo farmers and extension agents were trained in:

- Integrated Pest Management and how it can be practiced in callaloo production
- Identification of major callaloo pests and its importance in making decisions when choosing pesticides
- Scouting procedures and how pest frequency can be used in the timing of pest management intervention

The second field day '*Management of Callaloo Pests*' targeted farmers in Lakes Pen, St Catherine. This was a major collaborative effort by CARDI, RADA, The Ministry

of Agriculture and exporters of callaloo to urgently address the misuse of pesticides. Unacceptable levels of the pesticide chloropyrifos were found in cans of processed callaloo, which were exported to Canada. This finding has serious implications for the continuation of this market if the problem is not curtailed. The specific objectives of this field day were therefore to educate farmers on:

- The consequences of pesticide misuse on sustainability of markets
- Types and importance of information on pesticide labels
- Some suitable pesticides for use on callaloo
- Integrated Pest Management
- Proper post harvest handling

On both occasions farmers were given hands on exercises in scouting for lepidopteran pests and using a decision making tool to make spray decisions. These demonstrations were conducted on one of our experimental plots during the field day in Bushy Park where the farmers could see evidence that spraying based on an action threshold gave comparable yields to those obtained from plots that were sprayed twice as frequently based on a weekly calendar cycle. In Lakes Pen demonstrations were carried out on a farmer's field.

The need for farmers to modify their operations and employ new technologies to produce more competitive products was underscored during the presentations.

(5) Post harvest disinfestation of Callaloo*(D. Clarke-Harris and F. McDonald)*

Research Methods

Assessment of callaloo washer basket

The effectiveness of the callaloo washer basket designed to improve post harvest disinfestation of the produce was assessed. Two treatments: (I) callaloo washer basket and (ii) manual agitation (current practice) were compared in a replicated experiment (three replicates). For each method of washing 9.1 kg of callaloo was washed in 450 L of 0.6% sodium chloride (common table salt) solution and agitated for five minutes then rinsed twice in 450 L of water for a period of one minute each. A 1.5 kg subsample was removed from each wash load before treatment and the number of arthropods present counted and recorded. A post treatment sample of similar quantity was taken to determine the proportion of arthropod residues removed. Data were analysed using a t- Test.

Disinfestation

Four concentrations of common table salt (NaCl and water) solution (1%, 3%, 5%, 8%, 10% and 15%) and pure water were compared to determine an optimum concentration for removing pest residues from harvested callaloo stalks. Each treatment was repeated six times. 3.2 kg of callaloo stalks was used in each trial. Before treatment, a 1.5 kg sample was randomly taken from among pretreated stalks, all leaves examined, the number of each pest species found were recorded and the sample replaced. The desired solution was obtained by adding common table salt to 45.5L of water based on a weight to volume ratio. Callaloo stalks were submerged in solution and agitated for one minute then removed from solution and rinsed twice for one minute each in 45.5 L of water. Another 1.5 kg sample was taken after the final rinse and a post treatment assessment of remaining arthropods was conducted.

Monitoring Shelf life. The shelf life of the produce after washing was assessed for each treatment. Half a kilogram of callaloo stalks was trimmed of all unhealthy leaves and the remaining healthy leaves counted. The trimmed stalks were then placed in plastic bags, 7 cm in diameter which were pierced with six holes and refrigerated. The condition of the leaves on each stalk was examined over the next seven days and a record was made of leaf abscission and the number of healthy, wilted and decomposed leaves.

Results and Discussion

Washer basket

The proportion of total pest residues removed was not significantly ($p>0.05$) different between the two modes of washing. Mean arthropods removed during manual agitation was 87.2% compared to 81.0% using the basket. However, the wash basket greatly improved maneuverability of the wash load and its transfer to the rinse solution as well as reduced mechanical damage to the leaves during agitation.

Disinfestation

All concentrations of sodium chloride solution resulted in a higher proportion of the arthropods removed from the washed stalks than the control (Table 3). Although the highest disinfestation was obtained when the highest concentration was used the observed trend was not consistent. Treatment differences were not significant ($P>0.05$).

Arthropods present included mites, armyworms, leafwebbers and leafhoppers. The efficacy of removing these pest residues varied among pests. All arthropods except leafwebbers seemed to be more effectively removed with increased concentrations of salt. Further analyses will be conducted to determine whether salt concentration effected greater removal of some arthropod species.

Table 3. Disinfestation of callaloo stalks washed in varying concentrations of sodium chloride solution

Concentration of NaCl solution	Mean number of arthropods on callaloo stalks		Percent disinfestation
	Before washing	After washing	
water	152	46	70
1%	323	23	93
3%	157	22	86
5%	161	11	93
8%	163	7	96
10%	211	11	95
15%	93	6	94

Leafwebbers remaining on the leaves after washing in salt solution were desiccated but remained tangled in webbing or enclosed in folds of leaves. In salt solution the reduced weight and flattened shape of the organism after desiccation possibly results in the decreased ability to dislodge the insects during agitation while in pure water (control) the turgid insect is more easily removed. If statistical analyses show significantly higher removal of leafwebbers in pure water the recommendation for treatment of callaloo stalks with high residues of this insect should instruct a pre wash in pure water followed by washing in salt solution to remove other pests.

Shelf Life

Shelf life was not affected by any treatment used. All samples stayed fresh during the seven-day monitoring period. After initial washing in concentrations 8% - 15% however, the leaves wilted from the dehydrating effects of the salt. Subsequent rinses in water restored the turgidity of the leaves, which was retained for the seven-day period of observation.

Impact

The interception of pest residues on callaloo stalks presented at preclearance facilities for shipment to the United States is a frequent criterion for rejection. Post harvest treatment protocols at packing houses are not standardized. The commonly used wash solution of common table salt and water is not of a fixed concentration based on empirical data and the mechanism of manual agitation is not very efficient for manipulating the wash load.

The washer basket design allows for improved, uniformed manipulation of the entire wash load and standardization of the process. Appropriate post harvest treatment protocols could reduce pest residues on the product.

(6) Evaluation of Pheromone Traps as Early Warning Devices *(D. Clarke-Harris and S. Fleischer)*

Research Methods

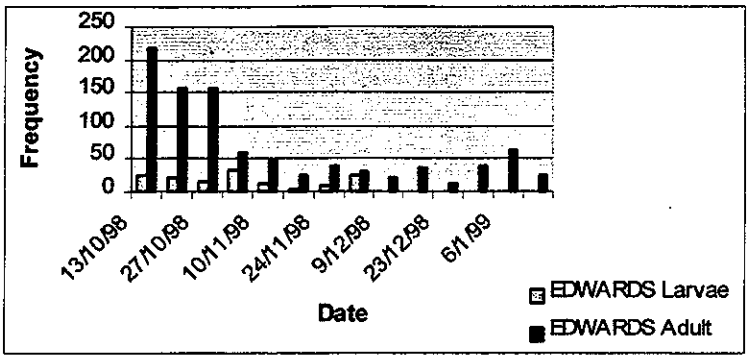
Traps baited with a lepidopteran sex pheromone were placed on three farms in Bushy Park to evaluate their effectiveness in monitoring moth flights and indicating the onset of lepidoptera outbreaks. Three traps baited with a female sex pheromone for *Spodoptera* species were set 75 mm apart in a triangular arrangement on each farm. Traps were checked once weekly and the moths caught were counted and recorded. The bait was replaced once every two weeks. Concurrently, data on larval populations were collected to determine the type of correlation between moth frequency and larval frequency. Six leaves from each of 25 plants were randomly selected and examined for the presence of lepidoptera larvae and the total number of larvae recorded.

Research Results and Discussion

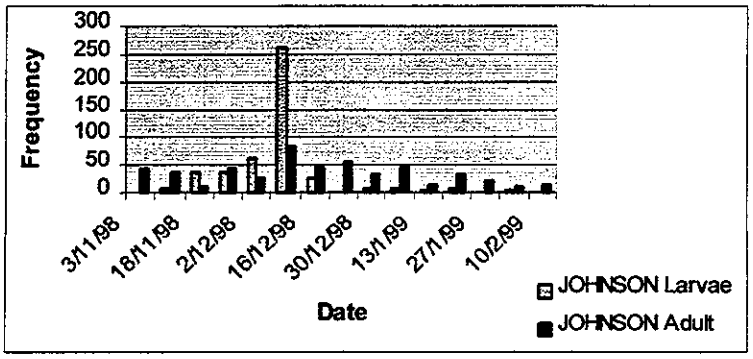
The data on adult and larval frequency of Lepidoptera recorded on the three farms are summarised in Figure 1(a-c). There is no visible trend however data will be analysed to determine whether there is direct or lagged correlation between moth catches and larval frequency.

Impact

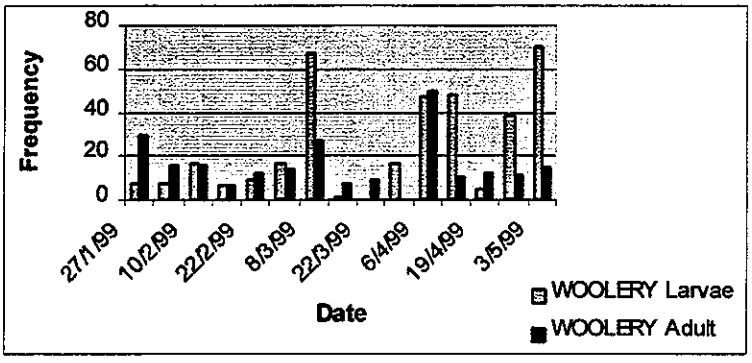
The use of pheromone traps would be a more efficient monitoring tool than visual observation of larvae if an action threshold for pesticide applications could be developed based on moth populations. If this method is effective at the very least it can be an early warning device to prompt more intensive scouting of fields in anticipation of egg laying and hence early instar larvae which are more susceptible to less toxic biological pesticides.



(a) Edwards' Farm



(b) Johnson's Farm



(c) Woolery's Farm

Figure 1(a-c): Comparison of moth catches by pheromone traps and larval frequency recorded on three farms in Bushy Park

NETWORKING

A. Workshop/Meetings/Seminars

- D. Clarke-Harris participated in the IPM CRSP Annual Planning Workshop, West Lafayette, in May 7th –8th, 1999.
- S. Fleischer participated in the IPM CRSP Caribbean Site meetings held in Charleston, SC. (June 27th – 30th, 1999)
- D. Clarke-Harris coordinated and presented a farmer training series - Integrated Pest Management-Monitoring Populations of Major Pests on Callaloo, Management of Pests in Callaloo.

- D. Clarke-Harris attended a CARINET workshop on Identification of whiteflies and mealybugs, Trinidad W I.

B. Researcher Investigator Exchanges

- Shelby Fleischer traveled to Jamaica (February 20th – 27th, 1 999) to develop journal articles with collaborators, develop workplan for Year 7 and observe field activities.

C. Research Information and Product Exchange

(a) Impact of IPM CRSP produced or recommended technology, including crop protection inputs, manuals, brochures etc.

(1.) D. Clarke-Harris disseminated callaloo pest management guides to farmers, extension and researchers in Jamaica. Copies of the publication was also given to collaborators in the Region.

(b) Assistance you have given to collaborating scientists with research equipment, supplies and/or other support

(1). Drs Shelby Fleischser and Irene Mbugua, and Mary Woodecki of Penn State University.

(2.) Dr Shelby Fleischer assisted in the selection and purchase of row and purchased new chemistries for evaluation.

Publications and Presentations

A. Publications

- Clarke-Harris, D. (1999) "Tips on Scouting Callaloo Fields for worms". IPM CRSP Pest Management Guide Series. 2pp.

B. Abstracts and Reports

- Clarke-Harris, D. and Fleishcer, S. (1999). IPM systems development of pests affecting callaloo. IPM CRSP 5th Annual Report, 1997-1998. (Management Entity, Ed.) Virginia Polytechnic Institute and State University, Blacksburg, VA.

Project Highlights

- The sampling tool to guide the timing of pesticide applications developed in year five was tested and demonstrated on four farms and showed the potential to reduce the frequency of pesticide applications by up to 60%.
- The biorational pesticides, Spintor, Emamectin benzoate and Tebufenozide showed potential to effect significantly greater control of lepidopterous pests on callaloo than current grower standard, λ-cyhalothrin.
- The technology to produce callaloo in a protected agriculture system using row covers to exclude major pest is being developed.
- A washer basket to increase the efficiency of post harvest disinfestation of callaloo was validated and shown to increase efficiency of post harvest disinfestation and reduce mechanical damage to callaloo stalks.
- Sixty callaloo farmers from two major callaloo growing areas in St Catherine were given hands on experience in pest identification and principles and practice of IPM and the use of the sampling plan/decision making guide for Lepidoptera.

Integrated Pest Management of Pests Affecting Hot Pepper, *Capiscum chinense*

Investigators: Richard Fery[1], Howard Harrison, Jr.[1], Judy. Thies[1], Sharon McDonald[2], Brain Nault[2], Sue Tolin[2], Frank McDonald[3], Sherman Weeks[3], Janet Lawrence[3], Dionne Clarke-Harris[3]
Other Collaborating Scientists: J. D. Mueller[4], T. P. Mack[2], L. R. Nault[5]; and J.C. Reid[6], Phillip Chung[7], Lisa Myers[8], Don McGlashan[8]

Abstract

Laboratory, greenhouse, and field studies were conducted to address pest problems associated with the production of peppers and sweetpotatoes in the Caribbean and the United States. One manuscript reporting research conducted, in part, with IPM-CRSP funds was published in a refereed journal. Additionally, two manuscripts reporting research conducted, in part, with IPM-CRSP funds are in preparation or have been submitted for publication in refereed journals. A breeding program to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into Habanero pepper was continued; the third backcross was completed and resistant plants from this backcross are being used to complete the fourth backcross. A breeding program was initiated to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into West Indies Red; the initial F_1 cross was completed and F_1 plants are currently being backcrossed to the West Indies Red parent. The resistance to the peanut root-knot nematode (*Meloidogyne arenaria* Race 1) in *C. chinense* was found to be conditioned by a single dominant gene; this finding confirms the results of the inheritance study conducted in 1998. The results of growth chamber tests confirmed earlier findings that resistance to southern root-knot nematodes (*M. incognita*) in *C. chinense* is partially compromised at high temperatures. However, the root galling response and nematode reproduction in the resistant Scotch Bonnet germplasm at high temperatures was significantly lower than in susceptible Habanero-type peppers. Root-knot resistant *C. chinense* cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates. The results of a second year of field tests conducted cooperatively with a CARDI investigator in St. Kitts confirmed that the recently released *C. chinense* germplasm lines PA-353, PA-398, and PA-426 are resistant to indigenous field populations of *Meloidogyne* spp. The results of greenhouse studies demonstrated that the southern root-knot nematode resistant C. chinense cultigens PA-353, PA-398, and PA-426 are also resistant to the peanut root-knot nematode (*M. arenaria* race 1). *Meloidogyne arenaria* race 2 was not highly pathogenic to any of the tested *C. chinense* cultigens.

Seven legumes (velvetbean, Iron-Clay cowpea, sunnhemp, soybean, Cahaba vetch, crimson clover, and hairy vetch) selected for their potential usefulness as cover-crop mulches for weed control in pepper plantings were evaluated for host suitability to southern root-knot nematodes; the velvetbean, Iron-clay cowpea, sunnhemp, and soybean entries were highly resistant and are potentially useful for managing *M. incognita* if used as a cover-crop mulch for weed control.

Viruses are a major constraint to hot pepper production in Jamaica. During the past year, studies were conducted to determine the dynamics of the aphid vectors, the epidemiology and evaluate the potential of stylet oil and cultural

[1] USDA-VL
[2] Virginia Tech
[3] CARDI
[4] Clemson University, Edisto Research and Education Center
[5] Ohio State University
[6] Kingston, Jamaica
[7] RADA
[8] MINAG

practices to reduce virus incidence. Over twenty species of aphids were identified throughout the time of sampling, with the period of greatest species diversity occurring during December 1998 to April 1999. The spread of TEV was slower in plants sprayed with stylet oil than unsprayed plants. As a stop gap to the virus problem which is crippling the hot pepper industry, West Indian Red hot pepper variety was introduced into four project areas inclusive of IPM CRSP target sites. Using IPM technologies, the West Indian red variety proved to be an economically viable crop for small farmers.

In 1998, high gall midge interceptions crippled the hot pepper industry in Jamaica, resulting in the enforcement of mandatory fumigation as a condition of entry of the product into US markets. This prompted several responses, many of which were lead by the IPM CRSP team. The development of a IPM strategy to reduce infestations was the focus of the activities and included both pre and post harvest investigations. During the past 12 months, a monitoring system that includes the assessment of larval infestation in fruits was developed. This methodology was used to assess populations in IPM studies that evaluated the potential of cultural practices and chemical insecticides to reduce gall midge infestations. The use of cultural practices in combination with selective chemicals fipronyl (Regent ®) and imidacloprid (Admire®) suppressed populations of the gall midge for over 3 weeks below a 5% threshold. These results are being used in technology transfer programmes being conducted by the task force. In addition, aluminum phosphide demonstrated its potential to kill >80% larvae within fruits without significant effect on the quality and shelf life of the peppers.

Objectives

1. Develop root-knot nematode (*Meloidogyne incognita*) resistant Habanero-type and West Indies Red-type peppers (*Capsicum chinense*).

2. Determine the inheritance of peanut root-knot nematode (*Meloidogyne arenaria*) resistance in *C. chinense*.

3. Determine the effectiveness of resistance to root-knot nematodes (*Meloidogyne incognita*) in Scotch Bonnet peppers (*Capsicum chinense*) grown at high temperatures.

4. Evaluate the performance of *Capsicum chinense* (Scotch Bonnet-type pepper) cultigens in St. Kitts.

5. Characterize the resistance to *Meloidogyne arenaria* races 1 and 2 in *Capsicum chinense* Jacq. cultigens.

6. Determine the potential of using cover-crop mulches to control root-knot nematodes in pepper plantings.

7. Evaluate pre and post harvest pest management tactics for the gall midge complex.

8. Train farmers in hot pepper production technology.

9. To monitor the seasonal abundance of aphids on farms in Bushy Park and Bodles, St. Catherine, Jamaica where Scotch Bonnet pepper, *Capsicum chinense* Jacq., is grown.

10. To compare the incidence of virus infection, the quality and quantity of *C. chinense* fruit in fields in which seedlings were a) protected with aphid proof screen before transplanting and then treated with multiple applications of stylet oil after transplanting; b) protected with aphid proof screen prior to transplanting only; and c) not protected or sprayed[1].

11. To investigate the temporal and spatial patterns of virus (e.g., tobacco etch virus) spread in a *C. chinense* field.

12. To compare the overall incidence of virus infection, and, quantity and quality of *C. chinense* fruit in fields in which early virus infected *C. chinense* plants are rogued versus those that remain in the field.

IPM Constraints

1. Root-knot nematodes and weeds are widely recognized as yield-limiting pests of peppers. *Fusarium oxysporum*, *F. batatas*, insects, and root-knot nematodes are widely recognized as yield limiting pests of sweetpotato. Additionally, many weeds and mulch crops are known to be alternate hosts of root-knot nematodes and other plant pathogens, and the alternate host status of weeds and mulch crops must be considered for successful implementation of an IPM program. The major constraints being addressed by this project are the unavailability of suitable pepper cultivars with useful resistances to diseases and pests, the unavailability of environmentally and toxicologically safe herbicides, and the lack of adequate technical information for

[1] Modification of objective 10 was necessary based on the absence of virus symptoms during the vegetative phase of the crop. Hence, objective 11.

making weed control recommendations for the pepper cropping systems in Jamaica.

2. As a stop gap to the virus problem which is crippling the hot pepper industry, West Indian Red hot pepper variety was introduced into four project areas inclusive of IPM CRSP target sites. Using IPM technologies, the West Indian red variety proved to be an economically viable crop for small farmers.

3. Useful management tactics were identified which can assist in reducing gall midge infestations and interceptions at US ports. The use of cultural practices in combination with imidacloprid or fipronly proved to very effective in suppressing pest populations below a 5% threshold for a least three weeks. With the knowledge of the issues surrounding the use of methyl bromide, aluminum phosphide has been identified an a possible post harvest fumigant.

Research Methods

(1) Develop root-knot nematode (*Meloidogyne incognita*) resistant Habanero-type and West Indies Red-type peppers (*Capsicum chinense*). *(R. Fery and J. Thies)*

Research Methods

The breeding program to develop a southern root-knot nematode resistant Habanero-type pepper was continued. Additionally, a new breeding program was initiated to develop a southern root-knot nematode resistant West Indies Red-type pepper. A traditional recurrent backcross breeding procedure is being used in both breeding programs. The donor parent of the dominant resistance gene being used in both programs is the germplasm line PA-426. PA-426, a Scotch Bonnet-type pepper released by the USDA in 1997, is highly resistant to the southern root-knot nematode. The recurrent parent for the Habanero breeding program is the Habanero-type cultigen PA-350. The recurrent parent being used in the West Indies Red breeding program is the Jamaican hot pepper cultivar West Indies Red.

Research Results and Discussion

During the past year, a greenhouse bioassay to evaluate BC_3 (third backcross) populations from the Habanero breeding program for reaction to the southern root-knot nematode was completed. Resistant plants were selected, and these plants are currently being used to complete the fourth backcross to the Habanero-type cultigen PA-350. Additionally, the resistant germplasm line PA-426 was successfully crossed with the Jamaican hot pepper cultivar West Indies Red. The F_1 of the PA-426 x West Indies Red cross is currently being backcrossed to the West Indies Red parent.

Impact

Previous IPM CRSP-funded research conducted at the U.S. Vegetable Laboratory has shown that none of the C. chinense cultivars currently available to U.S. and Jamaican farmers are resistant to the southern root-knot nematode. This nematode is a severe pest of this pepper species and the utilization of resistant cultivars would be the ideal way of addressing the problem. The previous research resulted in the discovery and release of three southern root-knot nematode resistant Scotch Bonnet-type germplasm lines. The results reported above indicate that the utilization of classical plant breeding methods can be used to quickly incorporate southern root-knot nematode resistance into *C. chinense* cultivars. The Habanero has become a popular pepper in the U.S., and the availability of a root-knot nematode resistant Habanero cultivar would provide U.S. growers an alternative to the use of soil fumigates to control root-knot nematodes in Habanero plantings. West Indies Red is a leading processing cultivar in Jamaica, and a root-knot nematode resistant version of this cultivar should be a valuable tool for use in any IPM program designed to control pepper pests in Jamaica.

(2) Determine the inheritance of peanut root-knot nematode (*Meloidogyne arenaria*) resistance in *C. chinense*. *(R. Fery and J. Thies)*

Research Methods

The data reported under this objective are from two greenhouse experiments conducted at Charleston, South Carolina, during the winter/ spring season of 1999. Seeds of all parental, F_1, F_2, and backcross generations were produced in the greenhouse using standard crossing and selfing procedures. The tests were conduced in 4.1 x 1.7 x 0.2 m benches containing a steam-sterilized mixture of about 6 soil : 3 sand : 1 peat moss (by volume). Seedlings were started in flats containing a sterilized artificial growth medium, and transplanted into the benches after true leaves had expanded. After the plants were established and growing, each plant was inoculated with ÷3,000 *M. arenaria* eggs. All *M. arenaria* populations were Race 1.

The planting arrangement was a 10 x 12 cm rectangular pattern. In order to minimize the effects of moisture and temperature stress, the outmost 2 rows around each bench were utilized as buffers. Greenhouse temperature was maintained between 24°C and 32°C and all plants were evaluated 13 to 14 weeks after inoculation. Each plant received 2 subjective scores, one for the prevalence of root galling and another for the prevalence of egg masses. The following scale was used to score the severity of galling: 1 = no galls; 2 = light galling, 1 to 25% of root system galled; 3 = moderate galling, 26 to 50% of root system galled; 4 = heavy galling, 51 to 75% of root

system galled; and 5 = severe galling, 76 to 100% of root system galled. The number of egg masses per root system were scored as follows: 1 = no egg masses evident, 2 = scattered egg masses covering 1 to 25% of the root system, 3 = moderate number of egg masses covering 26 to 50% of root system, 4 = numerous egg masses covering 51 to 75% of root system, and 5 = extremely large numbers of egg masses covering 76 to 100% of root system. All plants with gall severity scores of 1 to 2 were classified as root knot resistant; plants scored 3 to 5 were classified as susceptible. Chi-square tests for goodness-of-fit were used in testing all genetic hypotheses.

Experiment I. Plants of the parental, F_1, F_2, and backcross generations of the cross PA-426 x PA-350 were tested for resistance to *M. arenaria*. PA-426, a Scotch Bonnet-type pepper, is resistant to *M. arenaria*. PA-350, a Habanero-type pepper, is highly susceptible. The experimental design was a randomized complete block with four replications. Each plot contained five plants. Each replicate contained two plots of PA-426 plants, two plots of PA-350 plants, two plots of F_1 plants, eight plots of F_2 plants, eight plots of F_1 x PA-426 backcross plants, and eight plots of F_1 x PA-350 backcross plants. The seeds were planted on 15 January 1999, the seedlings were transplanted on 2 February 1999, established plants were inoculated on 23 February 1999, and the roots of each plant were evaluated on 25 May 1999. The 1.05% NaOCl procedure was used to extract eggs from bulked, fibrous root samples harvested from the parental and F_1 plots (R. S. Hussey and K. R, Barker. 1973. Plant Dis. Rptr. 57:1025-1028.)

Experiment II. Plants of the parental and F_2 generations of the cross PA-426 x Carolina Cayenne were tested for resistance to *M. arenaria*. Carolina Cayenne is a *C. annuum* cultivar that is highly resistant to several root-knot nematode species, including *M. arenaria*, *M. incognita*, and *M. Javanica*. The experimental design was a randomized complete block. Each plot contained five plants. Each replicate contained two plots of PA-426 plants, two plots of Carolina Cayenne plants, and eight plots of the F_2 plants. Additionally, each replicate contained two plots of the susceptible PA-350 (susceptible control). The seeds for this test were planted on 15 January 1999, the seedlings were transplanted on 2 February 1999, established plants were inoculated on 23 February 1999, and the roots of each plant were evaluated on 25 May 1999.

Research Results and Discussion

The procedures used to infest the established plants in the growing medium with *M. arenaria* eggs were effective and reliable. All homozygous lines with known reactions to the parasite reacted as expected.

Experiment I. PA-426 and PA-350 plants reacted to *M. arenaria* as expected (Table 1). PA-426 exhibited a high level of resistance. The roots of most of the PA-350 plants exhibited heavy to severe galling and egg masses were numerous. The frequency of phenotypes in the progeny generations indicated that the *M. arenaria* resistance in PA-426 is conditioned by a single dominant gene (Table 2). All 11 F_1 plants were resistant and all of the 159 F_1 x PA-426 plants were of the expected resistant phenotype. The F_2 segregated 3 resistant: 1 susceptible, and the F_1 x PA-350 backcross segregated 1 resistant: 1 susceptible.

Table 1. Gall indices, egg mass indices, and number of eggs per gram fresh root tissue for the *Capsicum chinense* germplasm lines PA-426 and PA-350 and the F_1 hybrid PA-426 x PA-350. All plants were inoculated with the peanut root-knot nematode, *Meloidogyne arenaria* race 1.

Population	Gall Index[1]	Egg mass Index[2]	No. eggs/g fresh root tissue
PA-426	1.00 B[3]	1.00 B	415 B
PA-350	4.66 A	4.70 A	56,837 A
F_1 (PA-426 x PA-350)	1.12 B	1.12 B	896 B

[1]Plants rated on a scale of 1 to 5; 1=no galling and 5= galls covered at least 81% of root system.
[2]Plants rated on a scale of 1 to 5; 1= no egg masses and 5 egg masses covered at least 81% of root system.
[3]Mean separation within columns at $P \leq 0.01$ by Duncan's multiple range test.

Table 2. Segregation for reaction to the peanut root-knot nematode (*Meloidogyne arenaria* race 1) in parental, F_1, F_2, and backcross generation of the cross PA-426 x PA-350.

Population	*No. of plants*		*Expected ratios (R:S)*[1]	*chi square*	*P*
	Resistance	Susceptible			
PA-426	40		All R	----------	----------
PA-350		40	All S	----------	----------
F_1	11		All R	----------	----------
F_2	117	41	3:1	0.08	0.80 -0.50
F_1 x PA-426	159		All R	----------	----------
F_1 x PA-350	78	78	1:1	0.00	1.00

[1]R = resistant (gall index ≤ 2), s = susceptible (gall index ≥ 3).

Experiment II. All of the plants of the parental lines of the PA-426 x Carolina Cayenne cross were resistant (Table 3). The lack of segregation in the F2 generation of this cross suggests that the dominant resistance gene in the *C. chinense* germplasm line PA-426 is allelic to a gene conditioning resistance to *M. arenaria* in the *C. annum* cultivar Carolina Cayenne.

Table 3. Segregation for reaction to the peanut root-knot nematode (*Meloidogyne arenaria* race 1) in parental and F_2 generation of the interspecific cross *Capsicum chinense* germplasm line PA-426 x *C. annuum* cv. Carolina Cayenne.

Population	No. of plants in each gall-index class[1]				
	1	2	3	4	5
PA-426	59				
Carolina Cayenne	58				
F_2	199				
PA-350[2]			4	30	26

[1] Gall index: resistant ≤ 2, susceptible ≥ 3.
[2] Susceptible control.

Impact

The peanut root-knot nematode is a potentially a major pest of pepper. Parasitism of susceptible cultivars results in severely stunted plants and significantly reduced yields. The ideal method to control this nematode in *C. chinense* plantings would be to use resistant cultivars. The results of this study indicate that a single dominant gene conditions the high level of resistance to the peanut root-knot nematode exhibited by the *C. chinense* germplasm line PA-426. This finding confirms the results of the inheritance study conducted in 1998 (results reported in last year s report).

The ease and reliability of evaluating plants for resistance to peanut root-knot nematodes and the availability of a simply inherited source of outstanding resistance makes breeding for peanut root-knot resistance a viable objective in *C. chinense* pepper breeding programs. This objective should be readily obtained by the application of conventional plant breeding methodologies.

(3) Determine the effectiveness of resistance to root-knot nematodes (*Meloidogyne incognita*) in Scotch Bonnet peppers (*Capsicum chinense*) at high temperatures. *(J. Thies and R. Fery)*

Research Methods

Our objective was to determine the heat stability of resistance to *Meloidogyne incognita* in Scotch Bonnet-type pepper (*Capsicum chinense*). Two *C. chinense* cultigens, PA-426 and PA-350, and two *C. annuum* cultivars, Charleston Belle and Keystone Resistant Giant, were used in this experiment. PA-426 is a Scotch Bonnet-type cultigen released by USDA in 1997 that is resistant to *M. incognita* and PA-350 is a susceptible habanero-type. Charleston Belle is a root-knot nematode

resistant, open-pollinated bell pepper. Charleston Belle is homozygous for the N gene, which conditions resistance to *M. incognita.* Keystone Resistant Giant is the susceptible recurrent parent of Charleston Belle. The experimental design was a split-plot with sub-plots arranged in a randomized complete block with three replications in time. Whole plots were three temperatures (24, 28, and 32 °C). Sub-plots were the four pepper genotypes with 18 blocks per chamber.

Seedlings of each genotype were started in the greenhouse in Metro-Mix 360. Twenty-one days later, single seedlings were transplanted into individual pots and each plant was inoculated with ca. 5,000 *M. incognita* eggs. Eighteen pots of each genotype were placed in each of three growth chambers that had been programmed to maintain a temperature of 24, 28, or 32 °C, with a 16 h/8 h (light/dark) cycle. Approximately nine weeks later, the roots were evaluated for root galling and egg mass production. Roots were rated for severity of galling and for egg mass production using a 1 to 5 scale (1 = 0 to 3% root system galled or covered with egg masses); 2 = 4 to 25%, 3 = 26 to 50%, 4 = 51 to 80%, and 5 = greater than 80% root system galled or covered with egg masses). The weight of each root system was recorded and eggs were extracted from roots of each plant using 1% NaOCl. Eggs were counted using a stereomicroscope. Nematode reproduction was assessed by calculating a reproductive index R = Pf/ Pi , where Pi = initial inoculum level and Pf = final inoculum level. Egg count data were log10 (x+1) transformed before analysis. Data were analyzed by temperature using the GLM procedure of SAS for Windows System Version 6.12 (SAS Institute, Cary, N.C.) and means were separated within temperatures using Duncan s multiple range test.

Research Results and Discussion

Susceptibility of PA-426, PA-350, Charleston Belle, and Keystone Resistant Giant increased as temperature increased from 24 to 32 °C (Table 4). Severity of root galling, egg mass production, numbers of egg/g fresh root mass, and reproductive index for all genotypes increased ($P<0.05$) as temperature increased. Overall, severity of root galling and nematode reproduction were less ($P<0.05$) for the resistant genotypes PA-426 and Charleston Belle than for the susceptible PA-350 and Keystone Resistant Giant. However, both of the resistant genotypes exhibited a partial loss of resistance at the higher temperatures. For example, the reproductive index of M. incognita for PA-426 increased from 0.59 at 24 °C to 18.13 at 32 °C. Nevertheless, the root gall index for PA-426 was only 1.92 at 32 °C, which is still within the resistant range (Gall Index < 2.0). The root galling response was similar for PA-426 and for the resistant check, Charleston Belle; however, at 32 °C nematode reproduction was greater ($P<0.05$) for Charleston Belle than for PA-426. The susceptible habanero cultigen, PA-350 supported nearly 5x more nematodes per gram fresh root than PA-426. Both PA-350 and Keystone Resistant Giant exhibited highly susceptible reactions at both 28 and 32 °C. Although the resistance of PA-426 was partially compromised at high temperatures, cultivars possessing this resistance may be a useful component of integrated systems designed to manage soilborne pests in hot climates.

Table 4. Gall index, egg mass index, numbers of *Meloidogyne incognita* eggs per g fresh root, and reproductive index of *M. incognita* for two *Capsicum chinense* cultigens and two *C. annuum* checks inoculated with *M. incognita* race 3 and grown at 24, 28, or 32°C. Growth chamber tests. [z]

Pepper species/ Accession	Gall Index[y]	Egg mass index[x]	No. eggs/g Fresh root	Reproductive index[w]
		24°C Test		
C. chinense				
PA-426[v]	1.03a[u]	1.02a	743a[t]	0.59a[t]
PA-350[s]	2.58b	2.35b	16450b	14.70b
C. annuum				
Charleston Belle[r]	1.03a	1.02a	332a	0.47a
Keystone Resistant Giant[q]	2.65	2.45b	12330b	19.27b
		28°C Test		
C. chinense				
PA-426	1.66a	1.72a	10163a	18.61a
PA-350	3.67b	3.60b	59813c	30.64b
C. annuum				
Charleston Belle	1.67a	1.70a	20809ab	17.23
Keystone Resistant Giant	4.47c	4.26c	32969b	44.87b
		32°C Test		
C. chinense				
PA-426	1.92a	2.04a	21733a	18.13a
PA-350	4.06b	4.12b	102641c	85.58c
C. annuum				
Charleston Belle	2.21a	2.27a	26580b	35.67b
Keystone Resistant Giant	4.73c	4.72c	71627c	112.01c[z]

[z] Each plant was inoculated with ~ 500 eggs at transplanting. Data are means of three experiments (n=54).
[y] Gall index: 1= 0 to 3% root system galled; 2 = 4 to 25%, 3 =26 to 50%, 4 = 51 to 80%, and 5 = >80% root galled.
[x] Egg mass index: 1 = 0 to 3% root system covered with egg masses; 2 = 4 to 25%, 3 = 26 to 50%, 4 = 51 to 80%, and 5 = >80% root system covered with egg masses.
[w] Reproductive index; Final population/initial population (Pf/Pi) of *M. incognita*, nine weeks after inoculation with 5000 *M. incognita* eggs.
[v] Scotch Bonnet-type (*C. chinense*) cultigen, resistant to *M. incognita*.
[u] Mean separation within a column and temperature by Duncan's multiple range test ($P<0.05$).
[t] Data were $\log_{10}(x + 1)$ transformed before analysis. Untransformed data are shown.
[s] Habanero-type cultigen (*C. chinense*), susceptible to *M. incognita*.
[r] Resistant *C. annuum* check.
[q] Susceptible C. annuum check.

Impact

The southern root-knot nematode, *M. incognita*, is a major pest in pepper growing areas of the world. The removal of methyl bromide from use in the U.S. and world-wide, as well as the loss of other traditional nematicides because of environmental concerns, has increased interest in using host plant resistance for managing plant parasitic nematodes in peppers and other vegetable crops.

However, expression of resistance to root-knot nematodes is heat sensitive in tomato and in bell pepper (*C. annuum*) (Thies, J. A. and Fery, R. L. 1998. J. Amer. Soc. Hort. Sci. 123: 1012-1015.). The majority of the world s pepper crop is produced in hot climates where root-knot nematodes are a severe pest; therefore, knowledge about the expression of root-knot nematode resistance in C. chinense is essential in the development of root-knot resistant Scotch Bonnet and habanero-type cultivars and for recommending cultivars for high temperature production regimes. Our results indicate that although resistance to root-knot nematodes is partially compromised at high temperatures (32 °C), the root galling response and nematode reproduction in the resistant Scotch Bonnet PA-426 is several-fold less than in the susceptible habanero. Thus, root-knot resistant *C. chinense* cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates.

(4) Evaluation of the performance of *Capsicum chinense* (Scotch Bonnet-type pepper) cultigens in St. Kitts. *(J. Thies and R. Fery)*

Research Methods

The purpose of this study was to evaluate the performance of three root-knot nematode resistant Scotch Bonnet-type cultigens in the Caribbean when grown in a field naturally infested with root-knot nematodes. A field study was conducted in a root-knot nematode *(Meloidogyne* spp.) infested field on the farm of Mr. Keithley Burroughs in La Valley region of St. Kitts. Five *Capsicum chinense* cultigens were used in this experiment. The genotypes evaluated in the test were three *M. incognita*-resistant Scotch Bonnet-type cultigens (PA-353, PA-398, and PA-426) released by USDA (HortScience 33:760-761. 1998), a *M. incognita*-susceptible Habanero-type cultigen (PA-350), and a West Indian (PA-560) cultigen. The experimental design was a randomized complete block with four replications. The experiment was planted on 4 Jan. 1999. Three-row plots were established on 1-m centers with 51-cm in-row plant spacing and 15 plants per row. Plots were fertilized with 8.6 and 9.0 kg 15-15-15 N-P-K on 15 Jan. 1999 and 13 Apr. 1999, respectively. Mature red or yellow (depending on genotype) fruits were harvested and weighed on 13 Apr., 19 Apr., 27 Apr., and 10 May 1999. On 10 May 1999, heights of all plants in each plot were recorded, the stems were clipped at the crown and the total fresh shoot weight of plants was recorded (data not shown). On 11 May 1999, approximately 100 cm3 soil was collected from the root zone of each plant in the plot and the soil was composited into a single sample. Then, the root systems were removed from the soil, washed, and rated for severity of galling and for egg mass production using a 1 to 5 scale (1 = 0 to 3% root system galled or covered with egg masses 2 = 4 to 25%, 3 = 26 to 50%, 4 = 51 to 80%, and 5 = greater than 80% root system galled or covered with egg masses). Root systems were also rated for the amount of fibrous roots using a 1 to 5 scale (1=many fibrous roots, 5=no fibrous roots). Second-stage juveniles (J2) were extracted from a 50 cm3 subsample of each soil sample using the sugar flotation method. Second-stage juveniles were counted using a stereomicroscope. Nematode count data were log10 (x+1) transformed before analysis. Data were analyzed using the GLM procedure of SAS for Windows System Version 6.12 (SAS Institute, Cary, N.C.), and means were separated using Duncan s multiple range test.

Research Results and Discussion

The three *M. incognita*-resistant *C. chinense* lines (PA-353, PA-398, and PA-426) exhibited minimal root galling (Table 5). The local Caribbean cultigen, West Indian Red (PA-560), and the susceptible Habanero check (PA-350) exhibited moderate root galling. The root-knot resistant cultigens (PA-353, PA-398, and PA-426) had less severe root galling on the roots ($P<0.05$) than West Indian Red (PA-560) and the Habanero (PA-350). PA-350 had a higher ($P<0.05$) egg mass index than the other cultigens. The fibrous root index appeared to be a useful indicator of resistance to root-knot nematodes; e.g., the resistant cultigens had more fibrous roots than West Indian Red and the susceptible Habanero. Numbers of second stage juveniles (J2) were <20 per 50 cm3 soil (data not shown). The susceptible PA-350 had fewer ($P<0.05$) plants per plot than PA-353, PA-398, and West Indian Red. West Indian Red had heavier ($P<0.05$) fruit yields than the other cultigens, except PA-350. The lack of significant differences in fruit yields between West Indian Red and PA-353 was unexpected because West Indian Red is typically a larger plant than the Scotch Bonnet and Habanero-type peppers. Plants of PA-353, PA-426, and West Indian Red were taller ($P<0.05$) than PA-350. Results of this study demonstrate that PA-353, PA-398, and PA-426 were resistant to the indigenous field population of *Meloidogyne* sp. in La Valley region of St. Kitts.

Table 5. Gall index, egg mass index, fibrous root index, plant stand, fruit weight, and plant height of six of *Capsicum chinense* entries grown in a field infested with *Meloidogyne* spp. St. Kitts, 1999.

Pepper cultigens	Gall index[z]	Egg mass index[y]	Fibrous root index[x]	Plant stand per plot	Total fruit weight per plot (kg)	Plant height (cm)
PA-353[w]	1.33a[v]	1.04a	1.71a	11b	2.65bc	52.3c
PA-398[w]	1.05a	1.03a	1.90a	13b	1.67ab	41.2ab
PA-426[w]	1.02a	1.00a	2.08a	10ab	1.49ab	47.2bc
PA-560[u]	2.14b	1.37a	2.64b	12b	3.17c	56.8c
PA-350 (Check)[t]	2.74b	2.04b	2.74b	8a	0.81a	33.5a

[z]Gall index: 1 = 0-3 % root system galled, 2 = 4 to 25%, 3 = 26 to 50%, 4 = 51 to 80% root system galled.
[y]Egg mass index: 1 = 0-3% root system covered with egg masses; 2 = 4 to 25%, 3 = 26 to 50%, 4 = 51 to 80%, and 5 = > 80% or more root system covered with egg masses.
[x]Fibrous root index; 1 = many fibrous roots; 5 = no fibrous roots.
[w]Scotch Bonnet-type germplasm line released by USDA; resistant to *M. incognita.*
[v]Mean separation within a column by Duncan's multiple range test ($P<0.05$)
[u]West Indian Red, local Caribbean cultigen.
[t]Habanero-type cultigen; susceptible to *M. incognita.*

The reactions of West Indian Red for severity of root galling and fibrous root score were similar to that of PA-350 (susceptible check), which suggests that West Indian Red is susceptible to the indigenous root-knot nematode population in the field used in this study. These results support our previous observation that West Indian Red is susceptible to *M. incognita* (1996-1997 IPM CRSP Annual Report).

Impact

Hot peppers (*C. chinense*) are very popular in the Caribbean market and have become increasingly important as an export crop to the U.S.A. and other countries. Root-knot nematodes (*Meloidogyne* spp.) cause severe yield losses in pepper world-wide. The loss of many nematicides from the market and increased public awareness of the environment has focused interest on the use of host resistance, if available, for managing root-knot nematodes in vegetable crops. Thus, the root-knot resistant Scotch Bonnet-type pepper lines PA-353, PA-398, and PA-426 should be a useful component of an integrated pest management system for hot pepper.

(5) Characterize the resistance to *Meloidogyne arenaria* races 1 and 2 in *Capsicum chinense* Jacq. cultigens*(R. Fery and J. Thies)*

Research Methods

The pepper genotypes used in all experiments were PA-353, PA-398, PA-426, PA-350, Charleston Belle, Carolina Cayenne, and California Wonder. PA-353, PA-398, and PA-426 are Scotch Bonnet-*type (Capsicum chinense* Jacq.) cultigens that are resistant to *M. incognita.* PA-350 is a habanero-type (*C. chinense*) cultigen that is susceptible to *M. incognita.* Charleston Belle is an *M. incognita*-resistant, open-pollinated bell pepper cultivar released by USDA, ARS that is also resistant to *M. arenaria* races 1 and 2, and *M. javanica.* Charleston Belle is homozygous for the N gene that confers resistance to *M. arenaria* races 1 and 2, *M. incognita*, and *M. javanica.* Carolina Cayenne is resistant to *M. arenaria* races 1 and 2, *M. incognita*, and *M. javanica*, and its resistance is conferred by the N gene and an additional recessive gene. California Wonder is susceptible to *M. incognita, M. arenaria* races 1 and 2, and *M. javanica.*

All seven pepper genotypes were evaluated in four separate greenhouse experiments for reactions to *M. arenaria* races 1 and 2. The experimental design for all experiments was a randomized complete block with 6 replicates. Each replicate consisted of 5 plants (n=30).

Seeds of each entry were germinated in flats containing Metro-Mix 360 in the greenhouse. Day/night greenhouse temperatures were maintained at 26 + 3°C. Three to four weeks later, 30 seedlings per entry were transplanted into a 4.0 x 1.8 x 0.25 greenhouse bench containing a steam-pasteurized medium of 2 sandy loam soil : 1 fine washed river sand (v/v). A 10 x 10-cm rectangular planting pattern was used. At planting, 5 mL tap water containing ca. 3000 eggs of the appropriate *M. arenaria* race were pipetted around the base of each plant. Eight to 11 weeks later, the root system of each plant was removed from the growing medium, washed, and rated for severity of root galling and egg mass production using a 1 to 5 scale where: 1 = 0% to 3% root system galled or covered with egg masses, 2 = 4% to 25%, 3 = 26% to 50%, 4 = 51% to

80%, and 5 = > 80% root system galled or covered with egg masses. Root gall and egg mass indices > 3 were considered susceptible reactions. Then the fibrous roots were clipped from the tap root, cut into 1 to 2-cm pieces and root weights recorded. Eggs were extracted from the entire root sample using the 1.0% NaOCl method. Eggs were counted using a stereomicroscope. A nematode reproduction factor (R) was calculated where R = Pf/Pi, Pi = the initial population level and Pf = the final population level.

Research Results and Discussion

The Scotch Bonnet-type cultigens PA-353, PA-398, and PA-426 exhibited high resistance to *M. arenaria* race 1 (Table 6). However, the Habanero-type cultigen of *C. chinense*, PA-350, was highly susceptible to *M. arenaria* race 1 (Table 6). PA-353, PA-398, and PA-426 exhibited minimal root galling (gall index=1.05, 1.15, and 1.02, respectively, average of two tests) in contrast to PA-350, which exhibited severe root galling (gall index=4.72, average of two tests) (Table 6). PA-353, PA-398, and PA-426 had 99.3%, 96.4%, and 99.3%, respectively, fewer (P<0.05) eggs per gram fresh root than PA-350 (average of two tests). PA-353, PA-398, and PA-426 are also highly resistant to *M. incognita*, but PA-350 is highly susceptible to *M. incognita*. The *M. incognita*-resistant *C. annuum* checks Charleston Belle and Carolina Cayenne exhibited high resistance to *M. arenaria* race 1, but the *M. incognita*-susceptible California Wonder was moderately susceptible to *M. arenaria* race 1. These results agree with results of earlier studies where both Charleston Belle and Carolina Cayenne exhibited high resistance to *M. arenaria* race 1 and California Wonder was susceptible (Thies, J. A. and Fery, R. L. 2000. J. Amer. Soc. Hort. Sci. 125: Accepted 15 Jul. 1999). Previous reports of resistance to *M. arenaria* in C. chinense include Surrinam-B, breeding lines 201 and 558-17-C and breeding line 56-547/7.

Table 6. Gall indices, egg mass indices, number of eggs per gram fresh root, and reproductive index of *Meloidogyne arenaria* race 1 of four *C. chinense* cultigens and three *C. annuum* check cultivars inoculated with *M. arenaria* race 1 [z].

Entry	Greenhouse Test I				Greenhouse Test II			
	Gall index[y]	Egg mass index[y]	No. eggs/g fresh root	Reproductive index[x]	Gall index[y]	Egg mass index[y]	No. eggs/g fresh root	Reproductive index[x]
C. chinense cultigens								
PA-353	1.03a[w]	1.05a	1130b	0.54a	1.06a	1.06a	426a	0.25a
PA-398	1.24a	1.24a	3517bc	2.03ab	1.07a	1.08a	834a	0.56a
PA-426	1.03a	1.04a	1071b	0.31b	1.01a	1.01a	783ab	0.39a
PA-350	4.70a	4.67c	96999d	18.62d	4.74c	4.69c	224989c	46.07b
Checks	1.00a	1.00a	253a	0.18a	1.00a	1.00a	1771a	1.68a
	1.19a	1.20a	2864bc	1.60bc	1.12a	1.12a	1006a	0.74a
Charleston Belle (R)[v]	2.88b	2.73b	15617c	8.00c	2.76b	2.65b	16832bc	10.15b
Carolina Cayenne (R)[v]								
California Wonder (S)[v]								

[z]Each plant was inoculated with ca. 3000eggs at transplanting. Data are means of six replicates (n=30).
[y]Rated on a scale of 1 to 5; 1 = 0 to 3% root system galled or covered with egg masses, 2= 4 to 25%. 3 = 26 to 50%, 4 = 51 to 80%, and 5 = greater than 80% root system galled or covered with egg masses.
[x]Reproductive index =Pf (final population)/ Pi (initial population).
[w]Values in a column followed by the same letter are not different (P<0.05) according to Duncan's multiple range test ($P \leq 0.05$).
[v]R=resistant; S=susceptible.

Meloidogyne arenaria race 2 is not highly pathogenic to any of the C. chinense cultigens. PA-353, PA-398, and PA-426 exhibited high resistance to *M. arenaria* race 2, and PA-350 exhibited moderately high resistance (Table 7). There was no visible galling on the roots of PA-353, PA-398, and PA-426 (gall index=1.00, average of two tests). However, minimal galling occurred on the roots of PA-350 (gall index=1.61, average of two tests). PA-353, PA-398, and PA-426 had 96.6%, 98.6%, and 99.1%, respectively, fewer (P<0.05) eggs per gram fresh root than PA-350 (average of two tests). The checks, Charleston Belle and Carolina Cayenne, exhibited little or no root galling (gall index=1.00 and 1.03, respectively, average of two tests), in either the greenhouse or growth chamber test, but California Wonder exhibited moderate galling (gall index=2.31, average of two tests). Charleston Belle and Carolina Cayenne had 99.7% and 98.7% fewer (P<0.05) eggs per gram fresh root than California Wonder. These results confirm those of previous reports where root gall severity and reproduction of *M. arenaria* race 2 were significantly greater for California Wonder than for Charleston Belle and Carolina Cayenne (Thies, J. A. and Fery, R. L. 2000. J. Amer. Soc. Hort. Sci. 125: Accepted 15 Jul. 1999).

Table 7. Gall indices, egg mass indices, number of eggs per gram fresh root, and reproductive index of *Meloidogyne arenaria* race 2 of four *C. chinense* cultigens and three *C. annuum* check cultivars inoculated with *M. arenaria* race 2 [z].

Entry	Greenhouse Test I				Greenhouse Test II			
	Gall index[y]	Egg mass index[y]	No. eggs/g fresh root	Reproductive index[x]	Gall index[y]	Egg mass index[y]	No. eggs/g fresh root	Reproductive index[x]
C. chinense cultigens								
PA-353	1.00a[w]	1.02a	249a	0.15a	1.00a	1.00a	60b	0.01b
PA-398	1.00a	1.00a	128a	0.08a	1.00a	1.00a	0a	0.00a
PA-426	1.00a	1.00a	79a	0.07a	1.00a	1.00a	5a	0.00a
PA-350	1.58b	1.41b	7547b	2.54b	2.15b	1.64b	1617c	0.006c
Checks	1.00a	1.00a	62a	0.03a	1.00a	1.00a	4a	0.00a
	1.05a	1.05a	323a	0.27a	1.00a	1.00a	4a	0.00a
Charleston Belle (R)[v]	1.81b	1.75c	19924b	7.75b	2.80c	2.72c	5907d	0.68d
Carolina Cayenne (R)[v]								
California Wonder (S)[v]								

[z]Each plant was inoculated with ca. 3000eggs at transplanting. Data are means of six replicates (n=30).
[y]Rated on a scale of 1 to 5; 1 = 0 to 3% root system galled or covered with egg masses, 2= 4 to 25%. 3 = 26 to 50%, 4 = 51 to 80%, and 5 = greater than 80% root system galled or covered with egg masses.
[x]Reproductive index =Pf (final population)/ Pi (initial population).
[w]Values in a column followed by the same letter are not different ($P<0.05$) according to Duncan's multiple range test ($P\leq0.05$).
[v]R=resistant; S=susceptible.

Impact

Root-knot nematodes (*Meloidogyne* sp.) limit pepper yields globally. Although the southern root-knot nematode (*M. incognita*) is probably the most important species of root-knot nematode world-wide, *M. arenaria* is also an important pest of many vegetable and field crops in temperate and tropical areas. The information that the Scotch Bonnet cultigens PA-353, PA-398, and PA-426 are resistant to both *M. arenaria* race 1 (the peanut root-knot nematode) and *M. arenaria* race 2 will be useful to extension personnel for making recommendations on crop rotations to manage root-knot nematodes and to plant breeders for who are developing root-knot resistant pepper cultivars.

(6) Determine the potential of using legume cover-crop mulches to control root-knot nematodes in pepper plantings*(H. Harrison)*

The purpose of this study was to determine the host suitability of various legume species and cultivars for *Meloidogyne incognita*. The use of legume cover-crop mulches has recently been recognized as an alternative strategy for managing weeds in tomato and pepper in the northeastern U.S. Hairy vetch has been recommended and used as a cover crop mulch for tomato. However, hairy vetch is an excellent host for the southern root-knot nematode *(M. incognita)* (unpublished data, J. Thies). In order to develop an integrated system for managing both weeds and root-knot nematodes, it will be critical to select cover crops that can be effectively used to control both pests.

Research Methods

Seven legumes selected for their potential usefulness as cover-crop mulches for weed control were evaluated for host suitability to the southern root-knot nematode, *M. incognita*. The seven legume entries were: velvet bean, Iron-Clay cowpea, sunnhemp, a soybean line selected for vigorous growth and foliage production, Cahaba vetch, crimson clover, and hairy vetch. Two cowpea cultivars, Mississippi Silver and Pinkeye Purple Hull, were included as root-knot resistant and susceptible checks, respectively. Seedlings of each genotype were started in the greenhouse in Metro-Mix 360. When the seedlings had two to three sets of true leaves, 30 seedlings per entry were transplanted into a 4.0 x 1.8 x 0.25 greenhouse bench containing a steam-pasteurized medium of 2 sandy loam soil : 1 fine washed river sand (v/v). A 10 x 10-cm rectangular planting pattern was used. At planting, 5 mL tap water containing ca. 3000 eggs of *M. incognita* race 3 were pipetted around the base of each plant. Day/night greenhouse temperatures were maintained at 26 + 3øC. Fifty-seven days later, the root system of each plant was removed from the growing medium, washed, and rated for severity of root galling and egg mass production using a 1 to 5 scale where: 1 = 0% to 3% root system galled or covered with egg masses, 2 = 4% to 25%, 3 = 26% to 50%, 4 = 51% to 80%, and 5 = > 80% root system galled or covered with egg masses. Root gall and egg mass indices > 3 were considered susceptible reactions. Then

the fibrous roots were clipped from the tap root, cut into 1 to 2-cm pieces and root weights recorded. Eggs were extracted from the entire root sample using the 1.0% NaOCl method. Eggs were counted using a stereomicroscope. A nematode reproduction factor (R) was calculated where R = Pf/Pi, Pi = the initial inoculum level and Pf = the final inoculum level.

Research Results and Discussion

Velvetbean, Iron-Clay cowpea, sunnhemp, and soybean were highly resistant to *M. incognita* race 3; each of these entries exhibited minimal galling and nematode reproduction, similar to the resistant cowpea check, Mississippi Silver (Table 8). However, velvetbean supported lower ($P<0.05$) nematode reproduction than any of the other entries (reproductive index = 0.24). Cahaba vetch exhibited moderate resistance (gall index = 2.27 and nematode reproductive index = 2.03). Crimson clover was susceptible, similar in reaction to the susceptible cowpea check, Pinkeye Purple Hull. Hairy vetch was highly susceptible (gall index = 5.00 and reproductive index = 39.99).

Impact

Our results indicate that velvetbean, Iron-Clay cowpea, sunnhemp, and the soybean line evaluated in our test may be potentially useful for managing *M. incognita* if used as a cover-crop mulch for weed control. The next step will be to evaluate one or more of these legumes in field trials as cover-crop mulches for managing weeds and root-knot nematodes. It is also important to note that hairy vetch should not be recommended as a cover-crop mulch in fields where the southern root-knot nematode is present. If present even in low numbers, *M. incognita* would be likely to build-up under a highly susceptible cover crop such as hairy vetch.

Table 8. Gall index, egg mass index, numbers of *Meloidogyne incognita* eggs per fresh root, and reproductive index of *M. incognita* for seven cover crop entries and two cowpea check cultivars inoculated with *M. incognita* race and grown in the green house for eight weeks.[z]

Cover crop entry	Gall Index[y]	Egg mass index[x]	No. eggs/g fresh root	Reproductive index
Velvetbean	1.00a[v]	1.00a	446a[u]	0.24a[u]
Iron-Clay Cowpea	1.00a	1.02a	1831b	1.28b
Sunnhemp	1.01a	1.07a	4026b	1.70bc
Soybean	1.02a	1.02a	4181b	1.75bc
Cahaba Vetch	2.27b	1.55b	10230c	2.03b
Crimson Clover	3.46c	3.31c	106909de	13.32c
Hairy Vetch	5.00d	4.90d	164754e	39.99d
Checks				
Pinkeye Purple Hull Cowpea (S)[t]	3.58c	3.60c	63668d	48.45d
Mississppi Silver Cowpea (R)[s]	1.01a	1.02a	3899b	1.87bc[z]

[z] Each plant was inoculated with ≈3000 eggs at transplanting. Data are means of six replicates (n=30).
[y]Gall index; 1=0 to 3% root system galled; 2=4 to 25%, 3 = 26 to 50%, 4= 51 to 80%, and 5= >80% root galled.
[x]Egg mass index: 1=0to 3% root system covered with egg masses; 2= 4 to 25%, 3= 26 to 50%, 4=51 to 80%, and 5=>80% root system covered with egg masses.
[w]Reproductive index: Final population /initial population (Pf/Pi) of *M. incognita*, eight weeks after inoculation with 3000 *M. incognita* eggs.
[v]Mean separation within a column and temperature by Duncan's multiple range test ($P<0.05$).
[u]Data were $\log_{10}(x+1)$ transformed before analysis. Untransformed data are shown.
[t]Resistant cowpea check.
[s]Susceptible cowpea check.

(7) Monitoring the seasonal abundance of aphids on farms in Bushy Park and Bodles, St. Catherine, Jamaica where Scotch Bonnet pepper, *Capsicum chinense*, is grown. *(S. McDonald (Graduate Student), B. A. Nault, S. A. Tolin).*

Research Methods

Four pepper farms were identified and selected, three in Bushy Park and one in Bodles, St. Catherine. On each farm, three water pan traps were placed within a pepper plot. Traps were made from 9" flower saucers, which were painted in a mosaic pattern using cobalt green and gold green acrylic paints. Each trap contained a 1:1 ratio of water to propanol/monoethanol glycol, which was collected and replaced weekly. The winged aphids found in the sampled fluid were counted and preserved in 70% ethanol for later identification.

Research Results and Discussion

Aphid populations varied significantly among farms ($p < 0.0001$). Farm 3 had the highest mean number of aphids per week (8) > Farm 4 (7) > Farm 2b (3) > Farm 1 (2). Aphid population varied significantly ($p < 0.0001$) with time in each of the three locations. Generally, aphid populations were greatest during mid-September 1998 to mid May 1999. The lowest flight periods occurred during mid May to August 1999.

On Farm 1 mean aphid count ranged from 0 to 13 per week. The highest count occurred during December 16-22, 1998 with the most common aphid species being *A. gossypii* Glover. The highest aphid flight period for Farm 2b was during the week of March 3-10, 1999 when the mean catch per trap was 12 aphids. (Sampling on this farm began in January 1999.) Mean aphid catch on Farm 3 ranged from 0 to 94, with the highest peak during December 30 1998 to January 6, 1999. There were several minor peaks in aphid flight during October 7-14, 1998 (mean = 37), and April 7–23, 1999 (weekly means = 25 and 22). The most common aphid species during these periods were *Aphis amaranthi* Holman, *Uroleucon ambrosiae* complex and *A. gossypii.* Farm 4 had mean counts ranging from 0 to 55 aphids per week. A major peak in aphid flight occurred during October 14-21, 1998 (weekly means = 41 and 21, respectively). *A. gossypii* was the most common aphid species then.

Over twenty species of aphids were identified throughout the time of sampling, with the period of greatest species diversity occurring during December 1998 to April 1999.

(8) Comparing the incidence of virus infection, the quality and quantity of *C. chinense* fruit in fields in which seedlings were a) protected with aphid proof screen before transplanting and then treated with multiple applications of stylet oil after transplanting; b) protected with aphid proof screen prior to transplanting only; and c) not protected or sprayed. *(S. McDonald (Graduate Student), B. A. Nault, S. A. Tolin, Virginia Tech).*

Research Methods

This was an on farm experiment conducted on one farm in St. Catherine parish. It had a completely randomized design comprising of 100 plants allotted to each of 3 treatments. The treatments were 1) uncovered seedlings that were not sprayed with stylet oil after transplanting, 2) covered seedlings that were sprayed with stylet oil after transplanting and 3) covered seedlings that were not sprayed with stylet oil after transplanting. Seeds were sown in trays and the seedlings kept covered with aphid exclusion cages or left uncovered in the field. Seedlings treated with stylet oil were sprayed once or twice weekly depending on the growth rate of the plants.

Research Results and Discussion

The virus did not affect the crop until late in the cropping cycle, hence, it was not possible to fulfill the objectives for this experiment.

(9) Investigating the effect of stylet oil in delaying or reducing the spread of tobacco etch virus in a hot pepper plot*(S. McDonald (Graduate Student), B. A. Nault, S. A. Tolin, Virginia Tech).*

Research Methods

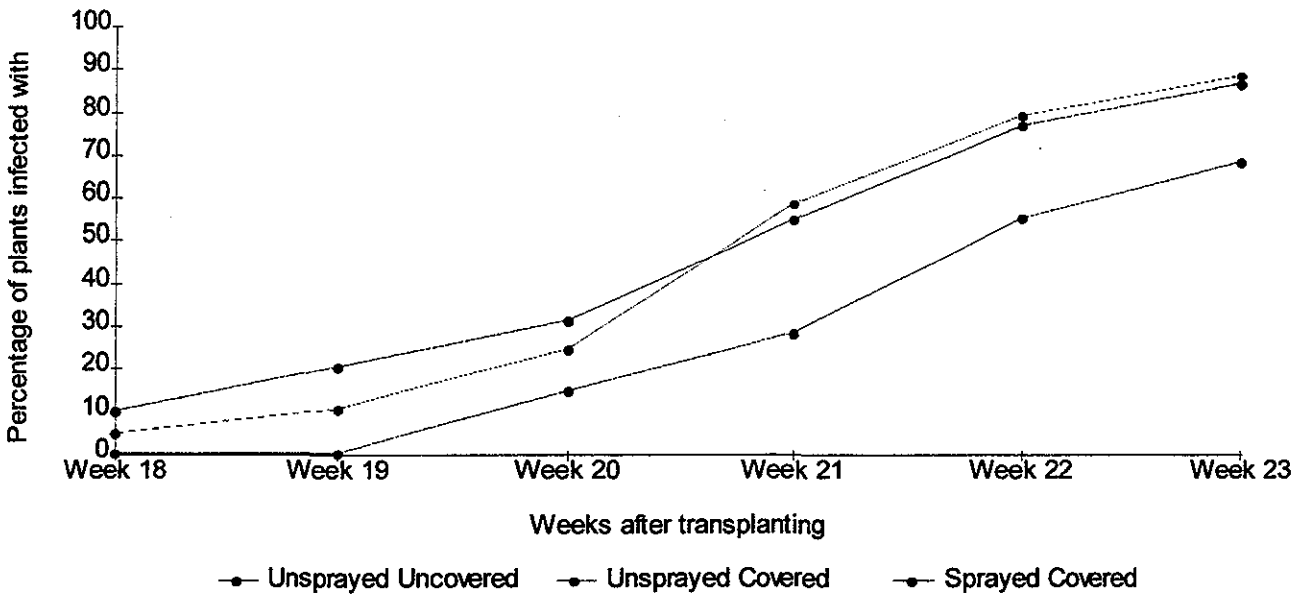
The plot used for the previous experiment was used to fulfill this objective. There were three treatments. Treatment 1 was comprised of plants that were covered in the seedling stage and sprayed with stylet oil after transplanting. Treatment 2 had plants that were covered in the seedling stage but not sprayed with stylet oil after transplanting. In treatment 3 the plants were not covered in the seedling stage nor sprayed with stylet oil after transplanting. For each treatment, the progress of TEV was monitored based on symptoms. Symptomatic plants were tagged each week. Data on yield were collected from the second harvest of this crop, as virus symptoms were only seen after the first harvest. Fruits were collected from both the sprayed and unsprayed plants showing symptoms. The fruits in each category were divided into marketable and unmarketable, counted and weighed.

Research Results and Discussion

Only tobacco etch virus (TEV) virus was confirmed in the Scotch Bonnet plants. TEV spread was slower, and the percentage infection was less, among plants that were

sprayed in comparison to plants that were not sprayed (Figure 1). Yield per pepper plant did not vary significantly ($p > 0.1$) with the time of virus appearance for either sprayed or unsprayed sections of the plot. This might have been due to the lateness of the infection. There were no significant differences ($p > 0.1$) in the ratios of marketable to unmarketable yield between sprayed and unsprayed pepper plants. For both treatments about 75% of the total yield was marketable.

Fig. 1. Effect of spraying on the spread of TEV in a pepper plot



(10) Comparing the overall incidence of virus infection, and, quantity and quality of *C. chinense* fruit in fields in which early virus infected *C. chinense* plants are rogued versus those that remain in the field. *(S. McDonald (Graduate Student), B. A. Nault, S. A. Tolin, Virginia Tech).*

Research Methods

This was an on farm experiment with a completely randomized design comprising of 100 plants allotted to each of 2 treatments. The treatments were 1) plants that were not rogued in the field, 2) plants that were rogued and replaced with virus free seedlings in the field. Virus free seedlings were used as planting source for both treatments. Seedlings were covered with aphid exclusion cages until transplanted. Replacement seedlings were transferred to 6" polyethylene bags at transplanting and kept covered until needed. Roguing and replacement of symptomatic plants will be done until about 6 weeks after transplanting. Serological tests were conducted on symptomatic plants to confirm the virus present. This experiment was conducted on one farm in St. Catherine.

Research Results and Discussion

This experiment was aborted as the farmer abandoned the plot due to the then poor marketing climate.

(11) Enhanced Hot Pepper Production Systems *(F. McDonald, D. Clarke-Harris)*

Over the past 3 years, under the IPM CRSP project efforts were made to gain an understanding of hot pepper cropping systems - *production practices, pest composition and dynamics*. Based on these studies, it was shown that one the main factors crippling the expansion of hot pepper production was the virus complex -Tobacco Etch Virus (TEV) and Potato Virus Y (PVY) which is transmitted by aphids including *Aphis gossypii* and *Myzus persicae*. In addition, studies showed that the West Indian Red cultivar which was bred by CARDI, was more tolerant than the local Scotch Bonnet pepper to this pest; yield reduction in virus infected WI cultivar was three times less than Scotch Bonnet pepper. As a result of this information, a project was launched through the Canadian Government (CIDA) to introduce the West Indian Red variety to small farmers using technologies generated under donor funded projects inclusive of the IPM CRSP. This action was seen

as a "stop gap" until a solution to the virus problem which is been tackled under the CRSP by a graduate student is achieved. Over the past twelve months, significant strides have been made in assisting small farmers in CRSP target areas in hot pepper production technology.

Objectives

- Increase farm production/productivity in hot pepper throughout the application of improved production technologies including efficient use of fertilizer, pest management practices and the farmers overall improved knowledge in good farm and crop management.
- Enable women farmers in selected parishes through training and the application of sustainable technologies in hot pepper production.

Research Methods

Establishment of Demonstration Plots. Demonstration plots were established in four (4) parishes – St Mary, Clarendon, St Catherine and St Thomas. On these plots the best technologies generated under several projects inclusive of the IPM CRSP was used to enhance current production technologies. Farms were monitored monthly to determine production and pest management practices, costs of inputs and income generated.

Production Technology

	Recommended Practices
Agronomic	❒ Plant spacing/densities (4,940 plants per hectare) ❒ Irrigation (drip) ❒ Plant beds 1.2 X 9.3 m
Fertility Management	❒ Organic- manure in holes at planting ❒ Inorganic – N:P:K 15:5:35 applied 3 times during the crop cycle; rates per plant are pre-planting 167g (sulphate of ammonia), 1g (NPK), harvest 100g
Pest Management	❒ Cultural practices - pruning, field sanitation, stripping of tree, removal of abandoned crops and diafenthiuron (Pegasus®) alternate hosts. ❒ Tolerant cultivar - West Indian Red ❒ Imidachloprid (Admire®) at planting, *Bacillus thuringiensis* (Agree®). For mites and lepidopteran pests, insecticide application is based on the presence of pests. Detection is made through weekly scouting and monitoring with sticky traps.

Technology Transfer

Technology transfer sessions were held to train farmers in the hot pepper IPM technology. Topics covered in the sessions included: pest identification, fertility management, principles of IPM. Technology transfer sessions were not only geared at production technology but also demonstrated the benefits of developing a sound marketing strategy i.e. an integrated approach to hot pepper production and marketing. Demonstration plots were used in the technology transfer process.

Research Results and Discussion

Eight (8) demonstration plots have been established. These satellite farms gave consistently good yields and the plants exhibited the expected vigour and resistance. It was observed that fields continued to yield fruits of ideal size and quantity even after 9 months of harvest. Cumulative yields and gross returns on the eight pilot farms at the end of the second quarter exceeded US$23,000 (Table 9).

Table 9. Economic returns of farmers cultivating West Indian Red cultivar.

Farms	Parish	Date of Transplant (Plant Density)	Yield to September (Kg)	Marketing Outlet	Av. Price US$/Kg	Gross Earnings US$
Farm # 1	Clarendon	03/07/98, (2,350)	9157.25	Local Processor	0.82	9,892.38
Farm #2	St Thomas	18/08/98, (1,300)	3211.36	Processor Exporter	0.99	3,532.5
Farm#3	Clarendon	20/08/98, (2,000)	7318.18	Exporter	0.82	7,843.75
Farm#4	Clarendon	08/07/99, (2,000)	113.64	Local Market	1.10	125.00
Farm#5	St Thomas	6/07/99, (2,000)	45.45	Local Market	1.10	50.00
Farm#6	Clarendon	16/07/99, (2,000)	45.45	Local Market	1.10	50.00
Farm#8	St Mary	10/10/98, (1,700)	1956.82	Local Processor	0.66	2,571.25

Participating farmers have verbally endorsed the superior productivity of the West Indian Red cultivar both in volume and duration of viability. Economic returns have been favourable and in one instance were equated to returns from an area of sugarcane twenty-fold larger than the 1.2 hectare demonstration plot. Local processors are

now benefiting from the productivity of this cultivar and farmers have reported increased demand for these pepper from this market. With the growing availability of West Indian Red cv. Some processors have noted that they have saved on importation of substitute hot pepper as local supplies are now more reliable.

One field day has been held with a total of 34 farmers attending. Many farmers expressed interest in cultivating the crop and as such there has been a high demand to obtain WI seeds from CARDI. A total of 6 Kg of seeds have been sold and this represents a total cultivation of approximately 8.1 hectares.

Impact

Towards developing a viable and sustainable hot pepper industry in Jamaica, current production technologies from Jamaica and the Eastern Caribbean were successfully introduced into selected parishes in Jamaica. Economic returns from producing hot pepper with the recommended technologies demonstrate that pepper is a lucrative crop for small farmers.

(12) Determination of the potential of colored sticky traps to assess populations of the gall midge complex; *Prodiplosis longifila* and *Contarinia lycopersci* (Diptera: Cecidomyiidae) *(J. Lawrence, D. Clarke-Harris)*

Objectives

- Determine the potential of using sticky traps to assess gall midge populations.
- Determine the trapping efficiency of various colored sticky traps to capture gall midge adults

Research Methods

Sticky traps of three colours - *red, green and yellow* were evaluated at the CARDI field station (UWI, Mona Campus) during the period September - December, 1998. The traps were constructed from cartridge paper covered with plastic and coated with an adhesive (Tangle foot®). Traps were suspended at the height of the plant canopy with bamboo sticks.

The field was divided into 6 blocks and traps were placed in a RCB design such that, 2 traps of each colour were present in each block (n = 54, total plant population = 336). The number of midges trapped was recorded weekly. Data were analyzed by ANOVA using JMP statistical software.

Research Results and Discussion

Gall midge adults were caught on traps of all colors. The yellow trap caught the largest number of adults when compared to red and green traps; the average per trap was 0.5, 0.10, and 0.16 adults for the yellow, red and green traps respectively (Figure 2). Given the high larval infestation observed during the study and the low number of adult midges caught, the traps may be useful as a detection tool Vs a monitoring tool in the IPM strategy being developed. The study is being continued so that, more precise conclusions can be made. In addition, the repeated study will also attempt to determine the optimal trap height required.

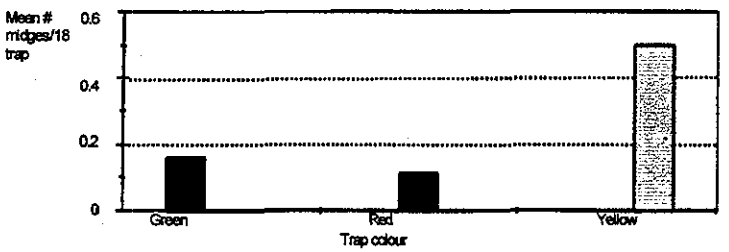


Figure 2. Mean weekly trap catches of gall midge adults.

Impact

The use of sticky traps to detect gall midge populations will be useful for developing a IPM strategy for these pests.

(13) Effect of cultural practices and chemical insecticides on infestations of the gall midge complex, *Prodiplosis longifila* and *Contarinia lycopersci* (Diptera: Cecidomyiidae) affecting hot pepper exports to the USA. *(J. Lawrence, D. Clarke-Harris, F. McDonald)*

Objective

To determine the effectiveness of cultural practices in combination with synthetic pesticides to reduce larval infestations

Research Methods

The study was conducted at the CARDI Field Station on pepper plants established in December 1997. The study site consisted of six plots each having a total of 48 plants.

Treatments evaluated included cultural practices and the application of chemical insecticides (*contact and systemic).*

Cultural practices involved thorough field sanitation - pruning and stripping trees, removal and destruction of crop residues. These practices were conducted at the beginning of the study and repeated whenever needed.

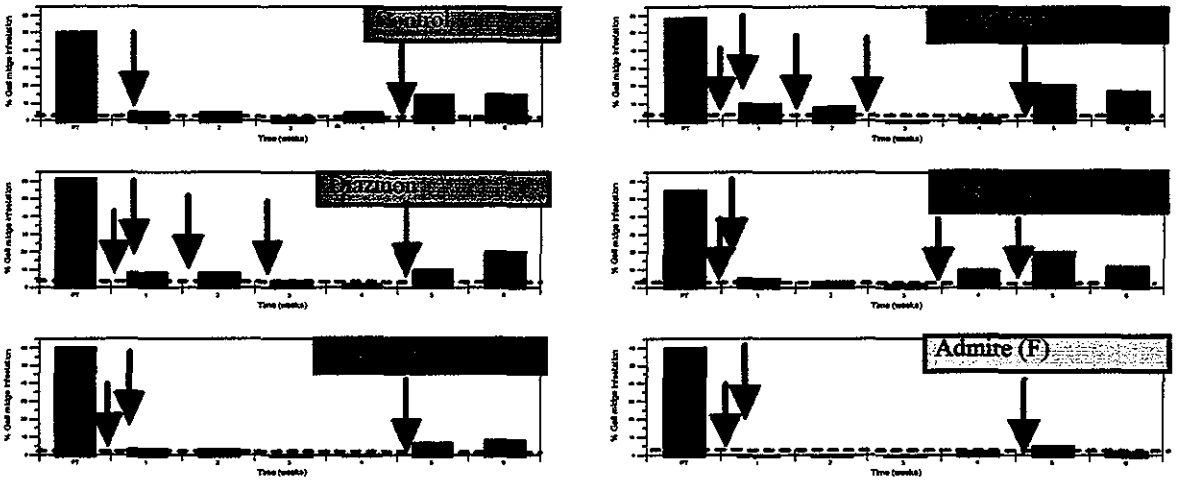
Four insecticides were evaluated, Immidachloprid (Admire ®, foliar and soil application) Fipronyl (Regent ®), Malathion and Diazinon. Treatments were applied at the recommended rate during the late afternoon after cultural practices were conducted. Applications were made with a hand held Sissmex applicator. A threshold of 5% fruit infestation was used as a guide to for re-application of treatments.

Larval populations were assessed pre and post treatment, the later being conducted weekly. Assessments were made by removing 10 pepper fruits from six plants (located at the top, middle and bottom sections of the plot) and dissecting the pedicels and calyx of fruits to determine larval infestation and mortality.

Research Results and Discussion

Gall midge populations were significantly reduced after cultural practices and insecticides were applied; mean reduction in midge population across treatments was 47.6% (Figure 3). This initial treatment held midge populations below the 5% threshold in plots treated with immidachloprid and fipronyl. For Malathion and Diazinon however, 3 applications had to be made before populations were reduced below the threshold. For the duration of the study, a total of 1 application was made for immidachloprid, 2 for fipronyl and 3 applications made for Diazinon and Malathion.

Across plots, during the last 2 weeks of observation populations increased significantly above the 5% threshold (Mean population levels). These observations could be due in part to the rainfall patterns being experienced during the period of the study, natural population emergence as well as the crop phenology. These factors are being examined. The study will be repeated on farms within the target areas.



Arrows indicate treatment dates - Chemical treatments (red arrows) - 16th November, 26th November, 4th December, 18th December. Cultural practices (green arrows) - 14th November, 16th December, Dotted line (----) indicates 5% threshold

Figure 3. Effect of Chemical Treatments and Cultural Practices on Gall Midge Infestations

Impact

In 1998, high gall midge interceptions crippled the hot pepper industry in Jamaica, resulting in the enforcement of mandatory fumigation as a condition of entry of the product into US markets. This prompted the several responses, many of which were lead by the IPM CRSP team. The development of a IPM strategy to reduce infestations was the focus of the activities and included both pre and post harvest investigations. During the past 12months, it was demonstrated that the use of cultural practices in combination fipronyl or imidacloprid suppressed populations of the gall midge complex below a 5% threshold for at least 3 weeks. These results are being used in technology transfer programmes being conducted by RADA.

(14) Effect of aluminum phosphide on larval stages of the gall midge complex *(J. Lawrence, D. Clarke-Harris)*

Objectives

- Determine the effectiveness of aluminum phosphide on larval mortality
- Determine the effect of aluminum phosphide on the quality of hot pepper fruits
- Determine the emission rate of the fumigant after each treatment period

Research Methods

A total of 18.1 Kg of West Indian red peppers was harvested from the CARDI DTC (September 19th, 1998). Peppers were sorted with respect to export quality criteria (green mature, medium size, firm), and two pounds of fruits weighed and placed in each of 16 cardboard boxes. Two boxes of pepper were then placed in each of 6 barrels (0.22 m^3). With the exception of the control, 0.2g of Aluminum phosphide (*Degescher Phostoxin pellets; Aluminum phosphide 55%, Inert 45%, Batch # - 3238*) was placed within each barrel. All barrels were sealed with duct tape and stored at room temperature. After 6, 12, 24 and 48 hours, 2 barrels were opened - *treated and un-treated (control)* and observations on phosphine emission (PH_3), larval mortality and fruit quality recorded.

Phosphine Gas Emission. After each exposure period, the level of phosphine gas emitted from each barrel was measured with a Drager detector tube (CH31101), 0 (immediately) and 10 minutes after the barrels were opened. Reading were taken at the edge of the barrel as well as 1 and 3 meters away

Pest Mortality. For each exposure period, the 2 boxes of pepper were removed from each barrel and peppers from both boxes mixed. A total of 25 peppers were removed, dissected and larval mortality determined. Any other pest observed within boxes or on fruits was also recorded.

Fruit Quality. An additional, 50 peppers were removed from boxes and stored at room temperature for one week. Fruit quality (fruit/stem rots, turgidity) was recorded daily.

Research Results and Discussion

Emission Readings. Phosphine gas was only detected on the edge of the barrel immediately after opening (0.1ppm). For all other positions and time, the gas was not detected. Due the lack of supplies emission readings were only recorded, 48 hours after fumigation.

Larval Mortality. Significant differences were observed in the level of larval mortality of treated and untreated hot pepper. For all exposure periods, larval mortality in peppers treated with phosphine was >80%, whereas for untreated fruits, larval morality never exceeded 12% (Table 10).

Table 10: The effect of aluminum phosphide on the mortality of the larval stage of the gall midge complex

Exposure Period (hrs)	% Larval Mortality (Treatment with AlP)	% Larval Mortality (No treatment - Control)
6	99	8
24	100	11
48	100	8

Fruit Quality. For all exposure times, the number of marketable fruits remaining after 3, 4, 6, or 7 days after harvest did not differ between treatments (Table 11). The study is being repeated and data will be analysed.

Table 11: Fruit quality after exposure to aluminum phosphide

	% Marketable Fruits/ Days after Harvest			
Exposure Period	3	4	6	7
Control	84	76	78	44
6 hours	74	76	58	48
24	96	68	48	44
48	82	74	56	56

N= 50 fruits at the beginning of the study.

Impact

Recognising the issues surrounding methyl bromide, the demonstration that aluminum phosphide has the potential to kill >80% larvae within fruits without significant effect on the quality and shelf life of the peppers is promising.

Networking Activities

A. Workshops, Seminars and Meetings

- R. L. Fery served as a member of the Advisory Committee for a Clemson University Ph.D. student funded by the Bean/Cowpea CRSP.
- R. L. Fery and J. A. Thies served as members of the Pepper Germplasm Committee, and attended the October 1998 meeting in San Antonio, TX.
- J. R. Bohac, R. L. Fery, H. F. Harrison, Jr., D. M. Jackson, and J. A. Thies participated in the IPM-CRSP Caribbean Site Planning Workshop, Charleston, SC, June 27-30, 1999, and each presented an overview of their IPM CRSP research efforts.
- R. L. Fery and H. F. Harrison participated in the IPM CRSP Planning Workshop, West Lafayette, IN, May 7-8, 1999.
- J. A. Thies attended National Sweetpotato Collaborators Group Annual Conference and contributed written Progress Report for 1998 entitled: Evaluation of regional and standard entries for reaction to root-knot nematodes . January 30-31, 1999. Memphis, TN.
- Three members of the CRSP team were appointed to the national task force to develop a strategy to reduce infestations and interceptions of the gall midge; Janet Lawrence, Phillip Chung and Don MCGlashan. Other members of the task force include representatives from Plant Quarantine, JEA, ABC and USDA-APHIS. A national strategy was developed by the task force and CARDI was given the responsibility to coordinate the compilation of the proposal. This proposal was submitted to the IPM CRSP for funding. In addition, a request was made to FAO for assistance.
- F. McDonald, J. Lawrence, and D. Clarke-Harris helped coordinated a workshop ": Integrated Commodity Approach to the Development of the Hot Pepper Industry". St Mary, Jamaica (November 1998).
- D. Clarke-Harris, F. D. McDonald, and J. L. Lawrence. Planned and coordinated hot pepper stake holders meeting "Development of marketing strategies for the hot pepper industry in Jamaica and the wider Caribbean". Kingston, Jamaica (October 23rd, 1999).

B. Researcher Investigator Exchanges.

- J. A. Thies traveled to St. Kitts May 9-15, 1999 to cooperate with Drs. Monica Gordon and Sherman Weekes (CARDI) in the evaluation of a hot pepper replicated field test for resistance to root-knot nematodes, and observe a replicated sweetpotato field test designed to evaluate USDA advanced lines and local cultivars for performance and insect resistance.

C. Research Information and Product Exchange.

- R. L. Fery shipped seed of five *Capsicum chinense* accessions and four *C. annuum* accessions to Dr. Sherman C. Weekes, CARDI, St. Kitts.
- R. L. Fery transferred seed of the C. frutescens cv. Tabasco to Mr. Don McGlassen, Jamaican Ministry of Agriculture.

Publications and Presentations

- R. L. Fery presented a poster entitled "Genetic analysis of resistance to the peanut root-knot nematode exhibited by the *Capsicum chinense* germplasm line PA-353" at the Annual Conference of the American Society for Horticultural Science, Minneapolis, MN, July 28-31, 1999.
- R. L. Fery presented a talk entitled "Genetic analysis and assessment of southern root-knot nematode resistance in hot pepper (*Capsicum chinense*)" at the National Pepper Conference, San Antonio, TX, October 13-15, 1998.
- J. A. Thies attended the Annual Meeting of the American Phytopathological Society and presented a talk entitled Expression of resistance to the southern root-knot nematode, *Meloidogyne incognita*, in *Capsicum chinense* and *C. annuum* at high temperatures. August 6-12, 1999. Montreal, Canada.
- The Jamaica Information Service (JIS) developed a television feature presentation on the gall midge problem. CARDI personnel involved in the gall midge research (Frank McDonald, Janet Lawrence, Desmond Jones) were interviewed and research activities being conducted in the lab and field highlighted (filmed).
- Lawrence, J. L. (1998). Integrated Pest Management (IPM) approach to pepper production and marketing in Jamaica. CARDI/IICA/MINAG Seminar " An Integrated Commodity Research Approach to the development of the Hot Pepper Industry. St Mary, Jamaica. (November 31st, 1998).
- Lawrence, J. L (1999) National strategic plan for the gall midge complex affecting hot peppers. Presentation made at IPM/Collaborative Research Support Project Consultative Caribbean Site Meeting USDA Laboratories, Charleston, SC.
- McDonald, F. D. (1998). CARDI's Research for development strategy: Pepper case study.

CARDI/IICA/MINAG Seminar " An Integrated Commodity Research Approach to the development of the Hot Pepper Industry. St Mary, Jamaica. (November 31st, 1998).

- McDonald, F. D. (1999). Hot pepper, *Capsicum chinense*, as an important export crop of the Caribbean and the research approach required to develop its competitiveness. Presentation made at IPM/Collaborative Research Support Project Consultative Caribbean Site Meeting USDA Laboratories, Charleston, SC.
- McDonald, F. D. (1999). Background on pepper production technology in Jamaica and the Wider Caribbean. Presented at CARDI/MINAG/JEA workshop Development of marketing strategies for the hot pepper industry in Jamaica and the wider Caribbean. Kingston, Jamaica. October 23rd, 1999.
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- Fery, R. L., J. A. Thies, A. Myers, R. Martin, J. Reid, S. McDonald, B. Nault, S. Tolin, and F. W. Ravlin. 1999. IPM systems development in hot pepper, Capsicum chinense. p. 96-115. In: IPM CRSP Fifth Annual Report, 1997-1998, Virginia Polytechnic Institute and State University, Blacksburg, VA.
- Fery, R. L., J. A. Thies, and S. C. Weekes. 1999. Southern root-knot nematode resistance in hot pepper (Capsicum chinense): Potential for the development of resistant cultivars for the U.S. and Caribbean markets. p. 6-23. In: Progress in IPM CRSP Research, Proc. Third IPM CRSP Symposium, 15-18 May 1998, Blacksburg, VA. Virginia Polytechnic Institute and State University, Blacksburg, VA.
- Thies, J. A., R. L. Fery, J. D. Mueller, and S. C. Weekes. 1999. Potential for using resistant peppers to manage southern root-knot nematodes in vegetable crops. p. 24-32. In: Progress in IPM CRSP Research, Proc. Third IPM CRSP Symposium, 15-18 May 1998, Blacksburg, VA. Virginia Polytechnic Institute and State University, Blacksburg, VA.
- Thies, J. A., and J. R. Bohac. 1999. Evaluation of regional and standard entries for reaction to root-knot nematodes, p. 28. In: W. D. McLaurin (ed.), National Sweetpotato Collaborators Progress Report, 1998.
- Thies, J. A., and J. R. Bohac. 1999. Sweetpotato. Reactions of regional and elite breeding clones and standard check cultivars to southern root-knot nematode race 3, 1998. Biological and Cultural Tests 14:187.
- McDonald, F. 1999. *Development of Marketing Strategies for the Hot Pepper Industry in Jamaica and the Caribbean*. Proceedings of the IPM CRSP Symposium
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- Lawrence, J. L. (1998). An Integrated Pest Management Approach to Hot Pepper Production and Marketing in Jamaica. Proceedings of CARDI/IICA/MINAG Seminar " An Integrated Commodity Research Approach to the development of the Hot Pepper Industry. St Mary, Jamaica. (November 31st, 1998). St Mary, Jamaica. pp. 8-14
- Fery, R. L., and J. A. Thies. Inheritance of resistance to the peanut root-knot nematode in hot pepper (Capsicum chinense). J. Amer. Soc. Hort. Sci. (submitted September 1, 1999).
- Thies, J. A., and R. L. Fery. Characterization of resistance to *Meloidogyne arenaria* races 1 and 2, M. hapla, and M. Javancia in Capaicum chinense Jacq. germplasm lines. Plant Disease (in preparation).

Training Output

- S. McDonald, visited the Division of Plant Industry, Florida Department of Agricultural and Consumer Services in Gainesville to be trained in aphid identification by Dr. Susan Halbert, a Homopterist. (March 21st – 28th, 1999).
- S. McDonald; PhD student at VPI conducted research on hot pepper in Jamaica during the past year.

Project Highlights

- One manuscript reporting research conducted, in part, with IPM CRSP funds was published in a refereed journal.
- Two manuscripts reporting research conducted, in part, with IPM CRSP funds are in preparation or have been submitted for publication in refereed journals.

- A breeding program to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into Habanero pepper was continued; the third backcross was completed and resistant plants from this backcross are being used to complete the fourth backcross.
- A breeding program was initiated to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into West Indies Red; the initial crosses were completed and the F_1 of this cross is currently being backcrossed to the West Indies Red parent.
- The resistance to the peanut root-knot nematode (*Meloidogyne arenaria* Race 1) in *C. chinense* was found to be conditioned by a single dominant gene; this finding confirms the results of the inheritance study conducted in 1998.
- The results of growth chamber tests confirmed earlier findings that resistance to southern root-knot nematodes (*M. incognita*) in *C. chinense* is partially compromised at high temperatures. However, the root galling response and nematode reproduction in the resistant Scotch Bonnet germplasm at high temperatures was significantly lower than in susceptible Habanero-type peppers. Root-knot resistant *C. chinense* cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates.
- The results of a second year of field tests conducted cooperatively with a CARDI investigator in St. Kitts confirmed that the recently released *C. chinense* germplasm lines PA-353, PA-398, and PA-426 are resistant to indigenous field populations of *Meloidogyne* spp.
- The results of greenhouse studies demonstrated that the southern root-knot nematode resistant *C. chinense* cultigens PA-353, PA-398, and PA-426 are also resistant to the peanut root-knot nematode *(M. arenaria* race 1). *Meloidogyne arenaria* race 2 was not highly pathogenic to any of the tested *C. chinense* cultigens.
- Seven legumes (velvetbean, Iron-Clay cowpea, sunnhemp, soybean, Cahaba vetch, crimson clover, and hairy vetch) selected for their potential usefulness as cover-crop mulches for weed control were evaluated for host suitability to southern root-knot nematodes; the velvetbean, Iron-clay cowpea, sunnhemp, and soybean entries were highly resistant and are potentially useful for managing *M. incognita* in pepper plantingsif used as a cover-crop mulch for weed control.
- Gall midge populations can be detected with yellow sticky traps.
- Cultural practices in combination with imidachloprid or fipronyl applied can suppress gall midge populations below a 5% infestation level for at least 3 weeks.
- West Indian Red cultivated with production technology generated under the IPM CRSP and other donor funded projects can provide small farmers with satisfactory economic returns.

IPM of Pests Affecting Sweetpotato, *Ipomoea batatas*

Investigators: Janet Lawrence[1], Lilory McComie[1], Frank McDonald[1], D. Mike Jackson[2], Janice Bohac[2]
Collaborating Scientists: Phillip Chung[3], Trevor Martin[3], Clive Edwards[4]

Abstract

A new insect pest attacking sweetpotatoes in Jamaica was identified as the sweetpotato leaf beetle (*Typophorus viridicyaneus* Crotch), and a scoring system for assessing the damage to sweetpotato roots caused by this insect was refined. Sweetpotato IPM component research focused on developing high yielding, red-skinned, cream-fleshed sweetpotato cultivars with resistances to root-knot nematodes, diseases, and insects. In addition, the integration of these varieties with a selective low toxic compound, fipronyl was initiated. Several USDA-developed sweetpotato clones and Caribbean varieties demonstrated good resistance to the sweetpotato leaf beetles, sweetpotato weevils, and/or the WDS soil insect complex in a replicated field test in Jamaica. Similar to 1997-1998 season, the promising lines appear to be White Regal and Picadito as well as the local varieties "Fire-on-land" and TI24-98. When compared to the grower standard - Sidges, combining White Regal with the selective pesticide fipronyl gave lower root damage. The regionalisation of the sweetpotato IPM was one of the highlights of the component. Researcher exchanges and visits to Jamaica, St Kitts and Nevis, St Vincent, Montserrat and St Lucia provided the medium to initiate sweetpotato research and has set the stage for future expansion of the IPM CRSP research activities.

Objectives

1. Identify a small white grub that has emerged as a new pest of sweetpotato in Jamaica and to initiate efforts to develop methodology needed to evaluate germplasm for resistance to various white grub species and other soil insects.
2. Develop high yielding, red-skinned, cream-fleshed sweetpotato cultivars with resistance to root-knot nematodes, diseases, and insects.
3. Determine the suitability of USDA-developed, red-skinned, cream-fleshed sweetpotato clones for commercial use in Caribbean countries.
4. Evaluate the performance of USDA and local export sweetpotato breeding lines for commercial use in the Caribbean.
5. Validate sweetpotato weevil IPM in various agroecological zones within the Caribbean (Jamaica and St. Kitts).

IPM Constraints

1. Sweetpotato weevils, sweetpotato leaf beetles, and the WDS soil insect complex significantly reduce sweetpotato production in Jamaica. The ultimate incorporation of pest management tactics, such as resistant breeding lines and the use of biorational insecticides, into the present IPM technology will greatly assist Caribbean farmers to produce high quality products which are competitive in international markets.
2. Dissemination of IPM technology to farmers in major sweetpotato growing areas in the Caribbean will facilitate the Region to produce high quality sweetpotatoes, which are internationally competitive.

Research Methods

(1) Taxonomic Determination of Soil Grubs infesting sweetpotatoes in Jamaica. *(M. Jackson, J. Lawrence, J. Bohac)*

Research Methods

A new insect pest attacking sweetpotatoes in Jamaica was collected as larvae and reared to adults in a screen cage in Jamaica. Adult specimens (nine pinned adult specimens; three from Ebony Park, two from Bodles, and four from Yoakum, Texas) were sent to S. W. Lingafelter (USDA, ARS, Systematic Entomology Laboratory, Communications, and Taxonomic Services Unit, Beltsville, MD) for identification.

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[1] CARDI
[2] USDA
[3] RADA
[4] OSU

Research Results and Discussion

S. W. Lingafelter positively identified the new insect pest as the sweetpotato leaf beetle, *Typophorus viridicyaneus* Crotch (Coleoptera: Chrysomelidae, Eumolpinae). A scoring system for assessing the damage to sweetpotato roots caused by this insect was developed in 1998 and refined in 1999.

Impact

The identification of the new insect pest of sweetpotato in Jamaica will facilitate the selection and development of a pest management strategy.

(2) Develop high yielding, red-skinned, cream-fleshed sweetpotato cultivars with resistances to root-knot nematodes, diseases, and insects. *(J. Thies, J. Bohac)*

Research Methods

Sweetpotato breeding program. The process of breeding sweetpotatoes that combine high yields, multiple pest resistances, and acceptable culinary quality involves many greenhouse, field, and laboratory procedures. The first procedure is to select which parents to enter into the polycross field nursery. Secondly, seedlings resulting from these crosses are tested in the greenhouse for reaction to the southern root knot nematode and Fusarium wilt pathogen. The 1999 field tests are in progress in Charleston, SC, to evaluate second year seedlings, advanced breeding lines, and elite breeding lines for insect and disease resistance. Field tests in Blackville, SC, are in progress to evaluate first year seedlings, second year seedlings, advanced and elite breeding lines for horticultural and yield characteristics. Following the 1998 field season, various tests were conducted in the winter of 1998-1999 on roots from sweetpotato breeding lines for storage, cooking, and culinary qualities. Also, further replicated greenhouse testing of advanced clones to confirm resistances to the southern root knot nematode and Fusarium wilt were conducted.

Evaluation for nematode resistance. Sixteen advanced lines and six check cultivars of sweetpotato were evaluated for resistance to southern root-knot nematode (M. incognita race 3) in a greenhouse test. The experimental design was a randomized complete block with three replicates. Each plot consisted of five terminal field-grown vine cuttings of a single entry planted 3 cm apart in a greenhouse bench containing steam-pasteurized soil (2 parts sand : 1 part loamy sand). Nematode inoculum was cultured on Rutgers tomato (Lycopersicon esculentum) in isolated greenhouse benches. Eggs were extracted from tomato roots using 0.5% NaOCl. Cuttings were planted on 24 June 1998 and the soil surrounding each cutting was infested with ca. 3,000 M. incognita eggs in 5 ml H2O. The greenhouse conditions were maintained for favorable growth of sweetpotato and nematode development. On 6 October 1998, the roots of the plants were lifted, washed, and evaluated for resistance to root-knot nematode using a 1 to 5 rating system, where 1 = 0 to 3% of root system galled or covered with egg masses, 2 = 4 to 25%, 3 = 26 to 50%, 4 = 51 to 80%, and 5 = >80% of root system galled or covered with egg masses.

Research Results and Discussion

Sweetpotato breeding program. The yield, quality, and insect resistance field trials being conducted in South Carolina during the 1999 crop season are still in progress. It is anticipated that additional high-yielding. Red-skinned, cream-flesh cultivars with resistance to insects and diseases will be identified as suitable for importation to Jamaica in 1999.

Evaluation for nematode resistance. The standard resistant and susceptible check cultivars performed as expected (Table 1). Eight entries were highly resistant (HR), which was similar in reaction to Sumor (HR-Check). Six entries were resistant (R), which was similar in reaction to Nemagold (R-Check). Two entries were intermediate-susceptible (I-S), which was slightly more resistant than Tinian (S-Check).

Impact

The ultimate release of a cream or dry fleshed sweetpotato cultivar with resistances to root-knot nematodes, Fusarium wilt, and insects will address some of the major constraints facing the sweetpotato industries in the USA and Jamaica.

(3) Evaluation of yield, storage potential and insect resistance traits of select USDA cream-flesh sweetpotato clones to standard Jamaican sweetpotato clones *(Janet Lawrence, Janice Bohac, D. Mike Jackson)*

The incorporation of pest tolerant sweetpotato breeding lines into the present IPM is being viewed as a practical and economical approach to managing pests in both the low-input and high-intensive production systems observed in the Caribbean and the USA. During the past season, breeding lines from the USA that showed potential in the 1997-1998 season along with the six local Jamaican export lines were evaluated for tolerance to the major pests of concern, yield and storage potential.

Objectives

- Evaluate yield and storage potential of twenty-two (22) USDA breeding lines and six (6) Jamaican export lines.
- Determine insect resistance in Jamaican cultivars and USDA breeding lines.

Research Methods

A museum of USDA and Jamaican sweetpotato breeding lines which showed potential during the previous growing season (1997 - 1998) was established in September at the CARDI field station. In December, an additional 9 lines which demonstrated high pest resistance in the USA were imported from the USDA South Carolina and established in the museum. From this museum, Twenty-two (22) USDA lines and six (6) local Jamaican export lines were selected for evaluation at the Bodles Research Station, St Catherine Parish. Each breeding line was planted on beds 23 - 30 cm high, 1m wide and spaced at 30 cm intervals. Plots consisted of 25 plants. Treatments were allocated in a randomized complete block design with four replicates.

Yield and Horticultural Traits. 150 days after planting, roots were harvested. Roots were graded into 3 size categories relating to local and export market standards (culls, marketable I and marketable II). The number of roots within each category was counted and weighed (kg). Observations on shape, skin and flesh colour, as well as storage potential was determined.

Insect Resistance. Roots were scored for pest damage resulting from sweetpotato leaf beetle larvae, sweetpotato weevils, white grubs, Wireworm-*Diabrotica-Systena* complex *(WDS)* and flea beetles. For [1]sweetpotato weevils and [2]sweetpotato leaf beetle larvae, damage was scored on a scale of 0 - 5 and 0 - 4 based on percentage of surface and internal damage and length of feeding channels, respectively. Roots damaged by [3]WDS were rated by assigning each root a score based on the number of feeding scars. Flea beetle damage was calculated as a proportion of total root damage. For each pest scored, a severity damage index was calculated using the formula below.

Severity Index Formula

$$\frac{(a \times \text{Score } 0) + \ldots\ldots + (a \times \text{Score } 5)}{\text{Total Number of Roots}}$$

Where a= number of roots with the particular score

Storage Potential. For each variety/breeding line, clean marketable sized roots were placed in a brown paper bag and stored at room temperature (26° ±3°). At two week intervals for 12 weeks, roots having soft rots and or had sprouted were discarded. The appearance of roots with respect to skin/flesh colour and texture, turgidity was also recorded.

Statistical Analysis. Data were analysed by Analysis of Variance (ANOVA) and means separated with Duncans New Multiple Range Test using SAS statistical software.

Research Results and Discussion

Yield and Horticultural Traits. Significant differences in yield per plant was observed among varieties (P= 0.0001, F= 8.3, df=24). The highest yielders (roots per plant) were the Jamaican lines – six weeks, TIS94-28 the USDA breeding lines – 93-78, 94-145 and Picadito. The average weight per plant being 1.31Kg, 0.89Kg, 0.67Kg, 0.67Kg and 0.58Kg respectively. All these lines possess acceptable export criteria of rose-red skin with cream- yellow flesh (Table 2).

Storage Potential. Many lines were lost after harvest due to soft rots and/or sprouting. In addition, the appearance of the roots (skin/flesh colour and texture and turgidity) deteriorated after six weeks of being in storage. Lines having significant losses after 6 weeks, included Picadito, TIS24-98, TIS30-30, Six Weeks and Sidges.

Insect Resistance. Compared to the previous season, the sweetpotato leaf beetle and sweetpotato weevil populations were low; less than 20 sweetpotato leaf beetles were observed at any one observation. Likewise for sweetpotato weevil, populations averaged 300 adults per night when monitored with low doses (10 µg) of sweetpotato weevil sex pheromones.

When compared to the susceptible check - SC1149-19, high levels of resistance to wireworm-*Diabrotica-Systena*, sweetpotato leaf beetle and sweetpotato weevil were demonstrated among breeding lines. Multiple pest resistance was also observed (Tables 3). In relation to the sweetpotato weevil, roots of the Jamaican lines "Fire-on-land" and TIS24-98 and the USDA breeding lines W308, Sumor, Picadito and 94-145 demonstrated a high level of tolerance to the pest. The crowns of these lines also exhibited high to moderate tolerance to the weevil. Varieties, Ti30-30, "Fire-on-land", White regal, Pi531116 and Pi538288 demonstrated high to moderate tolerance to the sweetpotato Leaf beetle and the WDS complex.

As demonstrated in the previous season (1998-1999), useful levels of resistance to major pests exists among US and Jamaican breeding lines. Lines such as White Regal, Picadito, W308 which were identified in the last season as having potential for incorporation into the present IPM, once again demonstrated the positive attributes of good yielders and tolerance to the pest complex. In addition, local lines TIS2488 and TIS30-30 which were obtained from the Ministry of Agriculture also displayed potential for incorporation into the present IPM. Previous farmer reports suggested that the line "fire on land " which is now being

[1] *Sweetpotato Weevil, Cylas formicarius Damage Rating. Crown - 0= no injury, 1= 1- 20% injured tissue, 2= 21- 40%, 3= 41- 60%, 4= 61- 80%, 5= 81- 100%.. Root - 0= no injury, 1= larval tunnels 0.01 - 0.50 cm deep and 0 - 6% internal tissue injury, 2= larval tunnels 0.5 - .0 cm deep and 6 - 12% internal tissue injury, 3= larval tunnels 1.0 - 1.5 cm deep and 12 - 24% internal tissue injury, 4= larval tunnels 1.5 - 2 cm deep and 24 - 48% internal tissue injury, 5= larval tunnels greater than 2 cm deep and >48% internal tissue injury.*

[2] *Immatures of the Sweetpotato Leaf Beetle, Typophorus viridicyaneus sp. gouge shallow areas on the surface of sweetpotato roots. Damage rating based on the length of feeding channels. 0= no injury, 1= >0 - 8 cm channel, 2= >8 - 15.0 cm channel, 3= >15 - 23cm channel, 4= >23 cm channel.*

[3] *Wireworm-Diabrotica-Systena complex (WDS) Score based on the number of feeding scars (0= no scars, 1= 1- 5 scars, 2= 6 - 10 scars, 4= more than 10 scars). Flea Beetle Damage - Narrow grooves just below surface.*

cultivated for export appeared to be more tolerant than the line Sidges, this was confirmed in this study.

Impact

The sweetpotato IPM component aims at identifying effective and economic management tactics that can reduce sweetpotato weevil and sweetpotato leaf beetle populations and root damage. The identification of US and Local sweetpotato breeding lines that are somewhat tolerant to these pests is a positive step towards developing an IPM strategy that can produce a high quality safe product for consumers.

Table 1. Yields and Storage Potential of USVL breeding lines and local Jamaican cultivars (Season II, 1999)

	Appearance		Yield		Storage Potential (% Roots of marketable quality)	
Sweetpotato Clone	Skin	Flesh	Total wt (Kg)	Avg. wt/ root (Kg)	6 Weeks	12 Weeks
USDA Lines						
93-78	Tan	Pale Yellow	22.3	0.12	90.4	61.5
94-145	Rose	Pale yellow	23.5	0.01	0	0
94-191	Rose	Pale yellow	20.2	0.10	100	56.6
94-196	Tan	Pale yellow	24.7	0.11	69.5	20.0
94-207	Rose	Pale yellow	32.5	0.07	90.0	80.0
95-61	Copper	Light Orange	34.0	0.05	79.2	20.9
95-175	Rose	Pale Yellow	13.6	0.14	93.75	32.6
95-190	Rose	Pale Yellow	9.6	0.09	91.5	38.5
96-47	Rose	Cream	9.2	0.09	95.5	60.2
96-51	Rose	Cream	7.2	0.33	100	38.5
W308	Tan	Pale Yellow	30.1	0.17	96.1	38.5
PI528288	Purple	Mottled Cream	9.7	0.13	100.0	100.0
PI9792	Rose	Cream	22.7	0.17	89.2	25.0
Picadito	Rose	White	17.3	0.32	60.0	26.0
Sumor	Tan	Cream	16.5	0.09	73.0	22.5
White Regal	Rose	Cream	14.5	0.17	91.7	38.5
Hi-Dry	White	White	12.8	0.23	39.0	0
Jamaican Varieties						
TI24-98	Rose	White	11.5	0.42	45.7	25.0
TI30-30	Rose	Cream	17.5	0.25	61.8	30.0
Fire-on-land	Rose	White	21.2	0.17	86.2	45.0
Quarter Million	Rose	Cream	10.0	0.28	85.4	18.5
Six Weeks	Rose	Pale Yellow	11.10	1.17	67.5	0
Sidges	Rose	Pale Yellow	11.37	0.16	55.3	0
Susceptible check SC1149-19	Tan	Orange	48.6	0.14	51.3	7.5

Notes: Storage Root Potential –roots lost due to sprouting, soft rots. In addition, fading of skin and discolouration of flesh colour, wrinking and turgidity were noted.

Table 2. Insect resistance ratings of USVL breeding lines and local Jamaican cultivars (Season II, 1999)

Sweetpotato Clones	% Clean	Sweetpotato Weevil (indices)		WDS Complex (Index)	Sweetpotato Leaf Beetle (index)
		Root	Crown		
USDA – Lines					
94-145	87.60	0.119	0.30	0.003	0.069
94-191	65.25	0.215	0.21	.0390	0.057
94-196	65.97	0.346	0.49	0.232	0.131
94-207	84.84	0.221	0.24	0.079	0.008
95-61	83.25	0.159	0.65	0.164	0.049
95-175	50.89	0.421	0.08	0.447	0.066
95-190	57.85	0.496	0.37	0.510	0.063
96-47	69.87	0.297	0.41	0.260	0.290
96-51	67.96	0.201	0.49	0.298	0.033
W308	91.72	0.075	0.38	0.113	0.035
PI528288	70.47	0.325	0.25	0.000	0.000
97-92	68.62	0.269	0.23	0.306	0.119
Picadito	81.93	0.127	0.28	0.214	0.095
Sumor	88.14	0.056	0.22	0.033	0.069
White Regal	70.18	0.148	0.61	0.197	0.027
Hi-Dry	42.97	0.184	0.33	0.594	0.108
Jamaican Lines					
TI24-98	74.71	0.094	0.21	0.196	0.136
TI30-30	55.84	0.265	0.20	0.069	0.023
Fire-on-land	83.45	0.049	0.25	0.095	0.023
Quarter Million	61.52	0.388	0.52	0.287	0.196
Six Weeks	64.10	0.301	0.38	0.191	0.085
Sidges	66.19	0.149	0.46	0.192	0.138
Susceptible check					
SC1149-19	25.67	0.778	1.15	0.972	0.027

Sweetpotato Weevil, *Cylas formicarius* Damage Rating. Crown - 0= no injury, 1= 1- 20% injured tissue, 2= 21- 40%, 3= 41- 60%, 4= 61- 80%, 5= 81- 100%.. Root - 0= no injury, 1= larval tunnels 0.01 - 0.50 cm deep and 0 - 6% internal tissue injury, 2= larval tunnels 0.5 - .0 cm deep and 6 - 12% internal tissue injury, 3= larval tunnels 1.0 - 1.5 cm deep and 12 - 24% internal tissue injury, 4= larval tunnels 1.5 - 2 cm deep and 24 - 48% internal tissue injury, 5= larval tunnels greater than 2 cm deep and >48% internal tissue injury. [1] Immatures of the Sweetpotato Leaf Beetle, *Typophorus* sp. gouge shallows areas on the surface of sweetpotato roots. Damage rating based on the length of feeding channels. 0= no injury, 1= >0 - 8 cm channel, 2= >8 - 15.0 cm channel, 3= >15 - 23cm channel, 4= >23 cm channel.. [1] Wireworm-*Diabrotica-Systena* complex (WDS) Score based on the number of feeding scars (0= no scars, 1= 1- 5 scars, 2= 6 - 10 scars, 4= more than 10 scars). Flea Beetle Damage - Narrow grooves just below surface.

(4) Evaluation of the potential of resistant varieties in combination with fipronyl (Regent®) for the management of the sweetpotato leaf beetle *(Janet Lawrence, D. Mike Jackson, Janice Bohac, Clive Edwards)*

During the past year, the economic importance of the Sweetpotato Leaf Beetle, significantly increased as the pest spread to a large number of major sweetpotato growing North and South districts of the island of Jamaica. Within these districts, it was reported that the pest defoliated over 60 hectares of sweetpotato and damaged over 80% of harvested roots. In an effort to address this problem, the most promising resistant varieties and chemical treatments from 1997 - 1998 season were selected and evaluated.

In the 1998-1999 IPM CRSP workplan, it was proposed that entomopathogens (e.g. *Beauvaria bassiana)* be evaluated for their potential to suppress beetle populations and damage; however, due to the inability to acquire an import permit for the entomopathogen, the treatment was omitted and the study revised to include the evaluation of the timing of application of fipronyl (a selective compound that showed promise during the previous season)

Objective

- Determine the potential of resistant varieties in combination with fipronyl to reduce beetle populations and root damage
- Determine the optimal timing for the application of fipronyl
- Determine yields and adaptability of USDA varieties under current farmer production practices.

Research Methods

Agronomic Practices. Sweetpotato varieties were planted on raised beds 1m wide and at planting intervals of 0.3m on an IPM CRP target farm in Ebony Park, Clarendon. Plots were irrigated as needed using overhead sprinkler system. Fertilizer (N:P:K - 11: 22: 22) was broadcasted within the first 6 weeks of planting.

Pest Management. Weeds within beds were removed by hand; those weeds occurring between treatment plots and surrounding the field were treated with the herbicide paraquat (Gramoxone®). Sweetpotato weevil infestations were managed with the current recommended IPM practices of mass trapping male weevils with female sweetpotato weevil sex pheromone and cultural practices.

Experimental Design. Three (3) breeding lines were evaluated; *Picadito* and USDA variety white regal, and the Jamaican local line - *Sidges.* The chemical pesticide evaluated was Fipronyl [BSI] (Regent®) applied at 100g ai. per hectare with a granular applicator. For each variety the pesticide was applied at either planting or 8 weeks after planting (root swelling). Treatments were allocated in a random complete block design with 4 replicates. Each treatment plot consisted of 30 plants (n= 120 per treatment). Plots were surrounded by guard rows of *Sidges.*

Parameters

Crop Phenology. The phenology of the crop was recorded every two weeks. Phenology was based on vegetative growth – vines established, vines running and storage root development - initiation, enlargement (swelling) and maturity.

Leaf Beetle Incidence. At planting, soil was sampled within a 1m quadrat to a depth of 4 – 6 cm from the top, middle and bottom sections of each treatment bed. The soil from each section was sieved and the number of larvae and adult beetles present was recorded. Ten plants and the surrounding soil were inspected biweekly the number of beetles recorded. Leaves were scored for damage by the beetle based on a rating scale of 0 - 5; 0 – no damage, 1- >0-10%, 2 - >10% - 30%, 3- >30% -50%, 4- >50% - 80% and 5->80%.

Root Damage. At harvest, the proportion of roots scared by soil grubs was recorded. Based on a rating scale described in earlier studies, roots from each treatment plot were scored and severity indices calculated.

Yields. All roots harvested were graded into 3 size categories relating to local and export market criteria (culls, market I and market II). The number of roots within each category was counted, weighed and recorded.

Data analysis. Data was analysed by Analysis of Variance (ANOVA) and means separated by Tukey's Multiple range test using JMP Statistical software.

Research Results and Discussion

Leaf Beetle Incidence. The mean total number of beetles observed fortnightly during the cropping cycle was 247, this was more than a 10 fold increase over the previous season. A high positive correlation was observed between beetle populations and crop phenology, a steady increase adult leaf beetles was observed as the crop matured; at storage root enlargement – swelling, populations as high as 1000 beetles were recorded (Figure 1). Leaf damage indices also showed similar trends.

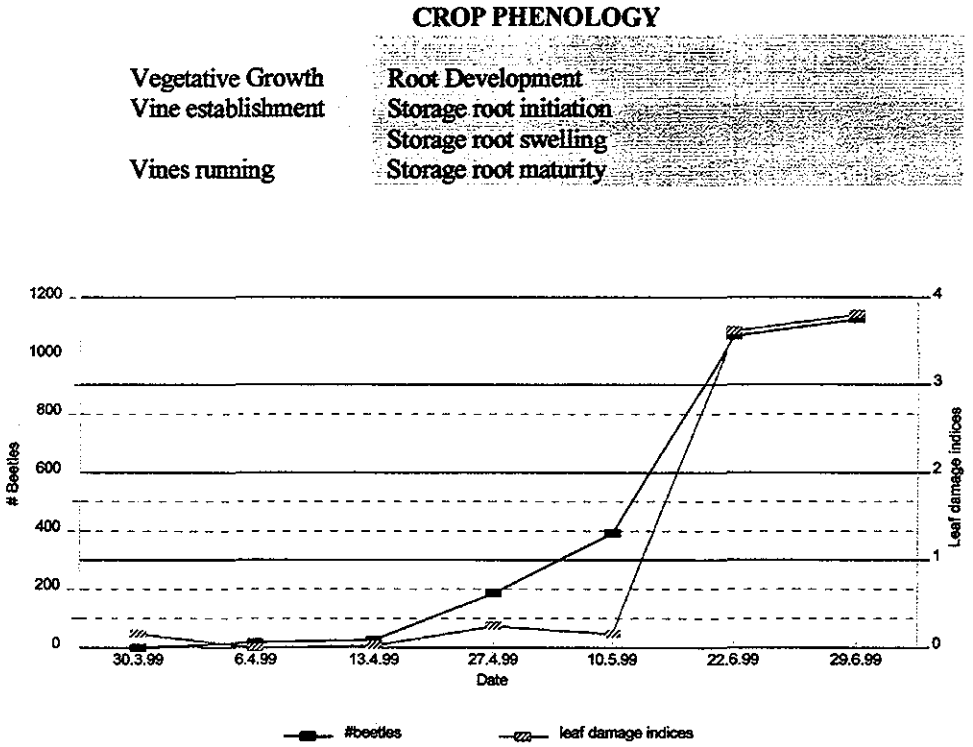


Figure 1. Sweetpotato leaf beetle, *Typophorous viridicyaneus* Crotch (Coleoptera: Chrysomelidae, Eumolpinae) population and leaf damage index in relation to crop phenology (February – June 1999, Ebony Park, Clarendon)

Root Damage. Roots damaged by sweetpotato leaf beetle averaged 85.5% of total harvested yields. White Regal had lower root damage than Picadito and Sidges, but this was not significant (P=0.42, F= 1.06, df=7) (Table 4). Differences were however observed among treatments in relation to the severity of root damage, White Regal had significantly lower damage than Picadito and Sidges, indices were 1.2, 2.1 and 2.3 respectively (P=0.013, F=3.4, df=7) (Table 4). In relation to the timing of application of fiprony, treatments at planting proved to be more effective than at root enlargement. Overall, White Regal treated with fipronyl at planting gave the least damage.

Table 4. The effect of USDA breeding and commercial Jamaican lines in combination with fipronyl (Regent®) on sweetpotato leaf beetle damage, Ebony Park, Clarendon.

Variety	No Application – Control		Application at Planting		Application at Root Enlargement	
	% Root Damage (±SE)	Severity Damage Index (±SE)	% Root Damage (±SE)	Severity Damage Index (±SE)	% Root Damage (±SE)	Severity Damage Index (±SE)
Picadito	99.2 (12.4)	1.5 (0.3)	69.9 (12.4)	2.3 (0.3)	87.2 (12.4)	2.6 (0.3)
White Regal	78.0 (12.3)	1.3 (0.3)	63.3 (14.5)	1.0 (0.4)	90.5 (12.4)	1.5 (0.3)
Sidges	92.60 (12.4)	2.6 (0.3)	93.7 (12.4)	2.2 (0.3)	97.5 (12.4)	2.4 (0.3)

Root Damage- P= 0.42 F= 1.06, df= 7; Severity Index – P=0.013, F=3.4, df= 7

Damage Index based on a rating scale. Immatures of the Sweetpotato Leaf Beetle, *Typophorus* sp. gouge shallows areas on the surface of sweetpotato roots. Damage rating based on the length of feeding channels. 0= no injury, 1= >0 - 8 cm channel, 2= >8 - 15.0 cm channel, 3= >15 - 23cm channel, 4= >23 cm channel. Severity Index Formula: (a x Score 0) + ...+ (a x Score 5)/ Total Number of Roots. Where a= number of roots with the particular score

Performance. Root yield averaged 4.55 kg. Significant differences were observed among sweetpotato lines (P=0.0014, F= 8.5, df=2). Sidges out yielded Picadito and White Regal both in total and average root weight (Table 5).

In contrast to the previous season, fipronyl did not give satisfactory management. This may be attributed to the high beetle population, especially in the later part of the cropping cycle. During this period, the level of fipronyl present from the application at planting may have been to low to provide sufficient management, on other hand the application late in the season was too late to effect knock down of the beetles.

The study demonstrates the necessity to consider both the crop phenology and beetle population when developing a spray application guide for the sweetpotato leaf beetle. An application too late in the season may run the risk of having marketable produce with pesticide residues, and at the same time the application has to be made before beetle numbers explode beyond an economic threshold. The challenge for the 1999 – 2000 season is therefore to strike a balance between these two critical indicators.

Table 5 Performance of USDA breeding lines and a local commercial variety under farmer production practices.

Sweetpotato Lines	Total Yield (kg/30 plant plot) (SEM)	Avg. Root Size (Kg) (SEM)
Picadito	2.7 (1.24)	0.08 (0.02)
White Regal	4.08 (1.25)	0.04 (0.02)
Sidges	8.2 (1.38)	0.18 (0.02)

Total Yield – P=0.0014, F= 8.55, df= 2, Average Root Size – P=0.0001, F= 12.81 df= 2

Impact

The trends in the study suggest that resistant varieties in combination with selective chemicals offers potential for incorporation into a sweetpotato IPM strategy.

(5). Working with participatory groups to disseminate sweetpotato weevil IPM technology *(J. Lawrence, L. McComie, F. McDonald)*

Objectives

- Identify and characterise existing sweetpotato cropping/production systems
- Determine economic status of sweetpotato pests
- Disseminate sweetpotato weevil IPM to farmers within major sweetpotato production areas in Jamaica and other countries within the Caribbean
- Assess the impact of introduced technology on quantity and quality of sweetpotato yields

Jamaica

Dissemination of IPM Technology to Sweetpotato Farmers in Major Growing Districts. During the past 18 months in Jamaica, the focus of the activities has been on the gathering of baseline data *(production systems, pest management practices, economic status of sweetpotato weevil)* and using a modified farmer field school approach to transfer the sweetpotato weevil IPM technology to over 200 farmers in major producing districts. The details of these activities were described in the annual report – year 5.

During the 1998-1999 project year, efforts were made to address queries, questions and concerns which farmers may have had with the technology. This was done though farm visits and meetings with farmers and extension. During these sessions/visits the following queries/questions were raised:

- The effect on the crop when the technology is being used and neighbouring farms are not
- Positioning pheromones in field surrounded by abandoned crops, and or highly infested fields.
- The toppling of traps due to due to heavy breezes
- Longevity of the pheromones
- New concerns facing farmers within the districts:
  1) Cracking of roots
  2) Sweetptato leaf beetle

Based on the above the following recommendations/actions were taken:

- Trap modifies to include stones in the base of the catchment container

- Farmers in districts began using the traps as barriers around newly planted crops if old abandoned crops were adjacent new fields.
- Three seminars were conducted to deal with the biology of the leaf beetle
- Research efforts were directed to identifying management strategies for the leaf beetle
- Roots were taken to determine if cracking was a result of nematodes. Confirmation has not yet been received.

Technical Assistance Request.

Based on the work being conducted under the CARDI/RADA/IPM CRSP programme, CARDI was asked by a bauxite company ALCAN to assist there over 3,000 tenant farmers with the management of the sweetpotato weevil. A proposal was therefore developed by CARDI and forwarded to ALCAN.

Pheromone dispensers that were purchased from the USA, continue to be sold through RADA. A total of 930 septa have been sold.

St Kitts

In order to initiate the regionalisation process, Dr Lilory McComie, Entomologist CARDI St Kitts visited Jamaica in July 12th -15th, 1999 to observe the IPM research being conducted. During the visit, Dr McComie was able to observe the use sweetpotato IPM technologies within major growing areas as well as varietal and pesticide trials being conducted for the management of the sweetpotato leaf beetle and sweetpotato weevil. Publications and protocols generated under the CRSP research programme and pheromone septa were given to Dr McComie for use in St Kitts. Based on the visit, Dr McComie established plots to evaluate the sweetpotato weevil IPM technology and is also evaluating sweetpotato lines from Antigua, St Kitts and the USDA for yield and insect resistance.

Preliminary Data – Evaluation of sweetpotato varieties for yield and insect resistance

A preliminary trial was done and harvested Feb/March 1999 in St. Kitts. Data is still to be analyzed statistically. Preliminary look at the data suggests that there might be some tolerant varieties. The 10 varieties planted are: Clarke, Sugar root, Antigua Mandella I, Antigua Mandella II, Local red skin, Jewel, PI 399163, Regal, SC 1149-19 & Sumor.

Another trial was re-established in St. Kitts & Nevis to be harvested in November Storage root formation may have been affected by dry weather and lack of irrigation on the stations so that harvesting may be later than the recommended three months. Monitoring with pheromone traps to determine weevil population pressure. is ongoing. Results to date are St. Kitts Wk. 6-213, Wk. 9 - 587 Wk. 13 -6735 after a 24 hour trapping period. This suggests that there is high weevil population at the CARDI field station in St. Kitts which caused a loss of approximately 70-80% of commercial harvest (at the station) in February 1999.

A list of farmers has been complied in St. Kitts for baseline farmer survey before introduction of the IPM programme among sweet potato farmers on the island..

Montserrat

A three module workshop was held in Montserrat. The 3rd module held September 6-7, 1999. One area of focus was IPM of the sweet potato weevil. The use of the pheromone trap was introduced several years ago but the technology was not in wide spread use. The 19 participants comprising mainly of farmers, extension officers benefited from the practically oriented training. IPM technology was done using overhead transparencies, posters, handouts, lectures and discussions. Participants were given copies of the IPM CRSP/CARDI handout on management of the sweetpotato weevil and pheromone trap construction.

On day one participants constructed weevil traps made from recycled materials, baited them with the sweet potato weevil pheromone and set them in the field. On day two the traps were examined, the weevil collected and counted. Farmers were favourably impressed by the efficacy of the trap and expressed an interest in obtaining and using them. Follow-up activities are to be done by the extension officers in Montserrat

St Vincent

A visit was made to St Vincent to observe the sweetpotato cropping systems and determine the pest composition. Based on farm visits, farmer's interviews and discussions with extension and researchers, it was determined that the major pests of importance is the sweetpotato weevil, *Euscepes postfaciatus* and white grubs, *Phyllophaga* spp. The current status of the sweetpotato weevil, *Cylas formicarius* is not known and hence a survey is to be conducted. Pheromone septa and protocols developed under the IPM CRSP programme were therefore forwarded for use in the survey. Based on the results of the survey, a research workplan will be developed.

Impact

Sweetpotato is an important crop for many countries within the Caribbean. Many of these countries are plagued by common pests. Under the sweetpotato IPM component, the ultimate goal is to regionalise the technologies developed to reduce these pests, such that, the quality and quantity of sweetpotato in the Region can be improved and the commodity can become competitive in international markets. This year the initiation of this process has set the stage for future expansion of IPM CRSP activities and achieving this ultimate goal.

Networking Activities

A. Workshops/Meetings/Seminars.

- J. R. Bohac, D. M. Jackson, and H. F. Harrison served as members of the Sweetpotato Crop Germplasm Committee. J. R. Bohac and D. M. Jackson attended the January 1999 meeting in Memphis, TN.
- J. R. Bohac is the U. S. Partner on the Clemson University/NAARI, Ugandan partnership on the McKnight Foundation project Development of high yielding multiple resistant sweetpotato germplasm.
- D. M. Jackson. Bohac, and J. Lawrence helped plan and attended IPM CRSP Caribbean Site: IPM Systems Development, Planning Meeting – Year 7 and Beyond, June 27-30, 1999, Charleston, SC.
- J. Lawrence attended the IPM CRSP Annual Planning Workshop. West Lafayette, IN. May 6-9, 1999

B. Research Investigator Exchanges.

- D. M. Jackson traveled to Jamaica in May 1999 to assist in J. Lawrence (CARDI) in evaluating two sweetpotato field trials. They developed rating systems for damage from the new grub species.
- L. McComie visited Jamaica (July 12-15) to observe sweetpotato research activities being conducted and initiate the regionalisation of sweetpotato IPM.
- L. McComie traveled to Monsteratt to conduct technology transfer sessions - Sweetpotato weevil IPM
- J. Lawrence traveled to St Lucia and St Vincent (July 26 - August 2, 1999) to observe sweetpotato cropping systems and initiate regionalisation of sweetpotato IPM technologies.

C. Research Information and product exchange.

Impact of CRSP-produced or recommended technology, including crop protection inputs, manuals, brochures, etc.

1) J. Lawrence provided reports, protocols and publications relating to sweetpotato research activities and pest management technology to researchers in St Kitts, and St Vincent.
2) Assistance you have given to collaborating scientists with research equipment, supplies and/or other support
3) J. R. Bohac shipped several USDA-developed, dry-fleshed sweetpotato clones and accessions to J. Lawrence to evaluate their potential in Jamaica.
4) D. M. Jackson secured a garlic extract from a California company for use in Jamaica as a pest barrier to the sweetpotato leaf beetle.
5) J. Lawrence purchased pheromone septa for IPM researchers in St Vincent and St Kitts
6) C. E. Edwards assisted with the identification of the most appropriate strains, application rates and timing of entomopathogenic nematodes to control sweet potato weevil (*Cylas*) and soil grubs. Biorational pesticides identified for field trials were strains of *Beauvaria bassiana* (Naturalist T®, Mycotrioles) and *Metarhizium sp* (BioBlast®) an insect growth regulator halofenzide (Mach 2®) and fipronyl (Chipco®, Regent®). Samples of all these biorationals were obtained by Dr. Clive Edwards who planned to carry them to Jamaica for the field trials. However, problems arose with all of these new chemicals, in obtaining permission to import them to Jamaica. Janet Lawrence initiated import permits but to date, only Mach 2® has been cleared for import which has seriously delayed the field trials scheduled for 1999.

Publications and Presentations

A. Presentations

- Jackson, D. M., J. Lawrence, L. McComie, J. R. Bohac, C. Edwards, and B. Nault. 1999. Integrated pest management (IPM) of major pests affecting sweetpotato in the Caribbean. Presentation made at IPM CRSP Caribbean Site: IPM Systems Development, Planning Meeting – Year 7 and beyond, June 27-30, 1999, Charleston, SC.

B. Abstracts and Reports

- Bohac, J. R., D. M. Jackson, and J. D. Mueller. 1999. Progress Report for 1998- Sweetpotato breeding and genetics. Page 28 *In* W. D. McLaurin (ed.), National Sweetpotato Collaborators Group Progress Report, 1998.
- Jackson, D. M., J. R. Bohac, and J. D. Mueller. 1999. Progress Report for 1998- Resistance of regional and standard sweetpotato entries to soil insects, Charleston, SC., 1998. Pages 28-30 *In* W. D. McLaurin (ed.), National Sweetpotato Collaborators Group Progress Report, 1998.
- Lawrence, J., M. Jackson, J. Bohac, P. Chung, and T. Martin. 1999. IPM Systems development of sweetpotato, *Ipomoea batatas*. Pages 115-127 In IPM CRSP, Integrated Pest Management Collaborative Research Support Program, Fifth Annual Report, 1997-1998 (Management Entity, Ed.). Virginia Polytechnic Institute and State University, Blacksburg, VA.

C. Symposium Proceedings

- Jackson, D. M., J. R. Bohac, J. Lawrence, and J. D. Mueller. 1999. Multiple insect resistance in dry-fleshed sweet potato breeding lines for the USA and Caribbean. Pages 274-280 *In* Progress in IPM CRSP Research, Proceedings of the Third IPM CRSP Symposium, 15-18 May 1998, Blacksburg, VA. Virginia Polytechnic Institute and State University, Blacksburg, VA, 327 pp.
- Lawrence, J., D. M. Jackson, and J. R. Bohac. 1999. Evaluation of USDA sweetpotato breeding lines as a potential tactic for managing sweet potato pests in the Caribbean and USA. Pages 298-304 *In* Progress in IPM CRSP Research, Proceedings of the Third IPM CRSP Symposium, 15-18 May 1998, Blacksburg, VA. Virginia Polytechnic Institute and State University, Blacksburg, VA, 327 pp.

Project Highlights

- A new insect pest attacking sweetpotatoes in Jamaica was identified as the sweetpotato leaf beetle (*Typophorus viridicyaneus* Crotch), and a scoring system for assessing the damage to sweetpotato roots caused by this insect was refined.
- Efforts were continued to develop high yielding, red-skinned, cream-fleshed sweetpotato cultivars with resistances to root-knot nematodes, diseases, and insects.
- The results of a replicated field test conducted in Jamaica indicated that USDA-developed sweetpotato clones (white Regal and Picadito) and Caribbean varieties (Fire-on-land, TI24-98) have good resistance to the sweetpotato leaf beetles, sweetpotato weevils, and/or the WDS soil insect complex and had acceptable marketable characteristics.
- The regionalisation of sweetpotato IPM technologies generated under the IPMCRSP was initiated in four islands, St Kitts and Nevis, St Vincent and has set the stage for expansion of the IPM research activities

PESTICIDE USE, RESIDUES, and RESISTANCE

The goal of this topic is to assess the extent to which pesticides are used on pepper, callaloo, and sweetpotato. We hypothesize that many of these pesticides remain on crops long after application even to the extent to which residues can be detected in local and export marketplaces. Thus, the activities described below attempt to quantify pesticide use and residues that can either cause human health problems or rejection in the marketplace. Resistance to pesticides may also be a result of excessive pesticide use or of those chemicals that degrade very slowly under field conditions. The second project described for this topic addresses the pesticide resistance question for callaloo and pepper arthropod pests.

Monitoring Pesticide Residue Levels on Callaloo

Investigators: Clive A. Edwards[1] and Dionne Clarke-Harris[2]
Collaborating Scientists: Frank McDonald[2] and Janet Lawrence[2]

Abstract

Over the past three years, results of market basket surveys have demonstrated that pesticide residues are present on marketable produce. In an effort to address the problem. IPM technologies geared at reducing spay applications were developed. To further demonstrate the benefits of these technologies, samples of callaloo from a field experiment which compared routine farmer spraying with a limited pesticide spraying regime were analyzed for pesticide residues.

Objectives

Compare residues of λ-cyhalothrin (Karate®) after routine farmer weekly spraying compared with three sprays based on pheromone trap catches of *Spodoptera* adults.

IPM Constraints

Over the past three years unacceptable levels of pesticide residues have been found on callaloo. The development of a spray application guide to eliminate the farmer practice of calendar spraying will significantly reduce pesticide residues on marketable callaloo. This study therefore further demonstrates the benefits of utilising this technology.

Research Methods

Two field experiments were set up at different field sites (Bushy Park, Mona). One batch of replicated plots at each site was treated with weekly sprays of λ-cyhalothrin at the recommended dosage to control *Spodoptera*. To the second batch of plots λ-cyhalothrin sprays were applied three times, at timings based on maximum moth activity assessed from pheromone trap catches. At approximately weekly interval, samples of callaloo leaves were collected from each treatment to assess insecticide residues.

[1] OSU
[2] CARDI

Research Results

In the field experiment comparing routine farmer spraying of λ-cyhalothrin with fewer pheromone based sprays, 26 samples of callaloo foliage were taken from two experimental sites, to be analyzed for residues of the insecticide at OSU. The residues have been extracted but are still awaiting final analysis. We hope these data will be available in time for the final annual report.

Impact

The demonstration of reduced pesticide residue levels on marketable callaloo, validates the usefulness of the technologies being developed under the IPM Systems development callaloo component

Networking Activities

A. Research Investigator Exchanges

- C. E. Edwards traveled to Jamaica (March 1999) to meet with Caribbean collaborators to develop the research workplan for Year 7 and tour research areas.

B. Research Information and Product Exchange

- Assisted in the production of scientific papers and IPM brochures.

Presentations

- Presented a seminar at CARDI entitled *"The use of microcosms and terrestrial model ecosystems in assessing the effects of pesticides on soil ecosystems"* attended by CARDI, MINIAG, RADA and UWI staff.

Social Economic, Policy, and Production System Analyses

Social, economic, policy, and institutional systems (human systems) have been shown to sometimes present overwhelming barriers to implementing IPM practices. The goal of this topic is to identify those components of human systems that constrain IPM adoption. The systems evaluated by the Caribbean research team include domestic and export markets and policies and practices associated with those markets, institutions and the policy environment of Jamaican agriculture, and farmgate economics as it relates to pepper, callaloo, and sweetpotato production and marketing (local and export).

SOCIAL AND GENDER-RELATED ISSUES THAT AFFECT IPM ADOPTION

Investigators: Sally Hamilton[1], Gary Schlosser[1], Tina Schlosser[1], Larry Grossman[1]
Collaborating Scientists: Janet Lawrence[2], Raymond Martin[2], and Dionne Clarke-Harris[2], Phillip Chung[3]

Abstract

The primary activity of Year 6 was the analysis of data collected during Year 5's baseline socioeconomic survey in three communities, each affiliated with the IPM CRSP for one target crop and each located in a distinct ecological zone and geo-political region. The goals of this activity were to identify (1) socioeconomic constraints to IPM adoption and (2) beliefs and practices that contribute to health and environmental problems associated with pesticide use. Gary Schlosser and Tina Schlosser, graduate students in the Department of Geography at Virginia Tech, have published results in their Masters theses, which can be downloaded at http://www.vt.edu. Key findings related to gender equity issues and socio-economic constraints to IPM adoption (see Objectives 1 – 3 below) are summarized in this report and are published in: G. Schlosser. *Gendered Production Roles and Integrated Pest Management in Three Jamaican Farming Communities.* M.S. thesis, Virginia Tech, 1999. Findings of the pesticide safety and health research are published in T. Schlosser, *Local Realities and Structural Constraints of Agricultural Health: Pesticide Poisoning of Jamaican Small-holders.* M.S. thesis, Virginia Tech, 1999.

The survey was designed to provide a probabilistic sample that would accurately profile the range of variation among potential IPM adopters in terms of farm size, livelihood strategies, labor availability and other socio-economic measures; current and preferred marketing channels for targeted crops; IPM knowledge and practice; access to technical extension and assistance; and knowledge and practice concerning disease and health risks associated with pesticide use (among other variables). The survey--and related informal focus groups, individual interviews, and

[1] Virginia Tech
[2] CARDI
[3] RADA

behavioral observation–were carried out with approximately equal numbers of women and men to ensure valid gender analysis. As at some other sites (Philippines, Uganda), it has been found that men and women have differing perceptions of their own, and their partners', roles in agriculture. Both tend to report somewhat larger roles for themselves than are reported by their partners, and both report somewhat smaller contributions by their partners than the partners report for themselves. Thus there is no substitute for direct interviewing—and observation, if possible—of both women and men concerning their involvement in production, marketing, and economic decision-making.

Among the gender equity issues addressed is whether the adoption of IPM is likely to alter the gendered division of labor and resources within households in ways that would disadvantage women. Findings indicate that IPM adoption would not disadvantage women. However, the potential benefits of IPM adoption may not be as available to women as to men, as women are less likely to receive relevant technical assistance or to be involved in technology development. Gender bias in technology design and delivery may also constrain adoption by households. Women are producers of targeted crops who make pest management decisions. Even women who do not farm are likely to have considerable control over farm incomes; this control can impact decisions concerning purchase of pesticides. Women farmers may be more pesticide dependent than men. As women have less access to information and technology-development processes than men, they may be less likely to incorporate IPM alternatives. It is recommended that IPM CRSP collaborators increase on-going efforts to include women farmers in participatory research and disseminate gender-disaggregated social science research results to cooperating extension officers.

Farmers showed substantial awareness of safety procedures but often chose not to practice them. A general lack of knowledge among health-care providers concerning identification and treatment of poisoning was observed, although both medical and agricultural branches of the national government have made efforts to address pesticide poisoning. Pesticide poisoning is widespread in Jamaica. The subsample of cases available for analysis of pesticide health and safety issues was too small to draw conclusions concerning gender differences, but there did not appear to be gender differences in pesticide safety knowledge, attitudes, or practice. Although women were likely to resort to pesticides, they were less likely than men to spray. This pattern may help to explain why women are less likely to be treated for pesticide poisoning. Qualitative information confirmed the lack of gender differences in pesticide safety knowledge, attitudes, and practices.

Objectives

1) To describe intrahousehold resource allocation patterns, the gendered division of labor and marketing of target crops, and household-level variables expected to determine women's participation in decision domains that impact adoption of IPM.
2) To describe gendered knowledge and practice of pest management
3) To describe gendered sources of information concerning pest management
4) To determine if there are significant differences in women's and men's perceptions of health and environmental risks related to pesticide use and their pest management practice

IPM Constraints

Social and economic constraints to IPM adoption and safe use of pesticides; health and environmental costs of unsafe pesticide use.

Research Methods

Methods of socioeconomic survey data collection were reported during Year 5. In order to test for ecological and macro-structural effects, as well as to sample potential adopters of all target crops, three communities were selected, representing distinctive patterns in ecological zone, geo-political profile, and target crop adoption. Methods of stratifying samples in large communities according to geographical location and socio-economic status (determined during community reconnaissance with key informants) were utilized in one of the communities. A probabilistic sample of at least 30 households in each of three communities was surveyed (total=95 households), including interviews with both male and female household heads. As the term *household head* is used here, it refers to senior household decision makers, i.e. adults who are responsible for supporting and reproducing the household. A household with a husband and wife, for example, would have both a male household head and a female household head. Although there are approximately equal numbers of men (71) and women (69) included in the sample, many households are represented by only a female or male head. Operationalizing measures of socio-economic variation was designed to afford comparison with studies across CRSP sites and other related research, and included measures that yielded operationally valid preliminary results based on the survey field test.

Open-ended interviews; additional structured interviews covering pest management and health knowledge, attitudes, and practice administered to a subset of survey participants; and participant observation also provided valuable information. Case studies of women and their families in socio-economically representative households added important dimensions to understanding the production constraints faced by farmers of both genders in each of the field settings. Qualitative information is needed to interpret brief survey answers concerning complex processes such as

negotiated joint decision-making by women and men within households. Also, it is important to observe behavior, as information reported during both surveys and other forms of interviewing represents informants' perceptions of behavior, and at times may be influenced by social relations between interviewers (or the institutions they represent) and informants. While behavior under observation is also affected by the presence of researchers, it affords many opportunities for clarification of processes being observed. The combination of quantitative and qualitative information offers the strongest informational base—one that is representative of the population under study and can also be interpreted in light of researchers' experience in the community.

Results

Research addressed both gender-based constraints to IPM adoption and gender equity issues. Equity issues included potential for increased labor for women on family farms where IPM is adopted, as IPM technologies can be labor intensive, as increased field labor can force women to abandon other income-producing activities; whether women are less likely to adopt because of these labor requirements. Additional equity issues involve CRSP choice of targeted crop and stage of production/processing, as women and men may work with different crops or depend differentially on sale of crops in the field or following storage or processing. It is important to ensure that constraints to women's productivity and income are addressed as well as those of men.

It is also important to understand gendered economic decision-making patterns, as women may make decisions that impact pest management practice at many points along the pest management decision chain. (In the Philippines, for example, CRSP research found that even women who do not work in household agriculture make budget decisions that can impact pest management practice.) If women do make relevant decisions, but do not have equal access to CRSP activities involving development and distribution of technology, they may be less likely to adopt IPM or to support adoption in their households. Thus socioeconomic data that is disaggregated by gender will help the CRSP to serve women farmers' needs, to take advantage of women's knowledge, and to reach out to farm women who have decision input at any point along the pest management decision chain.

Women are heavily involved in the work of farming in our three research communities. In Hazard/Donnington Castle, St. Mary, 100% of women interviewed gave their occupation as farmer; in Rose Hill, Manchester, 84% are farmers; and in Grove Farm and Lloyd's Pen, St. Catherine, where proximity to Kingston offers greater opportunity for women to earn off-farm incomes, 55% are farmers.

St. Catherine. Women have diverse sources of income in the St. Catherine communities. While 55% are farmers (compared with 88% of men), 25% are market vendors or higglers. Around half of the women farmers work in agriculture throughout the production cycle. Among 19 landowners (N = 44 household heads), men own more than twice as much land as women individually. About 1/5 of land is owned jointly by couples. One-third of the landholding population owns between 5.25 and 10.5 acres, the result of a land redistribution program. Most have less than 2 acres. Men also lease land.

Despite the gender disparities in landholding, crops are not divided along gender lines. The crop targeted by the IPM CRSP is callaloo. Eight female farmers (around 75%) and 12 male farmers (60%) produce callaloo. Post-harvest processing and marketing activities are divided equally among women and men.

Only "farmers" were asked questions related to IPM decision-making, a potential flaw in field methodology, as women were found to control incomes, including those from farming, equally with men. At CRSP sites in other countries, it has been found that women who control farm incomes may have considerable control over spending for pesticides, a decision domain that can influence pest management practice.

In St. Catherine, twice as many men as women answered questions concerning decision-making. As noted in the summary, this disparity affects reports of women's involvement, as both household heads tend to under-report partners' decision input. Only 9-11 women answered these questions. Between ¼ and 1/2 reported that they are primary or joint decision makers in agricultural decisions, depending on decision area. Nearly half decide market venues for farm products. One-third reported that they make decisions regarding whether to use pesticides and selection of pesticides together with their partners, and over half reported that they purchased pesticides. Men were more likely to report that they made decisions alone, but over ¼ reported that they made decisions about major crops together with the female head. Based on this small sample, it would seem that men are more likely to make agricultural decisions alone than are women, but women and men both make decisions in many households.

Seventy percent of all respondents reported that women decide how to use farming income, either individually or jointly with their partners. Over 80% of women reported this level of control of crop incomes. Their decision authority may extend to budgeting for pesticide purchase, which would impact amount and timing of pesticide use. Since half of women reported that they purchase pesticides, it is likely that they influence amount and timing of pesticide use. Further, among a small subset of farmers who answered questions concerning pest management practice, all of the women used pesticides against all pests.

Decision patterns cannot be tied to individual crops, and it should be noted that questions referred to "major crops". A wide variety of crops are produced in this area, and callaloo is not the major crop for 65% of producers. Thus, no conclusions with reference to women's decision input concerning the targeted crop can be drawn from the survey. However, it should be noted that the few women who answered questions concerning sources of pest management information reported that they taught themselves, while men learned from extension agents and other farmers. Although several farmers did not answer these questions, and the subsample reporting pest management practice was small, it would seem that women farmers are making pest management decisions in an information void.

Case studies focused on families in which men do more of the field work, while women market crops in Kingston and Old Harbour. Rotation of market days indicates that if these women were to become more involved in field labor due to the labor intensity of some forms of IPM, they are unlikely to lose income-producing opportunities. These cases, and women's high levels of involvement at several points along the marketing chain, point to women's knowledge of buyers' tolerance for pest damage. As women also produce the targeted crop and appear to make pest management decisions without benefit of extension services, it is important that the CRSP intensify efforts to incorporate women farmers into participatory technology development activities and make these research results available to those who disseminate IPM technologies.

St. Mary. In the study communities, all surveyed women and men are farmers; women also work as teachers and shopkeepers. The distribution of land is much more uneven than in St. Catherine. Most people own less than three acres, while nearly 1/5 have over 10 acres. Men individually own more than 80% of the land, and twice as many men lease land as do women.

The IPM-CRSP targeted crop is Scotch Bonnet hot pepper. Nearly half of all pepper growers are women. There is some specialization in crops by gender; in households where men and women grow different crops, all women grow peppers. Women both work in the fields (50%) and hire field labor (40%). Women are involved in agricultural labor throughout the production cycle.

Women's and men's reports of women's involvement in agricultural decision-making differ strikingly with respect to pest management. Among women farmers, 72% reported that they make decisions regarding whether to use pesticides and 58% select pesticides together with their partners. Most men reported that they alone make these decisions. Nearly half of women report buying pesticides, while less than ¼ of men say that women buy pesticides in their households. This level of disparity in women's and men's reports is difficult to interpret, as women and men agree on the level of women's participation in agricultural decision-making concerning most other decision measures.

Men and women agreed that, in general, they make joint decisions concerning major crops. Men and women also agree on the proportion of farming households in which both heads decide on the division of labor, hiring labor, use of farm income, and who is likely to buy pesticides. According to women, ¾ are decision-makers (either alone or together with partners) concerning major crops and the division of labor; 78% decide on market venues; and over 90% decide how to use farm income.

Women and men often interpret their own participation in decision-making as more or less than their partners perceive it to be. In some settings, women report lower levels of control than their husbands ascribe to them, perhaps indicating that the women feel they are minority partners in decision-making processes. When women are more likely to report decision input than their partners are to agree that they have input, this pattern may reflect patriarchal or machista value systems, in which men feel they will be viewed as less masculine if they share decision authority over important economic resources and processes with women, or it may reflect their a view that their wives merely propose action that the men then choose to ratify or reject.

Given agreement among women and men concerning the high level of women's involvement in other agricultural decision domains and the fact that, among a subset of farmers who reported pest management practice, women are much more likely to resort to pesticides than men, women's reports concerning pesticide decisions probably more nearly reflect pest management decision behavior. Case studies, also, suggest that women are likely to be involved in all agricultural decisions. Keeping in mind that all women farm, it is cause for great concern that here, as in St. Catherine, fewer women than men report receiving pest management information from extension services. As the IPM CRSP is committed to gender equity, it is especially important that the CRSP intensify efforts to incorporate women farmers.

Manchester. In Rose Hill, 84% of women are farmers, compared with 96% of men. In this community, women hold more land than in the other research areas. Most farmers have between 3 and 10 acres, and 1/5 have over 10 acres. One woman has 89 acres. A great deal of land is rented from mining companies. Although more than twice as many men own or have rental contracts for land than women, women hold more land than men, even without including the case of the woman with 89 acres.

There is little division of crops by gender. The IPM-CRSP target crop is sweet potato, which is produced by nearly all farmers and by equal numbers of women and men. Two-thirds of women report that they are decision-makers regarding production of major crops, and men agree with this report.

Women are heavily involved in pest management decision-making. Three-fourths of women say that, either individually or jointly with their partners, they decide to use pesticides, choose pesticides, and buy pesticides. Men do not disagree with their partners' reports regarding joint decision-making. Case studies confirmed these patterns. So few women were interviewed concerning pest management practice that no patterns emerged regarding gendered practice. Among these women, none had received information from extensionists; however, men did not appear to be much better served, as few men reported assistance with pest management.

Impacts

Findings offer CRSP researchers and cooperating extensionists an opportunity to better serve needs of all farmers who produce target crops and make relevant pest management decisions, regardless of gender. Increased adoption of IPM should result, enabling related improvements in farm income, health, and resource-base sustainability. Women appear to be differentially constrained with respect to IPM adoption, as they may have less access to CRSP project activities and related extension than men. This is particularly problematic, as women produce targeted crops and make pest management decisions, but may have less knowledge of pests than men. Women are unlikely to face differential labor constraints owing to potential IPM adoption.

Networking Activities

- Attended Caribbean Planning workshop – Year 6 and beyond at USDA vegetable lab, Charleston, June 28-29, 1999; presented summary of research results and recommendations.

Presentations

Gary Schlosser presented preliminary results at a conference of student geographers in March.

Training Output

Gary Schlosser and Tina Schlosser, graduate students in the Department of Geography at Virginia Tech, have published results in their Masters theses, which can be downloaded at http://www.vt.edu.

Project Highlight

Results of a probability-sample household survey in three IPM CRSP research communities showed that women produce and market targeted crops, choose among pest management alternatives, and select and purchase pesticides; as women appear to have less access than men to IPM-related extension, it is recommended that the CRSP intensify efforts to incorporate women farmers in field research activities and to disseminate gender-disaggregated information to extension officers.

Policies Affecting Production Practices for Domestic Markets and Export Opportunities of Jamaican Vegetables

Investigators: Darrell Bosch[1], David Orden[1], and Janet Lawrence[2]
Collaborating Scientists: Dionne Clarke-Harris[2] and Raymond Martin[2]

Abstract

At the beginning of Year 6, information had been collected on government policies potentially affecting IPM adoption in Jamaica. Information had been collected on the effects of IPM on costs and returns for callaloo, sweet potato, and sweet pepper. General information had been collected for vegetable production costs and returns for farmers in Ebony Park, Clarendon Jamaica. A modeling framework was developed for evaluating returns from IPM adoption for producers of callaloo, hot pepper, and sweet potato in Jamaica.

In November 1998, Ogrodowczyk made a two-week return visit to Jamaica. During this visit economic returns and costs were evaluated for farmers at Bushy Park, St. Catherine. Potential policies affecting IPM adoption were reviewed with policy analysts and government officials in Jamaica. Technical coefficients for IPM production of sweet potato, callaloo, and hot pepper were reviewed with the collaborating scientists from CARDI. A seminar describing research objectives, procedures, and preliminary results was presented to scientists at CARDI.

[1] Virginia Tech
[2] CARDI

From November through January, the analysis was completed, results written up in the thesis, and the thesis was successfully defended. A paper was written and presented by Ogrodowczyk at the Southern Agricultural Economics Association Annual Meeting, January 31—February 3, 1999 in Memphis, Tennessee.

Research findings indicated that the IPM systems developed for callaloo, hot pepper, and sweet potato are potentially profitable. The systems remain more profitable than conventional systems when 1) assumed chemical savings from IPM are eliminated; and 2) labor requirements for IPM are increased by 50%. When the assumed yield increase with IPM was reduced from 30% to 5% for the crops, IPM continued to be more profitable at Ebony Park but not at Bushy Park.

The policies evaluated included preclearance of vegetables for export, elimination of water subsidies, elimination of credit subsidies, a reduction in the real interest rate, elimination of the duty concession, a lowering of the Common External Tariff, and an appreciation of the real exchange rate. None of the policies had large effects on the returns to IPM adoption. Policies designed to liberalize the domestic economy are not likely to affect the potential for IPM adoption in sweet potato, callaloo, and hot pepper in Jamaica.

Objectives

To assess the impacts of various domestic and trade policies of Jamaica and of trade policies of the United States on the production practices of farmers involved in the IPM-CRSP program, to evaluate these impacts and draw conclusions in an economic framework.

IPM Constraints

Domestic and trade policy barriers to adopting IPM practices.

Research Methods

The practices necessary for the production of non-traditional exports by a farm in Clarendon, including the IPM systems developed by the IPM-CRSP program, were quantified. A linear programming model was developed to provide a framework for evaluating potential for IPM adoption on two representative farms representing site conditions at Bushy Park, St. Catherine and Ebony Park, Clarendon. Identification of IPM effects on crop yields, costs, and returns was accomplished through interviews with IPM-CRSP scientists and farmers as well as enterprise budgets and personal observations. Government policies that potentially affect profitability of IPM adoption were identified in interviews with government officials and policy analysts. Interviews and data collection were accomplished in three visits to to Jamaica in 1998 (February 3-10, June 27-July 18, and November 14-28) and the information was assembled into a linear programming model. The decision making variables within the farm model for Ebony Park include growing and selling hot pepper, pumpkin, sweet potato, corn, cassava, sugar cane and callaloo. Potential crops at Bushy Park are hot pepper, pumpkin, corn, okra, cucumber, and callaloo. The constraints include the inputs required for each of the crops: labor, fertilizer, herbicides, insecticides, water, and financial capital. Land availability is fixed at 10 acres for the Ebony Park farm and 5 acres for the Bushy Park farm. A risk constraint was incorporated to limit the amount of each crop as reported by farmers in the study areas. The objective function of the farm model is to maximize the returns to the fixed assets of the farm given the constraints and the returns above variable costs for the different enterprises. This model provided the framework for evaluating the economic incentives for IPM adoption as well as the impacts of policies.

Governmental policies, both export and domestic, towards the agricultural sector which could potentially affect IPM adoption and exports of non-traditional crops were quantified through a review of previous literature, additional interviews with government officials, and from annual reports of the Ministry of Agriculture, the Bank of Jamaica and the Rural Agriculture Development Authority. The policies include preclearance of vegetables for export, elimination of water subsidies, elimination of credit subsidies, a reduction in the real interest rate, elimination of the duty concession, a lowering of the Common External Tariff, and an appreciation of the real exchange rate. The evaluation of the policy effects on IPM adoption was accomplished by incorporating policies into the linear programming model. Relevant model parameters were varied to describe the effects of policies on farmers' incentives.

Results

The IPM systems for hot pepper, sweet potato, and callaloo were more profitable than the conventional systems. IPM sweet potato, hot pepper, and callaloo were adopted at the maximum levels possible on the Ebony Park farm. IPM hot pepper was adopted at the maximum level possible at Bushy Park while callaloo was adopted but not at maximum acreage. The IPM systems remained more profitable than conventional systems when 1) assumed chemical savings from IPM are eliminated; and 2) labor requirements for IPM are increased by 50%. When the assumed yield increase with IPM was reduced from 30% to 5% for the crops, IPM crops were retained in the Ebony Park model but not in the Bushy Park model.

The policies evaluated included preclearance of vegetables for export, elimination of water subsidies, elimination of credit subsidies, a reduction in the real interest rate, elimination of the duty concession, a lowering of the Common External Tariff, and an appreciation of the real exchange rate. None of the policies had large effects on the returns to IPM adoption. Policies designed to liberalize the domestic economy are not likely to affect the potential for IPM adoption in sweet potato, callaloo, and hot pepper in Jamaica.

Impact

Study results suggest that efforts should be made to educate Jamaican farmers about the profitability of IPM technologies. While IPM systems for hot pepper, sweet potato, and callaloo are still being field tested, the profitability of IPM is high and remains positive even when yield benefits of IPM are lowered, IPM labor requirements are raised, and chemical savings from IPM are removed. Liberalized economic policies including preclearance, reductions in credit and water subsidies, and reductions in the Common External Tariff are not likely to affect the profitability of IPM adoption. This result suggests that the government will not need to take special measures to promote IPM adoption in order to offset the effects of economic liberalization.

Networking Activities

Joe Ogrodowczyk, project Graduate Research Assistant, visited the Jamaica site from November 14 to November 28, 1998 to collect data at Bushy Park, St. Catherine, to exchange information with CARDI scientists collaborating on the project, and to interview government officials and policy analysts.

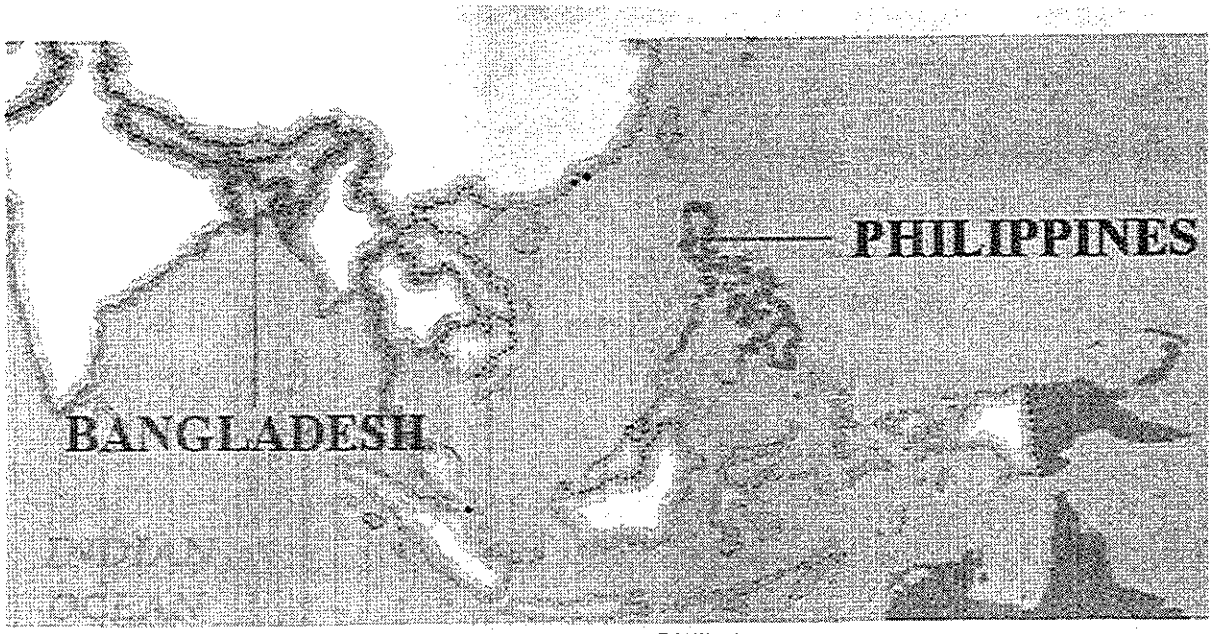
Publications and Presentations

Ogrodowczyk, Joseph. 1998. "Policies Affecting Production Practices and Adoption of Integrated Pest Management for Jamaican Farmers in Ebony Park, Clarendon." M.S. thesis, December. 204 pp.

Ogrodowczyk, Joseph, Darrell J. Bosch, and David R. Orden. "Policies Affecting Production Practices and Adoption of Integrated Pest Management for Jamaican Farmers in Ebony Park, Clarendon." Paper presented at the Southern Agricultural Economics Association Annual Meeting, Memphis, Tennessee, January 31-February 3, 1999. Abstract will be published in the Journal of Agricultural and Applied Economics 31:1 (July 1999).

Project Highlight

An evaluation of the economic incentives for farmer adoption of IPM for callaloo, hot pepper, and sweet potato indicates that IPM can potentially increase farmers' yields and net returns. Government policies of lowering technical trade barriers by encouraging preclearance of vegetables prior to export, removing subsidies of irrigation water and credit, and lowering the Common External Tariff will not reduce the profitability of IPM adoption.



ASIA

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IPM CRSP Asia Site in the Philippines

The sixth year IPM research activities in the Asia site in the Philippines covered three major topics with sub-activities for each one. These activities included (a) multidisciplinary on-farm pest management experiments, (b) multidisciplinary laboratory, greenhouse, and microplot experiments, and (c) socioeconomic analysis. Research activities continued to promote and enhance interdisciplinary research. One focus for the year was on the validation of promising IPM technologies/practices for vegetables after rice, particularly in onions and eggplant. Most field experiments were conducted in farmers' fields in San Jose, Nueva Ecija, and in a two-hectare demonstration field in Bongabon, Nueva Ecija, provided by the NOGROCOMA farmers through Mrs. Dulce Gozon. Laboratory and greenhouse experiments were conducted at PhilRice Central Experimental Station at Maligaya, Muñoz, Nueva Ecija and U.P. Los Baños, while microplot experiments were conducted at the Visayas State College of Agriculture (VISCA). A fourth activity involved advanced training of researchers and graduate students and developing linkages with other institutions, networks, and CRSPs.

Integrated Weed Management Strategies in Rice-Onion Systems

Investigators: A.M. Baltazar[1], F.V. Bariaun[1], E.C. Martin[2], M.C. Casimero[2], F. Bajo, Jr[2], S.R. Obien[2], S.K. De Datta[3], and A.M. Mortimer[4]

Abstract

A single herbicide treatment and one hand weeding provided comparable weed control efficacy and onion yield with those of the current farmer's practice of one herbicide application followed by two to three hand weedings. The succeeding hand weeding operations were not necessary because the weed population had been reduced by the use of traditional cultural practices like rice hull burning and inter-row cultivation. Results from these studies will be used to develop short and long term integrated management strategies based on a rotation systems approach in an effort to reduce expensive and labor-consuming direct weed control inputs, thus decrease production costs due to weed control in rice-onion cropping systems.

Objectives

To evaluate the efficacy of various combinations of chemical, cultural, and mechanical methods of weed control in onion in rice-onion cropping systems.

IPM Constraints

The dominant weed, *Cyperus rotundus*, cannot be controlled by post plant application of herbicides so that despite the intensive herbicide application by farmers this remains to be the major problem weed in Bongabon, Nueva Ecija. During the fallow period, glyphosate application before planting combined with tillage can help reduce *C. rotundus* population during the onion season as these methods can effectively reduce the number of tubers that are buried in the soil.

Research Methods

Study 1. Evaluation of tillage in combination with chemical and mechanical weed control methods

A field study investigating the effects of three tillage practices (conventional, deep, and shallow) in combination with chemical and mechanical weed control methods was done in Bongabon, Nueva Ecija province during the 1998-99 dry season. Tillage served as the main plot while the method of weed control served as the subplot. The experiment was laid out in a split plot in Randomized Complete Block design (RCBD) with three replications. The conventional

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[3] Virginia Tech
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tillage (15 cm plow depth) was done with a small two-wheeled rotavator. Deep tillage (> 20 cm plow depth) was done using a four-wheeled tractor. Shallow tillage (10 cm) was accomplished using a carabao driven plow. Two passes of plowing and harrowing were done for each tillage type. Six weed control treatments were imposed: T1 = pre-plant glyphosate followed by (fb) oxyfluorfen at 6 days after transplanting (DAT); T2= pre-plant glyphosate fb one hand weeding (HW) at 30 DAT; T3= pre-plant glyphosate fb 2 hw at 30 and 45 DAT; T4 = oxyfluorfen fb three HW at 30, 45 and 60 DAT (Farmer's practice); T5 = Weed free check and T6= Unweeded check. Glyphosate [N-(phosphonomethyl)} glycine1] was applied at 7 days before transplanting at the rate of 1.1 kg ai/ha and oxyfluorfen [2-chloro-1- (3-ethoxy-4nitrophenoxy)-4-trifluoromethyl) benzene] was applied at 0.06 kg/ha at 6 DAT with a 16 L hydraulic knapsack sprayer calibrated to deliver 500 L/ha using a 8002 Teejet flat fan nozzle. Forty five day old seedlings (cv Red Creole) were transplanted in raised furrows spaced at 10 cm between hills and 50 cm between furrows. Fertilizer was applied at the rate of 120-60-60 kg NPK /ha divided in three equal splits at 10, 20 and 30 days after transplanting. Irrigation was provided as needed. Inter-row cultivation was done three times at 15, 30 and 45 days after transplanting. NPV-CRSP, a microbial biocontrol agent developed by IPM-CRSP, was applied twice during the season to control onion leaf defoliators. Plants were harvested when 75% of the onion plants had bent "necks". Pertinent data like bulb yield, bulb number/m^2 and average weight/bulb, and weed biomass, were obtained and analyzed using Analysis of Variance. Means were compared using Duncan's Multiple Range Test at 5% level of significance.

Study 2. Evaluation of rice hull burning in combination with chemical and mechanical weed control methods.

A field study to evaluate the effects of rice hull burning in combination with mechanical and chemical methods of weed control in a rice-onion cropping system was conducted at PhilRice-CES during the 1998-1999 dry season. Rice hull burning was used as the main plot and weed control methods served as the sub-plot. The experiment was laid out in a split plot in a Randomized Complete Block Design with three replications. Rice hulls about 15-20 cm deep were evenly distributed and burned prior to land preparation. Two passes each of plow and harrow were done to evenly incorporate the rice hull ash. Ten weed control treatments were imposed as follows: T1= hand weeding (HW) at 30 days after transplanting (DAT); T2= HW twice at 30 and 45 DAT; T3= oxyfluorfen followed by one HW at 30 DAT; T4= oxadiazon fb 1 HW at 30 DAT; T5= fluazifop-butyl at 30 DAT; T6= oxyfluorfen fb fluazifop; T7= glyphosate at 7 days before transplanting; T8= oxyfluorfen fb 2 HW at 30 and 45 DAT.; T9= weed free check and T10= unweeded check. Glyphosate {N- (phosphonomethyl)} glycine1} was applied at the rate of 1.1 kg ai/ha, at 7 days before transplanting, oxyfluorfen [2-chloro-1-(3-ethoxy-4nitrophenoxy)-4-trifluoromethyl) benzene] at 0.06 kg ai/ha at 6 DAT, fluazifop [(+2-[4-[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxyl)] propanoic acid)] at 0.8 kg ai/ha at 25-30 DAT and oxadiazon [3-[2,4-dichloro-5-(1-methoxy)phenyl)-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2(3H)-one] at 0.9 kg ai/ha at 6 DAT were applied with a 16 L hydraulic knapsack sprayer calibrated to deliver 500 L/ha using 8002 Teejet flat fan nozzle. Forty five day old seedlings (cv Red Creole) were transplanted into 1 x 6 m plots. Plants were spaced at 10 x 15 cm between hills. Fertilizer was applied 120-60-60 kg NPK/ha divided in three equal splits at 10, 20 and 30 days after transplanting. Irrigation was done as needed. Interrow cultivation was done three times at 15, 30 and 45 days after transplanting. To control damage by insect defoliators, microbials (NPV-CRSP) were applied twice during the season. Plants were harvested when 75% of the onion plants had bent "necks". Pertinent data including bulb yield, bulb number/m2 and average weight/bulb, and weed fresh weight, were obtained and analyzed using Analysis of Variance. Means were compared using Duncan's Multiple Range Test at 5% level of significance.

Results

Study 1. Evaluation of tillage in combination with chemical and mechanical weed control methods.

Across tillage practices, weed control efficacy from a single pre-plant application of glyphosate followed by one hand weeding was comparable with those of the farmer's practice (oxyfluorfen fb 3 HW) and glyphosate fb 2 HW as indicated by the biomass at 60 DAT of the three most dominant weeds, *C. rotundus, E. colona,* and *T. portulacastrum* (Table 1). Pre-plant application of glyphosate followed by oxyfluorfen at 6 DAT did not control weeds and was comparable to the unweeded check. Tillage alone did not affect the weed biomass. With weed control methods, weed biomass in plots that were sprayed with pre-plant glyphosate followed by one hand weeding or two hand weedings were comparable with the farmer's practice. The interaction of tillage and weed control practice was not significant among treatments. These results indicate that one hand weeding provided sufficient control of weeds when a pre-plant application of glyphosate was made. Similar results were obtained in separate studies conducted in Bongabon in 1996 and 1997 evaluating the effects of applying one herbicide application at about 7-14 DAT in combination with one hand weeding at 30 DAT (Baltazar et al, 1997).

Table 1. Biomass of the three dominant weeds, *Echinochloa colona, Trianthema portulacastrum* and *Cyperus rotundus* at 60 DAT as affected by tillage and weed control methods, Bongabon, Nueva Ecija, 1998-99 dry season.

Treatment	Mean Weed fresh weights (g/m²)			Weed Control Mean
	Conventional Tillage	Deep Tillage	Shallow Tillage	
E. colona				
Gly fb oxy	369.48 ab	353.84 a	179.85 ab	301.06 a
Gly fb 1 HW	23.69 c	29.21 bc	371.98 bc	141.63 b
Gly fb 2 HW	84.74 bc	21.74 c	33.68 bc	46.72 b
Oxy fb 3 HW (FP)	60.19 bc	48.96 a-c	26.35 c	45.17 b
Weed free Check	0.00 d	0.00 d	0.00 d	0.00 d
Unweeded Check	990.21 a	440.03 ab	804.97 a	745.07 a
Tillage Mean	254.72	148.96	236.14	213.27
T. portulacastrum				
Gly fb oxy	569.91 a	228.90 a	501.25 a	433.35 a
Gly fb 1 HW	637.39 a	581.46 a	272.40 a	497.08 a
Gly fb 2 HW	246.60 a	561.35 a	362.55 a	390.17 a
Oxy fb 3 HW (FP)	362.10 a	439.73 a	680.10 a	493.98 a
Weed free	0.00 b	0.00 b	0.00 b	0.00 b
Unweeded	127.63 a	335.11 a	174.30 a	212.35 a
Tillage Mean	323.94	357.76	331.77	337.82
C. rotundus				
Gly fb oxy	0.00 b	0.00 b	5.48 a	1.83 b
Gly fb 1 HW	29.27 a	20.49 a	9.14 a	19.64 a
Gly fb 2 HW	36.56 a	10.68 ab	9.41 a	18.88 a
Oxy fb 3 HW (FP)	35.77 a	20.01 a	10.00 a	21.93 a
Weed free	0.00 b	0.00 b	0.00 a	0.00 b
Unweeded	1.82 b	9.94 b	2.41 a	4.72 b
Tillage Mean	17.24	10.19	6.07	11.17

Means followed by a common letter are not significantly different at 5% level of significance, average of three replications.

In conventional tillage, comparable onion (cv. Red Creole) bulb yields were obtained in plots in which glyphosate was applied preplant at 7 DBT followed by one hand weeding, with the plots treated pre-plant with glyphosate fb 2 hand weedings, oxyfluorfen fb three hand weedings at 15, 30 and 45 DAT (farmer's practice) and the weed-free check (Table 2). Yields obtained from these treatments ranged from 12 to 13 t/ha. In deep tillage, bulb yield in plots treated with glyphosate fb one hand weeding at 30 DAT was lower than the yield in the farmer's practice but was comparable to plots sprayed with glyphosate fb 2 HW at 30 and 45 DAT and the weed free check. Similar trend was observed in shallow tillage. Significantly lower yield was obtained in plots in which glyphosate was applied fb oxyfluorfen at 6 DAT compared with the treatments of glyphosate fb 1 HW at 30 DAT, glyphosate fb 2 HW at 30 and 45 DAT, farmer's practice and the weed-free check.

Table 2. Bulb yield, average bulb number /m^2 and average bulb weight of onion as affected by tillage and weed control methods, Bongabon, Nueva Ecija, 1998-99 dry season.

Treatment	Tillage			Weed Control Mean
	Conventional	Deep	Shallow	
Bulb yield (t/ha				
Gly fb oxy	3.80 b*	3.03 c	2.85 c	3.23 c
Gly fb 1 hw	12.37 a	9.45 b	9.80 b	10.54 b
Gly fb 2 HW	12.08 a	11.28 ab	12.07 ab	11.81 ab
Oxy fb 3 HW (FP)	12.03 a	12.68 a	12.78 a	12.50 a
Weed free Check	13.53 a	11.33 ab	9.62 b	11.49 ab
Unweeded Check	2.87 b	1.63 c	2.58 c	2.36 c
Tillage Mean	9.45	8.24	8.28	8.65
Number of Bulb/m^2				
Gly fb oxy	25.3 bc	24.0 b	21.7 b	23.7 b
Gly fb 1 HW	33.7 ab	34.4 a	38.0 a	35.3 a
Gly fb 2 HW	36.0 a	34.3 a	38.0 a	35.9 a
Oxy fb 3 HW (FP)	36.3 a	35.0 a	36.3 a	35.9 a
Weed free	40.3 a	38.3 a	39.0 a	39.2 a
Unweeded	16.3 c	17.3 b	15.7 b	16.4 c
Tillage Mean	31.3	30.6	31.4	31.1
Bulb weight (g/bulb)				
Gly fb oxy	31.23 bc	36.00 bc	21.00 b	26.07 b
Gly fb 1 HW	42.40 ab	37.93 ab	40.50 a	40.28 a
Gly fb 2 HW	39.23 ab	35.87 ab	51.27 a	42.12 a
Oxy fb 3 HW (FP)	46.46 a	41.86 a	44.93 a	40.79 a
Weed free	47.03 a	36.67 ab	38.68 a	40.79 a
Unweeded	19.43 c	17.43 c	18.50 b	18.45 c
Tillage Mean	37.63	32.62	35.18	35.35

Means followed by a common letter are not significantly different at 5% level of significance, average of three replications.

No significant interaction was observed between tillage and weed control practice. In deep and shallow tillage, the onion bulb yield in plots sprayed with glyphosate fb 1 HW (10.5 t/ha) was comparable with that of the glyphosate fb 2 HW and the weed free check but was lower than the farmer's practice. In conventional tillage, however, yields in plots sprayed with glyphosate fb 1 HW had yields comparable to that of the farmer' practice. The number of bulbs/m^2 and the average weight/bulb obtained in plots with glyphosate applied fb one hand weeding were comparable with those with glyphosate applied fb two hand weedings, the farmer's practice (oxyfluorfen fb 3 HW) and the weed free check.

Farmers spend about 10-20% of the total cost of production for weed control and this was verified in the field study conducted. As the density of weeds is high in Bongabon, about 60 man-days is needed to hand weed a hectare of onion, which amounts to P5,000 (10%) when pre-plant glyphosate is applied followed by one hand weeding (Table 3). With pre-plant glyphosate followed by two hand weedings , the cost is about P9,000 (19%). The cost of weed control in current farmer's practice is about P13,000 (27%). Farmers can save 50-60% in the cost of weed control with one to two hand weedings per season. Weed control is important during the first 30 to 45 days after transplanting so that the hand weeding operation has to be done during this period. Weeds that grow after this period can be controlled by the subsequent inter-row cultivation. Therefore, the hand weeding done by farmers after this period is no longer necessary as this only increases the cost of production.

Table 3. Yield and cost of weed control inputs in bulb onion cv. Red Creole in which various weed control methods were used in combination with tillage. 1998-99 dry season.

Treatment	Mean Yield (t/ha)			Hand weeding Cost			Total	% of Total Production Cost
	Conventional	Deep	Shallow	Md/ha	P/ha	Herbicide/ha		
G fb Oxy	3.80 b	3.03 c	2.85 c	-	-	1338.25	1338.25	2.68
G fb 1 HW	12.37 a	9.45 b	9.80 b	60.2	4214	973.25	5187.25	10.37
G fb 2 HW	12.08 a	11.28 ab	12.07 ab	120.4	8428	973.25	9401.25	18.80
Oxy fb 3 HW (FP)	12.03 a	12.68 a	12.78 a	181.2	12684	973.25	13657.25	27.31
Weed free	13.53 a	11.33 ab	9.62 b	210.0	14700	365.00	15065	30.13
Unweeded	2.87 b	1.63 c	2.58 c	-	-	-	-	-

Glyphosate = 2.29 L/ha at 1.1 kg ai/ha Cost/L = P425
Oxyfluorfen = 0.25 L/ha at 0.06 ka ai/ha Cost/L = P1,060

Table 4. Total weed control costs, % of total production costs and reduction in total weed control costs of various weed control methods, Bongabon, Nueva Ecija, 1998-99 dry season.

Treatment	Total Weed Control Cost (P/ha) [2]	% of Total Production Cost [3]	Amount Reduced [1]	
			P/ha	Percent
G fb Oxy	1338.25	2.68	12,319.00	12,319.00
G fb 1 HW	5187.00	10.37	8,470.00	62.20
G fb 2 HW	9,401.25	18.80	7,255.75	53.12
Oxy fb 3 HW (FP)	13,657.25	27.31	-	-
Weed free	15,067.00	30.13	-	-
Unweeded Check	-	-	-	-

1 Amount reduced compared with farmer's practice
2 US $ = Php 38.00
3 Total production cost in onion = P50,000.00 (Gaskell, 1994)

Study 2. Evaluation of rice hull burning in combination with chemical and weed control methods.

Rice hull burning effectively reduced the biomass of the three most dominant weeds, *Ipomoea triloba*, *T. portulacastrum*, and *C. rotundus* at 60 DAT (Tables 5-7). Higher weed biomass was observed with *C. rotundus* at 60 DAT in the unburned plots (Table 5). Pre-plant glyphosate application alone, oxyfluorfen fb fluazifop, and one hand weeding alone did not control *C. rotundus* in the unburned plots. With rice hull burning, however, the biomass of *C. rotundus* obtained from these treatments were comparable with that of the farmers' practice and the weed free check. No *C. rotundus* grew in the unweeded check as it failed to compete with the *I. triloba* and *T. portulacastrum*, which had a broader canopy and hence outshaded *C. rotundus*

Table 5. Biomass of *C. rotundus* at 60 DAT as affected by rice hull burning in combination with chemical and mechanical weed control methods, PhilRice-CES, Munoz, Nueva Ecija, 1998-99 dry season.

Treatment	Mean fresh weight (g/m²)		Weed Control Mean
	Burned	Unburned	
1 HW	6.12 a [1]	22.64 ab	14.38 a
2 HW	5.65 a	0.66 a	3.16 ab
Oxyfluorfen fb 1 HW	2.14 a	2.48 bc	2.31 ab
Oxadiazon fb 1 HW	3.15 a	0.00 c	1.56 b
Fluazifop alone	0.00 a	0.00 c	0.00 b
Oxyflourfen fb fluazifop	5.42 a	35.47 a	2-.43 a
Glyphosate fb 1 HW	5.86 a	50.18 a	28.02 a
Oxyfluorfen fb 2 HW (FP)	5.42 a	11.25 a-c	8.34 ab
Weed free Check	0.00 a	0.00 c	0.00 b
Unweeded check	0.00 a	0.00 c	0.00 b
Rice Hull Burning Mean	5.98	12.27	9.12

[1] In a column, means followed by a common letter are not significantly different at 5% level of significance; average of three replications.

Table 6. Biomass of *I. triloba* at 60 DAT as affected by rice hull burning in combination with chemical and mechanical weed control methods, PhilRice-CES, Munoz, Nueva Ecija, 1998-99 dry season.

Treatment	Mean fresh weight (g/m²)		Weed Control Mean
	Burned	Unburned	
1 HW	0.00 a	9.91 bc	4.96 b
2 HW	7.00 a	7.94 bc	7.47 b
Oxyfluorfen fb 1 HW	3.59 a	27.42 b	15.51 b
Oxadiazon fb 1 HW	1.94 a	3.00 bc	2.47 b
Fluazifop alone	29.27 a	35.75 bc	32.51 ab
Oxyflourfen fb fluazifop	0.00 c	27.07 bc	13.54 b
Glyphosate fb 1 HW	0.75 a	7.03 bc	3.89 b
Oxyfluorfen fb 2 HW (FP)	0.00 a	4.52 bc	2.26 b
Weed free Check	0.00 a	0.00 c	0.00 b
Unweeded check	21.31 a	89.25 a	55.28 a
Rice Hull Burning Mean	6.31	21.19	13.79

[1] In a column, means followed by a common letter are not significantly different at 5% level of significance; average of three replications.

Table 7. Biomass of *T. portulacatrum* at 60 DAT as affected by rice hull burning in combination with chemical and mechanical weed control methods, PhilRice-CES, Munoz, Nueva Ecija, 1998-99 dry season.

Treatment	Mean fresh weight (g/m²)		Weed Control Mean
	Burned	Unburned	
1 HW	57.28 ab	115.21 a	86.24 ab
2 HW	81.45 a	152.38 a	116.91 ab
Oxyfluorfen fb 1 HW	24.30 bc	227.65 a	125.98 b
Oxadiazon fb 1 HW	67.45 a	169.21 a	118.33 ab
Fluazifop alone	78.08 a	161.81 a	119.95 ab
Oxyflourfen fb fluazifop	86.16 a	426.97 a	256.56 ab
Glyphosate fb 1 HW	108.35 a	299.75 a	204.05 a
Oxyfluorfen fb 2 HW (FP)	83.51 a	163.82 a	123.66 ab
Weed free Check	0.00 c	0.00 b	0.00 c
Unweeded check	60.92 ab	490.20 a	275.56 ab
Rice Hull Burning Mean	64.75	220.70	142.72

[1] In a column, means followed by a common letter are not significantly different at 5% level of significance; average of three replications.

Onion bulb yields were significantly affected by rice hull burning and weed control method. The bulb yields were higher in plots with rice hull burning compared with the unburned plots (Table 8). Plots treated with oxyfluorfen fb 1 HW had yields comparable to the farmer's practice and the weed-free check in both the burned and unburned plots. The other herbicides when combined with 1 HW were not as effective as oxyfluorfen probably because they were not effective on the dominant weeds. Fluazifop is specifically effective against grasses, hence was not effective on *T. portulacastrum* and *I. triloba*, which are broadleaf weeds. Two hand-weeding operations at 30 and 45 DAT were not effective in reducing competition due to weeds as indicated by the low yield. Apparently, removing the weeds at 30 DAT is late as significantly lower yield was obtained in this treatment. The average weight/bulb was likewise significantly affected by the interaction of rice hull burning and the weed control treatments. The average bulb weight in plots treated with oxadiazon fb 1 HW was significantly heavier compared with the unburned plot receiving the same treatment (Table 9). In both the burned and unburned plots, the weed free check and the farmers practice had more bulbs/m^2 compared with the rest of the treatments (Table 10).

Table 8. Bulb yield of onion (cv Red Creole) as affected by rice hull burning in combination with various chemical and mechanical weed control methods, PhilRice-CES, Munoz, Nueva Ecija, 1998-99 dry season.

Treatment	Mean bulb yield (t/ha)		Weed Control Mean
	Burned	Unburned	
1 HW	6.58 d	4.10 d	5.34
2 HW	6.23 d	2.75 d	4.49
Oxyfluorfen fb 1 HW	12.54 b	8.90 b	10.72
Oxadiazon fb 1 HW	10.12 c	6.53 c	8.32
Fluazifop alone	6.31 d	3.33 d	4.82
Oxyflourfen fb fluazifop	9.52 c	3.45 d	6.48
Glyphosate fb 1 HW	3.10 e	2.78 d	2.93
Oxyfluorfen fb 2 HW (FP)	14.44 ab	8.33 bc	11.39
Weed free Check	16.02 a	11.70 a	13.86
Unweeded check	0.67 f	0.27 e	0.47
Rice Hull Burning Mean	8.55	5.21	6.88

[1] In a column, means followed by a common letter are not significantly different at 5% level of significance; average of three replications.

Table 9. Onion yield (cv Red Creole) as affected by rice hull burning in combination with chemical and mechanical weed control methods, PhilRice-CES, Munoz, Nueva Ecija, 1998-99 dry season.

Treatment	Average bulb weight (g/bulb)		Weed Control Mean
	Burned	Unburned	
1 HW	36.90 bc	30.50 c	33.70
2 HW	28.70 cd	30.53 c	29.62
Oxyfluorfen fb 1 HW	67.50 a	55.50 a	61.50
Oxadiazon fb 1 HW	59.37 a	40.20 b	49.78
Fluazifop alone	38.80 b	23.73 cd	31.27
Oxyflourfen fb fluazifop	44.23 b	32.77 bc	38.50
Glyphosate fb 1 HW	22.27 d	18.40 d	20.33
Oxyfluorfen fb 2 HW (FP)	63.60 a	58.70 a	61.15
Weed free Check	59.10 a	53.07 a	61.15
Unweeded check	10.10 e	6.23 e	8.17
Rice Hull Burning Mean	43.06	34.96	39.01

[1] In a column, means followed by a common letter are not significantly different at 5% level of significance.

Table 10. Onion yield(cv Red Creole) as affected by rice hull burning in combination with chemical and mechanical weed control methods, PhilRice-CES, Munoz, Nueva Ecija, 1998-99 dry season.

Treatment	Average no. of bulbs (no/m^2)		Weed Control Mean
	Burned	Unburned	
1 HW	30.3 d	25.7 d	28.0 d
2 HW	33.3 b-d	28.0 cd	30.7 cd
Oxyfluorfen fb 1 HW	30.7 cd	30.0 b-d	30.3 cd
Oxadiazon fb 1 HW	36.7 b-d	29.3 cd	33.0 bc
Fluazifop fb 1HW	39.0 ab	33.3 bc	36.2 b
Oxyflourfen fb fluazifop	37.0 bc	30.3 b-d	33.7 bc
Glyphosate fb 1 HW	36.0 b-d	29.7 cd	32.8 bc
Oxyfluorfen fb 2 HW (FP)	44.7 a	36.3 ab	40.5 a
Weed free Check	44.7 a	40.0 a	42.3 a
Unweeded check	10.7 e	11.0 e	10.8 e
Rice Hull Burning Mean	34.3	29.4	31.8

[1] In a column, means followed by a common letter are not significantly different at 5% level of significance.

With the reduction in weed biomass due to rice hull burning, about 20 man days are needed to hand weed a hectare of onion (Table 11). Depending on the herbicide and the frequency of hand weeding operation, weed control cost was lower, ranging from P1,065 to P3,165 with rice hull burning. Without rice hull burning, the total cost of weed control ranged from P1,415 to P5,265. The savings that can be incurred with the various weed control methods ranged from P365 (12%) to P2800 (66%) when rice hull burning is done compared to the current farmers' practice. Without rice hull burning, it ranged from P1065 (7%) to P3,835 (73%). Application of fluazifop fb hand weeding was more expensive than the current farmer's practice in plots where rice hull burning was done as the herbicide was not effective on the dominant broadleaf weeds. Hence, more man-days were required to remove the weed.

Table 11. Yield and cost of weed control inputs in bulb onion (cv. Red Creole) as affected by various weed control methods and rice hull burning, PhilRice-CES, Munoz, Nueva Ecija, 1998-99 dry season.

Treatment	Ave. yield (t/ha)		Hand weeding Cost Ha/ha [1]		Hand weeding Cost Php/ha [2]		Herbicide Cost	Total Cost of Weed Control [3]	
	RHB	W/o RHB	RHB	W/o RHB	RHB	W/o RHB		RH B	W/o RHB
1 HW	6.6	4.1	20	40	1400	2100	-	1400	2100
2 HW	6.2	2.8	40	60	2800	4200	-	2800	4200
Oxy fb HW	12.5	8.9	10	15	700	1050	365	1065	1415
Oxa fb 1 HW	10.1	6.5	12	15	840	1050	1400	2240	2450
Flua fb 1 HW	6.3	3.3	20	30	1400	2100	2684	4084	4784
Oxy fb Flua	9.5	3.5	-	-	-	-	3049	3049	3049
Gly fb 1 HW	3.1	2.8	20	30	1400	2100	973	2373	3073
Oxy fb 2 HW	14.4	8.3	40	70	2800	4900	365	3165	5265
Weed free	16.0	11.7	80	120	5600	8400	-	5600	8400
Unweeded	0.7	0.3	-	-	-	-	-	-	-

[1] 8 hr/man-day at P70/manday; [2] 1 US $ = Php 38.00

[3] Cost of herbicides: oxyflourfen – P365/ha; Fluazifop – P2544/ha; Oxadiazon –P1400/ha, glyphosate- P795 /ha at recommended rates

Discussion

The weeds growing in the two fields are quite similar except for *I. triloba,* which was a dominant weed in the field where rice hull burning was done. More intense weed pressure was observed in Bongabon as indicated by the higher biomass of the three most dominant weeds. Consequently, the number of man-days needed to hand weed one hectare was three times more in Bongabon than in the field in which rice hull burning was done. Rice hull burning effectively reduced weed growth. Hence, the number of man-days required to hand weed a hectare of onion was reduced by 50%, consequently reducing weed control cost by 24 to 39% compared with the unburned plots. Weed control and yields obtained in plots treated with oxyfluorfen fb 1 HW yielded comparably with the farmer's practice and the weed-free check in both field studies. Our results show that with the current conventional tillage practice done by farmers, one herbicide application followed by one hand weeding controlled weeds just as effectively and yielded comparably with the farmer's practice The succeeding hand weeding operations were not necessary as the weeds which grew later in the season were effectively controlled by inter-row cultivation. This implies that in onion, a weed-free field is not necessary to get maximum yields.

With the correct choice of herbicide and proper timing of hand weeding operation, the farmer's practice can be reduced to one herbicide and one hand weeding. Results of these studies confirm the observations of previous field studies that one herbicide and one hand weeding can provide adequate control of weeds in Bongabon (Baltazar et al, 1997).

The results of these studies are short-term management strategies to provide immediate solutions to current weed problems with the use of agronomic approaches involving various combinations of herbicides, hand weeding, and cultural practices. These will be integrated with long-term management of perennial weeds like *C. rotundus*, which is dependent on the reduction of populations of its underground propagules, the tubers. A study on the dynamics of *C. rotundus* tuber population as affected by cultivation and herbicides is in progress. Also, the appearance of *C. rotundus* in increasing populations in rice (in our survey) provides an opportunity to control this weed during the rice season with selective measures that are not possible during the onion season. Studies of this nature are also now being initiated. Such methods make use of long-term strategies involving rotation systems approach, which is the major objective of our research.

Impacts

Our data confirm results obtained in year 5, showing that one herbicide application followed by one hand weeding can provide sufficient weed control with no significant reduction in yields. The total cost of weed control can be reduced by 50-60%, which means a lower cost of production and thus increased profits for farmers. This also provides comparison of chemical and cultural methods of weed control in the tropics vs. purely chemical methods in the US.

Networking Activities

S. K. DeDatta traveled to the Philippines in October 1998 to work with the weed science group on experimental protocols and reporting of research results.

Workshop Attended

Workshop to develop a training module on IPM in Rice-Vegetable Cropping Systems held at PhilRice in July, 1999.

Publications and Presentations

Baltazar, A.M., E.C. Martin, M. C. Casimero, F.V. Bariaun, S.R. Obien and S.K. De Datta. 1999. Agro-ecological approaches to managing weeds in rice-onion cropping systems. Paper presented during the 30th Pest Management Council of the Philippines held at the Philippine Rice Research Institute, Maligaya, Munoz, Nueva Ecija 4-6 May 1999. **(Best Paper Award for Weed Science)**

Baltazar, A.M., E.C. Martin, M. C. Casimero, F.V. Bariaun, S.R. Obien and S.K. De Datta. 1999. Major weeds and dominance patterns in rainfed rice-onion cropping systems. Phil. Agricultural Scientist. 82(2): 167-178.

Project Highlight

Field studies to evaluate complementary/integrated management strategies against weeds in onion following rice in rice-onion cropping system showed that the cost of farmer's weed control practices can be reduced by 50% from one herbicide application followed by three hand weedings to one herbicide application and one hand weeding without reducing weed control efficacy and onion yields.

Potential of Nuclear Polyhedrosis Virus (NPV) and *Bacillus thuringiensis* (Bt) for *Spodoptera* Control in Yellow Granex Onion

[Microbial Control of *Spodoptera* in Onion]

Investigators: L.E. Padua[1], A.C. Lapus[1], V.P. Gapud[2], C.V. Pile[2], B.E. Santiago[2], N.S. Talekar[3], V.F. Recta[4], and E.G. Rajotte[4]

Abstract

Microbial field experiments for 1999 dry season saw the emergence of *Helicoverpa armigera* as a new pest of onion in addition to *Spodoptera litura*. Since the onion plants were also damaged by *H. armigera*, the larval counts of both species were combined.

Larval densities on onion from the Bongabon Demo Farm showed lowest counts in plots treated with NPV alone and NPV+Bt, followed by Bt plots and Lambda-cyhalothrin (Karate) plots. Although the differences among these treatments did not appear significant, they are better than the untreated control plots. The same trend was also observed for the San José site, except that only Bt-treated plots had significantly lower larval counts compared to untreated control plots during the last week of sampling.

The degree of onion leaf damage in Bongabon is the same for the treated and untreated control plots. However, NPV-treated plots in San Jose had the lowest leaf damage and were significantly different from both the Lambda-cyhalothrin and untreated control plots.

Onion yields were highest in NPV-treated plots in both Bongabon and San Jose. In Bongabon, yield differences among the treatments were not significant, but they were better than the untreated control. NPV-treated plots in San Jose, however, differed significantly to the Lambda-cyhalothrin and untreated control plots.

Objectives

- To mass produce NPV-CRSP for field trials in combination with Bt.
- To develop a better formulation for NPV.
- To evaluate the efficacy of NPV-CRSP against *S. litura*.
- To continue field trials using NPV-CRSP and Bt as microbial control agents against *S. litura*.

IPM Constraints

The absence of alternatives to insecticides in controlling *S. litura* in onions has left farmers with no option but to use insecticides. The study on microbials is expected to provide other options for the farmers in managing *S. litura*.

Research Methods

The wettable powder formulation of NPV-CRSP developed in 1998 at the Insect Pathology Laboratory in U.P. Los Baños was used for the 1999 dry season field experiments replacing the crude suspension. Mass rearing of *S. litura* in the laboratory was continued to provide for the mass production of NPV-CRSP needed for the experiments and bioassay studies.

The concentration of the microbial treatments Bt alone, NPV alone and NPV+Bt was raised to 40 grams wettable powder per liter of water from the previous 20 grams/liter. Likewise, the sampling size was increased from 10 to 20 plants per plot with 4 replications per treatment. A shift from daytime sampling to night hours was also proposed to reflect the actual *Spodoptera* population. A farmer's field in Palestina, San Jose and a field in the Demo farm in Bongabon, Nueva Ecija were used to compare the effects of the microbial treatments and Lambda-cyhalothrin application (farmers' practice) on cutworm larval densities and onion yields. Each treatment was set up in RCBD using 4 replicated plots measuring 4m x 5m each. Treatments were applied four times at bi-weekly intervals. Monitoring of larval populations was also done bi-weekly.

[1] University of the Philippines Los Baños
[2] Philippine Rice Research Institute
[3] AVRDC
[4] Penn State University

The degree of onion leaf damage caused by larval feeding among the treatments was measured by taking the percent of leaves damaged per plant, every two weeks starting 4 weeks after transplanting. Onion yields were also recorded after harvest.

Results

NPV-CRSP was mass-produced in the laboratory. Out of the six kg wettable powder formulated with 6.79 x 10^8 polyhedral inclusion bodies (Pubs) per gram, 3.8 kilograms were used for the microbial field experiments. A 2-kg WP (in addition to 1 liter crude extract) was applied as a blanket spray to minimize the effects of insect damage on the weed and plant pathology field experiments. Currently, a total of 3 kg NPV crude extract have been produced for future field experiments and for bioassay studies on *S. litura*, *S exigua* and *H. armigera*, which will be the focus of next year's activities.

Polyhedral inclusion bodies (PIBs) of 25 NPV-infected larvae were quantified/estimated with an average count of 3.61 x 10^8 PIBs per larva for the third instar. Estimation of PIBs for the 4th and 5th instar larvae will be done next year.

Initial bracketing of NPV-CRSP for the first (1 - day old), second (3-day old) and third (6-day old) instar larvae of *S. litura* is near completion in preparation for the determination of the median lethal concentration (LC_{50}). Initial findings show significant larval mortalities on the fourth and fifth day of exposure of the insect to treated diet. Bioassay of the NPV Indian isolate and semi-purified NPV-CRSP will follow.

The comparative effects of Bt product, NPV-CRSP crude extract and Lambda –cyhalothrin on *S. litura* + *Helicoverpa* larval populations from farmer's field in NOGROCOMA Demonstration Farm, Bongabon, Nueva Ecija are shown in Table 1. Since the onion plants were also damaged by *H. armigera*, the larval counts of both species were combined.

Table 1. Effect of *B. thuringiensis* product, NPV-CRSP wettable powder and L. cyhalothrin (Karate) on larval count (*S. litura* + *Helicoverpa*) per plant. Bongabon, Nueva Ecija, 1998-99 Dry Season.

Treatment	Mean No. of Larvae per Plant (n=20 plants)				
	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
Bt	.02	.01 u	.14 u	.29 u	.24 u
NPV	.02	.08 u	.10 u	.25 u	.22 u
NPV+Bt	.01	.01 u	.12 u	.29 u	.24 u
L. cyhalothrin (Karate)	.01	.04 u	.14 u	.29 u	.26 u
Untreated Control	.00	.29	.49	.90	.79
ANOVA Results					
MS for Treatment	.0004	.054	.106	.310	.240
MS for Error	.0008	.016	.019	.017	.013
p-value for F-test	.691	.013	.009	.000	.000

[u] Significantly different from untreated control, using LSD test at P = 0.05; WAT – weeks after transplanting

Cutworm larval densities remained relatively low during the 1999 season in Bongabon despite the increased sample size from 10 to 20 plants per plot and per treatment. Increasing the concentration of the microbial treatments to 20-40 g/L likewise showed no significant advantage of microbials over insecticide applications, yet they are comparable. One problem identified was the widely spaced sampling intervals for all treatments. As observed during one of the field visits, dead larvae were recovered from the treated plots 4 days after spraying. This was also confirmed from initial bioassay studies of NPV-CRSP where high larval mortality was recovered during the 4th to 5th day after exposure to treated diet. Furthermore, *S. litura* larvae were observed to be quite mobile, hence, larval movement from one plot to another was possible owing to the close distance (one meter border) between plots. The proposed night sampling did not materialize due to security reasons. However, univariate ANOVA applied on the results from each sampling date show that the larval counts from all treated plots are significantly lower than those from the untreated control plots from weeks 6 through 12. The same results were obtained for the Palestina site, except for the last week of sampling, when only Bt-treated plots had significantly lower larval counts compared to untreated control (Table 2).

Table 2. Effect of *B. thuringiensis* product, NPV-CRSP wettable powder and L. cyhalothrin (Karate) on larval count (*S. litura* + *Helicoverpa*) per plant. San Jose, Nueva Ecija, Philippines, 1999 Dry Season.

Treatment	Mean No. of Larvae per Plant (n=20 plts)			
	4 WAT	6 WAT	8 WAT	10 WAT
Bt	.01	.06 u	.15 u	.08 u
NPV	.02	.19 u	.04 u	.14
NPV+Bt	.01	.11 u	.11 u	.15
Karate	.00	.26 u	.34 u	.15
Untreated Control	.00	.81	2.80	.20
ANOVA Results				
MS for Treatment	.0003	.368	5.627	.008
MS for Error	.0006	.080	2.658	.007
p-value for F-test	.747	.018	.141	.366

[u] Significantly different from untreated control, using LSD test at .05 level; WAT – weeks after transplanting

In Bongabon, the results of leaf damage from all five sampling dates showed no significant differences due to treatment. However, univariate ANOVA applied on the results from each sampling date showed that there were differences toward the later part of the season (Table 3). In San Jose, only NPV-treated plots were significantly different from the Lambda-cyhalothrin-treated and untreated control plots 8 weeks after transplanting (Table 4). Nevertheless, leaf damage levels for both sites were not impressive enough to show any substantial impact on onion yields. The great disparity in yields between San Jose and Bongabon sites appears to be influenced by other variables, e.g., soil properties, the cultivation techniques involving rice hull burning, planting density, and incidence of soil-borne diseases, particularly pink root, and root-knot nematodes. Onion yields were highest in NPV-treated plots in both the Bongabon Demo Farm and in San Jose. Although the yield differences among treatments in Bongabon were not significant, yields were better than in the untreated control plots. Yields from NPV-treated plots in San Jose, however, were significantly higher than those in the Lambda cyhalothrin and untreated control plots (Table 5).

Table 3. Extent of leaf damage from five treatments observed over five sampling periods, Bongabon, Nueva Ecija, 1998-99 Dry Season.

Treatment	Mean percent leaf damage (n=20 plants)				
	4	6	8	10	12
Bt	0.85	11.65	14.70	18.25	20.30
NPV	0.32	16.42	16.48	14.15 u	18.22 u
NPV+Bt	0.32	14.58	12.98	19.20	17.75 u
Karate	0.42	17.45	16.78	17.50	19.82
Untreated Control	1.20	16.85	17.05	18.95	21.45
ANOVA Results					
MS for Treatment	0.60	22.10	11.95	16.72	9.24
MS for Error	1.25	30.77	5.67	5.76	2.09
p-value for F-test	0.75	0.60	0.14	0.07	0.02

[u] Significantly different from untreated control, using LSD test at .05 level.

Table 4. Percent onion leaf damage from five treatments observed over four sampling periods. San Jose, Nueva Ecija, 1998-99 Dry Season.

Treatment	Weeks After Transplanting (WAT)			
	4	6	8	10
Bt	1.65	1.92 u	5.50	7.15
NPV	2.45	3.62 u	2.92 u k	5.60
NPV+Bt	0.98	2.92 u	4.10	5.55
Karate	2.22	3.40 u	5.72	5.95
Untreated Control	2.48	6.75	6.18	7.30
ANOVA Results				
MS for Treatment	1.64	13.15	7.21	2.90
MS for Error	2.46	1.86	3.13	3.47
p-value for F-test	0.63	0.004	0.12	0.53

[u] Significantly different from untreated control, using LSD test at .05 level
[k] Significantly different from Karate (chemical control), using LSD test at .05 level.

Table 5. Effect of *B. thuringiensis* product, NPV-CRSP wettable powder and Lambda cyhalothrin on onion yields (t/ha). Bongabon and San Jose, Nueva Ecija, 1999 Dry Season.

Treatment	Bongabon Site	San Jose Site
Bt	21.45	89.60 u
NPV	26.25 u	97.50 u k
NPV+Bt	25.78 u	87.90
Karate	24.92 u	80.32
Untreated Control	19.28	77.90
ANOVA Results		
MS for Treatment	36.82	244.56
MS for Error	6.47	52.50
p-value for F-test	0.008	0.017

[u] Significantly different from untreated control, using LSD test at .05 level.
[k] Significantly different from Karate (chemical control), using LSD test at .05 level.

Impact

It has been shown that NPV and Bt can be viable alternatives to chemical insecticide use. Thus, it would greatly benefit onion farmers who are dependent on chemical insecticides for control of cutworm. Direct effects are reduced pesticide use, better health of farmers, and sustainable *Spodoptera* management. In addition, farm-produced NPV will cut down on cost of crop protection by farmers. As a result, the market quality of their onion produce will be greatly enhanced by their low insecticide residue levels, thereby meeting the export requirements of foreign markets.

Networking Activities

Poster/Paper Presentations

1. A paper describing results of IPM-CRSP studies on *Spodoptera* management using microbials in rice-onion systems was presented at the annual conference of the Pest Management Council of the Philippines held in May 4-6, 1999 at PhiRice, Munoz, Nueva Ecija.

2. Presented a poster entitled: "Potential of Bt+NPV for the Control of *Spodoptera* on Onions in Central Luzon, Philippines," during the joint annual meeting of the Entomological Society of America and Phytopathological Society of America held November 8-12, 1998 at Hilton Hotel, Las Vegas, Nevada, USA.

Networking

E. Rajotte traveled to PhilRice in October 1998 to evaluate research results and participate in planning for Year 7 experiments.

Research Information

Prepared three (3) fact sheets on the Pests of Onion and their Management for adoption by onion farmers.

Publications and Presentations

L.E. Padua, V.P. Gapud, E.C. Martin, C.V. Pile, B.A. Santiago, N.S. Talekar, G.F. Recta, E.G. Rajotte and A.C. Lapus. 1999. Use of Nuclear Polyhedrosis Virus (NPV) and *Bacillus thuringiensis* (Bt) for *Spodoptera* control in Yellow Granex Onions. Philippine Entomologist. (In Review).

Presented IPM-CRSP Research/Technologies in collaboration with NOGROCOMA members on July 30, 1999 at PhilRice, Maligaya, Muñoz, Nueva Ecija and participated in by NOGROCOMA members and Barangay Captains of Bongabon, Nueva Ecija.

Training Output

Took part in the training entitled, "Training for Agriculture Technicians and Farmer-Leaders on Rice-Vegetables with Emphasis on IPM" on August 2-6, 1999 at PhilRice, Maligaya, Muñoz, Nueva Ecija.

Project Highlights

- Six kilograms of NPV-CRSP wettable powder have been produced and were used for microbial field experiments and as blanket spray for the weed and plant pathology experiments. An additional three (3) kilos of NPV are being kept in cold storage for future use.
- Completed the final draft of three (3) fact sheets on Insect Pests of Onion (Common cutworm, *S. litura*; Onion armyworm, *S. exigua* and Onion leaf miner, *Liriomyza sp.*) and their Management.
- Quantified polyhedral inclusion bodies (PIBs) of twenty-five (25) NPV-infected 3rd instar larvae of *S. litura* with an average count of 3.61×10^8 PIBs per larva.
- *H. armigera* emerged as a new pest of onion in both Bongabon and Palestina sites for the 1999 dry season.
- The combined larval densities of *S. litura* and *H. armigera* did not differ among the treatments but were significantly different from the untreated control plots in both Bongabon and San Jose sites.
- Onion yields were highest in NPV-treated plots, for both Bongabon and San Jose, but not significantly different among the treatments in Bongabon. NPV-treated plots in San Jose differed significantly from Lambda-cyhalothrin and untreated control plots.
- Differences in cutworm larval densities, level of onion leaf damage, and onion yields between San Jose and Bongabon are attributed to planting density, soil type and the presence of other lepidopterous larvae, e.g. *H. armigera.*
- NPV alone and NPV+Bt are potential alternatives to insecticides for managing *Spodoptera litura* and *H. armigera* in onions.

Effects of Rice Hull Burning and Deep Plowing on Soil-Borne Diseases and the Rice Root Knot Nematode in Rice-Onion Cropping Systems, with Supplemental Nematode Control Using Soil Amendments

Investigators: R.T. Alberto[1], G. Galut[2], E.B. Gergon[2], C. Ravina[2], V.L. Judal[2], M. Casimero[2], E.C. Martin[2], F. Bajo[2], A. Baltazar[3] and S.A. Miller[4]

Abstract

Burning of rice hulls approximately 15 cm thick significantly reduced soil microbial populations and incidence and severity of pink root in onion. Application of compost did not result in significant effects on the soil microbial population, or on incidence and severity of pink root of onion.

Deep plowing and burning rice hulls up to 30 cm deep significantly reduced initial nematode population densities. Plants grown in chicken and cow manure-treated plots consistently gave the lowest number of galls, egg masses and population in the roots and soil but effects were not comparable with the nematicide, Nemacur. Vesicular-arbuscular mycorrhizae (VAM) combined with chicken and cow manure applied 2 and 4 weeks before the onset of nematode significantly reduced the number of galls, egg masses and population of the nematode, comparable with Nemacur. VAM infection was significantly higher in this treatment suggesting that interference may be a mechanism of reduction in nematode development.

Out of the 27 plant species evaluated for their nematicidal activity, 13 consistently showed high activity against *M. graminicola*. These include neem tree (*Azadirachta indica*), papaya (*Carica papaya*), Euphorbia (*Euphorbia heterophylla*), and kuyot (*Dioscorea hispida*). Extracts were potent even at 25 percent concentration.

The use of *Tagetes* sp., *Crotalaria incana*, and *C. mucronata* significantly reduced the number of galls and nematode population in the roots and soil. Likewise, a 2-month fallow period effectively reduced nematode population in the soil.

Objectives

1. To determine the effectiveness of rice hull burning and compost in controlling pink root and other soil-borne diseases of onion.

2. To assess the effect of rice hull burning, deep plowing, VAM, animal manure, and plant species with nematicidal properties on population levels of root-knot nematode.

3. To determine the effect of rice hull burning and compost in onion yield.

Research Methods

1. Soil-borne fungal diseases

Rice hulls 6 inches thick were burned on a 5m x 12m plot known to be infested with the pink root pathogen, *Phoma terrestris,* and the root knot nematode (*Meloidogyne graminicola*). A plot was marked off without rice hulls next to the burned area. The plots were spaced 0.5m apart. Each plot was sub-divided into two 5m x 6m subplots; either subplot with or without compost. The experiment was replicated four times, with replicates spaced 1 m apart. Soil and roots samples were collected at 30, 60 and 90 DAT for pink root and nematode counts. All the plots were managed according to farmer's practice. Yields were determined from a 2m x 3m-area at the center of each plot.

2. Nematode Control

a. Rice hull burning and deep plowing (San Jose study site)

The experimental plots were set up in a farmer's field infested by rice root-knot nematodes and laid out in split-split-split plot design with 2 main plots, sub-plots, and 2 sub- sub- plots with 5 replications.

The main plots were: (1) standard plowing, 4-6 cm deep, using a carabao-drawn plow and (2) deep plowing, 12 cm

[1] Central Luzon State University
[2] Philippine Rice Research Institute
[3] University of the Philippines Los Baños
[4] Ohio State University

deep, attained by two plowings using a motorized rotavator. The sub-plots were covered with: (1) 15 cm-thick rice hulls and (2) 25 cm- thick rice hulls distributed on the surface of the plots and burned for three days before plowing, and one sub-plot (3) without rice hull cover. The sub-plots were further divided into two, one plot was provided with compost in addition to recommended fertilizers while the other plot received inorganic fertilizer alone. Each sub-sub plot measured 30 m^2.

The initial nematode population densities of each plot were determined four days after rice hull burning by taking soil samples at different depths of 0-10 cm, 11-20 cm, and 21- 30 cm. Ten soil cores grouped into one sample were taken per plot. One month after transplanting (P1), ten root and soil samples from the rhizosphere were collected at random within the sampling area. These were followed by samplings at mid-season (Pm) and at harvest (Pf).

The percentage of root galling was assessed per plant. The roots were cut into segments 1-cm long, mixed, and 3-gram roots were processed for nematode densities by incubating in water for three days. Soil samples were processed using a modified Baermann funnel technique. At harvest, onion bulbs were sorted by the farmers into small and large sizes and weighed.

b. Nematode (Bongabon study site)

The experiment was a repetition of our experiment last season. Ten 5 m x 6 m plots were marked in a nematode-infested field in Bongabon Demo farm. The plots were arranged in a split plot randomized complete block design with five replications. In each replication, one of the plots remained free of rice hull while the other plots as well as the rest of the field were covered with rice hull 15 cm thick. These plots were further divided into two, and compost plus complete fertilizer was applied to one plot while the other plot received only complete fertilizer. Onions were transplanted according to farmers' standard practice. Nematode densities in each plot were evaluated before transplanting, one month after transplanting, at mid-season of the crop, and at harvest. At each sampling time, five 200 cm^3 soil samples and ten root samples were collected at random from each plot. In addition, onion yields were determined from both burned and unburned plots.

3. Biofertilizers

Different biofertilizers as possible soil amendments for suppression of *M. graminicola* were evaluated in the field and in the greenhouse following randomized complete block design with five replications. The field experiment was conducted at the Bongabon Demo farm in 5 x 6 m plots using the onion cv. Yellow Granex. The biofertilizers used and their rates of application based on the manufacturer's recommendation were as follows: Rhizo-N, 200 kg/ ha; Biogreen or Cocorich, 5,000 kg/ha; DSAC compost, 5,000 kg/ha; BIO-N, 1.5 kg/ha plus 500 kg of 14-14-14/ha, and VAM (vesicular arbuscular mycorrhizal fungi) at 240 kg/ha plus 500 kg of 14-14-14/ha. Complete fertilizer (14-14-14) at 10 bags/ha was applied as control. All treatments were broadcast on the field prior to transplanting except for Bio-N. Bio-N was mixed in water and the seedlings were soaked in this solution for 30 minutes one hour before transplanting in Bio-N treated plots. Root and soil samples for nematode extraction were collected in the same manner with crop rotation experiment for three times during the duration of the experiment.

A greenhouse experiment using same treatments, rates, and methods of applications with addition of chicken manure was also done in metal pans, 1 x 1 meter filled with *M. graminicola*-infested soil. Seedling emergence, heights, and number of nematodes in the roots after 30 and 45 days of exposure to *M. graminicola* were determined.

4. VAM and Animal Manure

The animal manure (cow, chicken, sheep, goat and pig) were first air dried in the screenhouse and their efficacy in suppressing the root-knot nematode was evaluated by applying 10 tons/ha in 8-inch diam clay pots filled with sterilized soil. To infest the soil, 300 eggs of *M. graminicola* were inoculated. A nematicide (Nemacur) was used for comparison using 1.5 kg ai/ha. In the second experiment, different rates (2 tons, 5 tons and 10 tons/hectare) of the chicken and cow manure were evaluated. In the third experiment VAM was combined with chicken and cow manure. 50 g of VAM was applied in combination with cow and chicken manure using 5 tons per hectare.

Time of application of manure combined with VAM (simultaneous, 2 weeks after nematode inoculation, 1 month after nematode inoculation, 2 weeks after VAM and manure application, 1 month after VAM and manure application) was likewise evaluated.

Data gathered were top and root weights of green onion, numbers of galls and egg masses produced, population of nematode in the roots and in 300 g of soil. VAM spore counts and percent VAM infection (number of infected root segments intersecting a line divided by the total number of root segments intersecting a line times 100) was also determined.

5. Antagonistic Plants

Leaves of 27 plant species were extracted using mortar and pestle. Five ml of the extract was placed in glass vials and approximately 25 larvae of the nematode were dipped in the extract for 24 hours. Then the extracts with the larvae were poured in one-week old rice seedlings for bioassay. The number of galls produced was counted under the microscope after 35 days. A control plant was provided.

In another set of experiment, the effect of different concentrations (100%, 75%, 50%, and 25%) of selected plant extracts was evaluated. The same procedure was followed as in the first experiment.

6. Soil Amendments

Micro-plots of 2.4 x 0.75 meters were prepared and inoculated with 1,000 eggs of *M. graminicola* and later sown with 30 seeds of rice (var. UPLRi5). The rice plants were allowed to grow in the micro-plots for 60 days. Rice plants were harvested and their galled roots together with the egg masses were evenly buried in the plots. Constant watering was done to enhance egg hatching and increase the nematode population in the micro-plots. After one week, seeds of *Crotalaria incana, C. mucronata, Tagetes* sp. and rice (UPLRi5) were sown in the micro-plots. A clean fallow treatment was included and the treatments were replicated three times. The plants were allowed to grow for 90 days. Sixty days after sowing, 10 plants from each of the micro-plots were sampled and the roots were washed carefully in running water and later cut into small pieces. From each root system, 5 grams were taken and the number of galls were counted and assayed for nematode larvae using the modified Baermann funnel method. Likewise, ten-200 g soil samples were taken from each plot and nematode larvae were extracted by the modified Baermann funnel method. The larvae extracted from the roots and soil were counted under the stereomicroscope with the aid of a hand tally counter. The same procedures were followed when plants were harvested at 90 days. There were two trials made for this experiment.

Results

1. Soil-borne fungal diseases

Burning rice hull of approximately 6 inches thick in the field significantly reduce the pink root disease incidence and severity in onion. At 90 days after transplanting, the fungal colony forming units (CFU's) in burned plots were significantly lower than unburned plots due to the heat generated by the burning rice hull. Yields in burned plots were significantly higher than unburned plots, which may in part be attributed to the production of silicon and potash, which improve soil fertility (Deanon, personal communication). The application of compost had no significant effects on the total culturable fungal population, disease incidence and severity, or the yield.

2.a. Rice hull burning and deep plowing (San Jose study site)

Deep plowing and rice hull burning up to 30 cm deep significantly reduced the initial nematode population densities. The level of reduction between the two depths of rice hulls burned was not significantly different. Using standard plowing, the number of nematodes in the soil detected at different depths was not significantly different in each plot. Few juveniles of *M. graminicola* survived heat treatment from burning 30 cm thick rice hulls and deep plowing (Table 1).

Table 1. Effect of different depths of rice hulls burned (RHB) on the population of *Meloidogyne graminicola* at different sampling depths four days after treatment.

Treatment	Depth of Sampling, cm		
	10	20	30
Deep Plowing/With Compost			
No RHB	19a	24a	10a
RHB, 15 cm	1b	0b	0b
RHB, 30 cm	0b	0b	0b
Deep Plowing/Without Compost			
RHB, 15 cm	3b	0b	0b
RHB, 30 cm	0b	1b	2b
Standard Plowing/With Compost			
No RHB	2a	0a	0a
RHB, 15 cm	1a	0a	1a
RHB, 30 cm	0a	0a	0a
Standard Plowing/Without Compost			
No RHB	1a	1a	3a
RHB, 15 cm	0a	5a	0a
RHB, 30 cm	0a	0a	0a

In a column under each main plot and depth of sampling, means followed by a common letter are not significantly different at the 5% level by DMRT.

The soil population of *M. graminicola* remained low up to two months after transplanting and greatly increased on the third month. On the other hand, nematode density in the roots started to increase on the second month (Table 2). The number of nematodes recorded at each sampling period, however, was not significantly different between treatments.

Plots with burned rice hulls gave significantly higher yields of Yellow Granex onions than unburned plots. Onion yield was higher in plots that received 30 cm thick rice hull than those plots with 15 cm thick burned rice hull although their differences were not statistically significant (Table 3). Likewise, yields from plots with or without additional compost were not different (Fig. 1). Deep tillage contributed to production of larger bulbs. Plots with burned rice hull and plowed up to 30 cm gave significantly greater number of large bulbs than plots free of rice hull and given standard plowing.

Table 2. Population density of *Meloidogyne graminicola* juveniles (J2) in the roots of onion plants at different time after transplanting.

Treatment	1 month after transplanting		2 months after transplanting	
RHB, cm	Deep Plow	Standard	Deep Plow	Standard
30	69 a	4 a	1248 a	1079 a
15	32 a	32 a	537 a	395 a
0	55 a	21 a	669 a	440 a

Table 3. Effects of tillage and thickness of rice hull burned on the yield of onion.

Treatment	Total yield/30 m2 (kg)		
RHB, cm	With Compost	Without Compost	S-mean
30	152 a	145 a	148 a
15	134 ab	127 a	130 a
0	102 b	91 b	97 b
	Deep Plow	Standard	
30	69 a	77 a	73 a
15	56 a	51 ab	53 a
0	39 a	19 b	29 b

In a column under each main plot and depth of sampling, means followed by a common letter are not significantly different at the 5% level by DMRT.

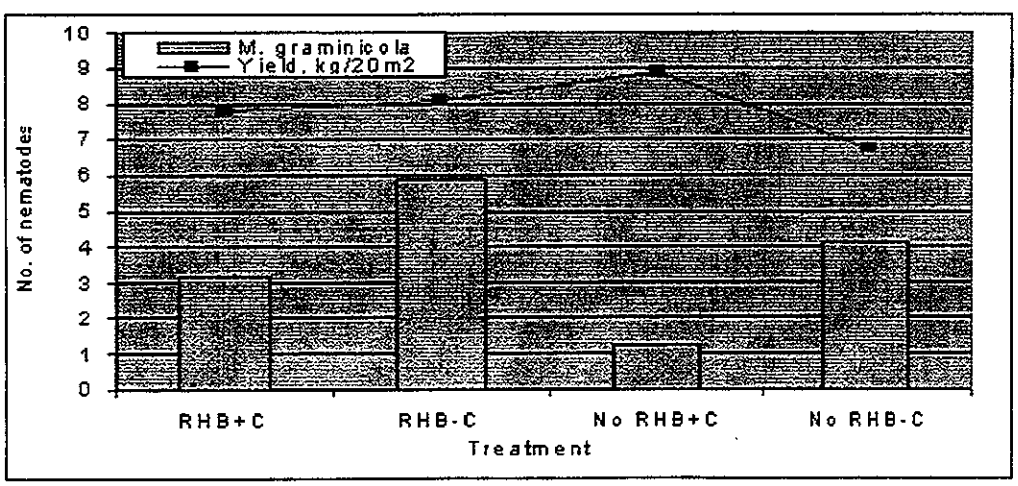


Fig 1. Effect of rice hull burning on the population of *Meloidogyne graminicola* and yield of Yellow Granex onion. Bongabon, Nueva Ecija.

b. Nematode (Bongabon study site)

Heavy infestation of armyworm occurred throughout the farm that resulted to unreliable yield data. The addition of Sagana 100 did not provide additional benefits to the plants especially on yield increase.

The results of the experiment this season was quite dissimilar or inconsistent with our previous data. This could be attributed to some changes made in the protocol where only 10 cm thick rice hull were applied on the surface instead of 15 cm. The yields obtained were low and no differences were observed among the treatments.

3. Biofertilizers

Last season, our greenhouse studies showed that VAM gave the highest seedling incidence and tallest seedlings, and lowest population densities of *M. graminicola* in the field using Yellow Granex and Tanduyong onions. When we repeated the experiment in the greenhouse, VAM was comparable with the control in terms of seedling emergence and plant height 30 and 45 days after inoculation but it remained to be the most effective in reducing root knot infection in Yellow. Our field study, although it turned out to be poor, again showed the same trend observed last season. The lowest population density of *M. graminicola* was obtained in VAM-treated plots (Fig. 2).

4. VAM and Animal Manure

Table 4 showed that chicken and cow manure were effective in reducing root galls, egg masses and nematode population in roots and soil compared with the other three animal manure but not comparable with the nematicide. Five tons of chicken and cow manure (Table 5) gave significant reduction in the development of the nematode compared to using only 2 tons/ha. No significant differences were observed compared to using 10 tons/ha. In most cases combining chicken manure with VAM (Table 6) gave significant effects on the development of the nematode. Applying VAM and chicken manure 2 and 4 weeks before nematode inoculation significantly affected the its development and were comparable to the nematicide.

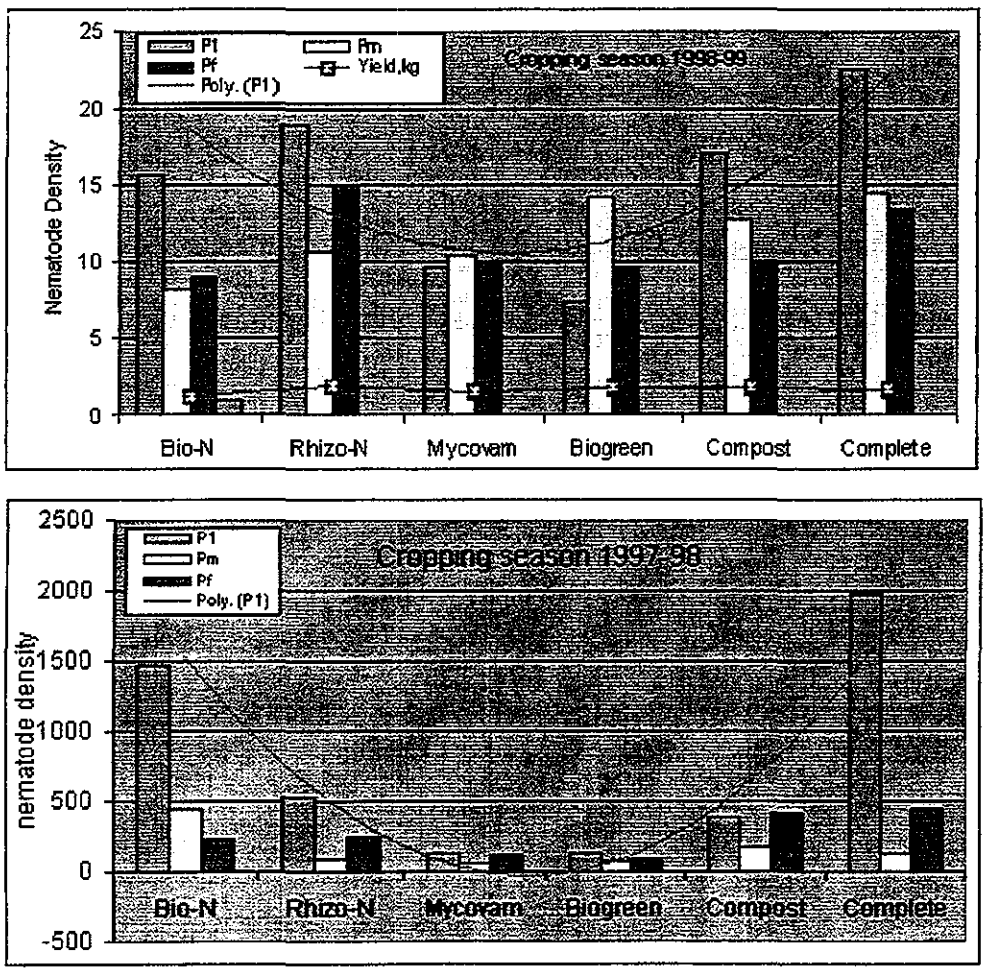


Fig. 2 Effect of different biofertilizers on the population of *Meloidogyne graminicola* and yield of Yellow Granex. Cropping seasons 1997-1998 and 1998-1999, Bongabon, Nueva Ecija.

Table 4. Effects of different animal manures on the growth of green onion and *Meloidogyn graminicola* population. [1]

Treatments	Top weight[2]	Root weight	Galls	Egg masses	Population in roots	Population in soil
Uninoculated	7.6 b	1.6 abc	0.0 c	0.0 c	0.0 d	0.0 d
Nematode alone	7.5 b	1.2 c	97.4 a	108.0 a	116.0 a	129.0 a
Chicken manure	10.3 a	2.0 ab	46.0 b	50.4 b	55.6 c	67.4 c
Cow manure	11.1 a	2.4 a	38.2 b	58.0 b	50.6 c	69.2 c
Sheep manure	10.2 a	2.2 ab	83.6 a	90.4 a	85.8 b	99.2 b
Goat manure	10.1 a	2.1 ab	79.2 a	83.4 a	91.0 ab	110.0 ab
Pig manure	9.5 a	2.1 ab	89.2 a	95.4 a	94.0 ab	111.2 ab
Nemacur	7.8 b	1.5 bc	11.2 c	9.2 c	17.8 d	21.6 d

[1] 5 g root samples was taken per plant for galls, egg masses and population in roots; 300 g soil sample per pot [2] Numbers with the same letters are not significant using DMRT.

Table 5. Effects of different rates of cow and chicken manures on growth of green onion and *M. graminicola* population.

Treatments	Top weight	Root weight	Galls	Egg masses	Population in roots	Population in soil
Uninoculated	13.0 c	3.7 cd	0.0 d	0.0 d	0.0 f	0.0 e
Nematode alone	12.0 c	2.7 d	70.8 a	80.8 a	246.0 a	135.0 a
Chicken manure						
2 tons/ha	23.3 b	4.9 bc	42.3 b	54.0 ab	129.3 bc	88.0 b
5 tons/ha	30.7 a	7.6 a	22.5 c	35.3 bc	47.8 e	44.0 cd
10 tons/ha	31.2 a	7.9 a	20.0 c	24.3 bcd	67.3 e	39.5 cd
Cow manure						
2 tons/ha	16.5 c	4.2 cd	61.5 a	74.5 a	165.0 b	87.8 b
5 tons/ha	26.9 ab	6.3 ab	30.5 bc	36.5 bc	128.5 bc	61.5 bc
10 tons/ha	24.4 b	6.6 ab	27.8 bc	32.0 bcd	108.3 cd	52.0 cd
Nemacur	16.7 c	3.0 d	16.0 c	16.3 cd	42.3 e	21.8 de

[1] 5 g root samples was taken per plant for galls, egg masses and population in roots; 300 g soil sample per pot
[2] Number with the same letters are not significant using DMRT.

Table 6. The effect of combining VAM with cow and chicken manure on growth of onion and *Meloidogyne graminicola* population.[1]

Treatments	Top weight	Root weight	VAM spore count[2]	% VAM infection[3]	Galls	Egg masses	Population in roots	Population in soil
Uninoculated	9.1	2.5	0.0 d	0.0 d	0.0 d	0.0 d	0.0 c	0.0 d
Nematode Alone (N)	9.5	2.8	0.0 d	0.0 d	42.3 a	58.3 a	81.9 a	143.1 a
VAM alone	12.0	3.3	71.3 bc	75.8 bc	0.0 d	0.0 d	0.0 c	0.0 d
N + VAM	10.0	3.6	57.3 c	61.3 c	23.5 b	23.0 b	37.8 b	46.8 b
N + VAM + Cow manure	10.0	3.2	76.0 b	77.8 b	13.0 c	17.5 bc	24.3 b	26.1 c
N + VAM + chicken manure	10.9	3.5	92.3 a	82.8 a	5.0 d	4.8 cd	9.0 c	21.0 cd
Nemacur	9.2	3.5	0.0 d	0.0 d	1.0 d	1.0 d	2.0 c	13.9 cd

[1] Numbers with same letters are not significantly different at P = 0.05 using DMRT.
[2] VAM spores were determined from 50 g soil sample and extracted using Allen et al. (1979) method.
[3] VAM infection was assessed from 100 (1 cm) root segments per plant using the Gridline Intersect Method of Giovannetti and Mosse (1980)

5. Antagonistic Plants

Thirteen plant species showed high nematicidal activity against *M. graminicola*. No galls were formed in the roots of rice seedling 35 days after inoculation of the nematode dipped in the extract for 24 hours. Neem tree, Papaya *Euphorbia*, and Kuyot showed potential against the nematode because their extracts were still potent even at 25 percent concentration (Table 7).

6. Soil Amendments

No galls were observed on *Crotalaria* species and *Tagetes* 60 and 90 days after planting in the infested micro-plots suggesting that they are either antagonistic or non-host plants to the rice root-knot nematode. Two compounds [a-terthienyl and 5-(3-buten-1-ynyl)-2,2'-bithienyl] from *Tagetes* were found effective to several nematodes including root-knot species. The alkaloid monocrotaline in *Crotalaria* may be inhibitory to nematodes (Chitwood, 1993). Nematode density in the soil was tremendously reduced by the treatments. The clean fallow treatment had the lowest nematode density in the soil 60 and 90 days after transplanting. This was expected since the plots were weeded and turning the soil may have profound effect on the nematode larvae due to the heat of the sun. The result of this micro-plot experiment in two trials confirmed the earlier results from the pot experiment using the same treatments.

Table 7. Number of galls produced in rice seedlings 24 hours after dipping the nematode larvae in the different plant extracts at different concentrations.

		Concentration (%)			
Plant Species	**Common name**	**100**	**75**	**50**	**25**
Azadirachta indica	Neem tree	0	0	0	0
Swetenia macrophylla	Mahogany	0	0	2.0	11.0
Crotalaria incana	Crotalaria	0	0	0.33	7.67
Tagetes erecta	Marigold	0	0	9.67	15.00
Carica papaya	Papaya	0	0	0	0
Euphorbia heterophylla	Euphorbia	0	0	0	0
Dioscorea hispida	Kuyot	0	0	0	0
Tinospora rumphii	Makabuhai	0	0	1.33	11.33
Inoculated control		20.67			

[1] Rice seedlings were replicated 3 times

Impacts

Along with reduction in pink root infection in onion, there was also reduction of the initial nematode population.

The use of chicken and cow manure alone at 5 tons per hectare can significantly reduced nematode development and population density in roots and soil. Combining chicken and cow manure with VAM can further reduced the nematode especially when VAM and the manure are applied ahead of the nematode. While we see the limitations of this method of managing the nematode especially the availability of manure this is an alternative method. Likewise small landowner farmers who grow onion can use this.

Plant extracts with nematicidal activity can be used as an alternative method against *M. graminicola*. This is feasible and more economical because these plants are abundant and locally available.

Networking Activities

Have helped plan, participated, acted as resource person and moderator in the following workshops:

- "Workshop on Cultural Management Practices and IPM for Vegetables". PhilRice, Munoz, N.E. July 14-15, 1999.
- "Training for Agriculture Technicians and Farmer Leaders on Rice-Vegetables with Emphasis on IPM". PhilRice, Munoz, N.E. August 2-6, 1999.
- S. Miller traveled to PhilRice in October 1998 and February 1999 to evaluate research results and participate in planning for Year 7 experiments.

Publications and Presentations

"Management of Soil-Borne Diseases in Rice-Vegetable Systems". 30th Annual Scientific Meeting and Convention, Pest Management Council of the Philippines, May 4-6, 1999. PhilRice, Munoz, Nueva Ecija.

"The Soil-Borne Diseases in Rice-Vegetable Systems". 30th Annual Scientific Meeting and Convention, Pest Management Council of the Philippines. May 4-6, 1999. PhilRice, Munoz, Nueva Ecija.

"Antagonistic Effects of Bacillus sp. (LEP 118) Against Soil-Borne Pathogens in Rice-Vegetable Systems". 30th Annual Scientific Meeting and Convention, Pest

Management Council of the Philippines. May 4-6, 1999. PhilRice, Munoz, Nueva Ecija.

"Management of Soil-Borne Diseases in Rice-Vegetable Systems". 21st Annual Scientific Meeting. National Academy of Science and Technology . May 4-6, 1999. Manila Hotel. Manila, Philippines.

"Bacterial Wilt of Eggplant Caused by *Ralstonia solanacearum*". Training for Agricultural Technicians and Farmer Leaders on Rice-Vegetable with Emphasis on IPM. August 2-6, 1999. PhilRice, Munoz, Nueva Ecija, Philippines.

"Diseases of Onion and Eggplant in Rice-Vegetable Systems". Training for Agricultural Technicians and Farmer Leaders on Rice-Vegetable with Emphasis on IPM. August 2-6, 1999. PhilRice, Munoz, Nueva Ecija, Philippines

Project Highlights

This study showed that soil sterilization through rice hull burning could significantly reduce the soil microbial population as well as the soil-borne pathogens resulting in low incidence and severity of pink root infection in onion.

Effects of Crop Rotation on Incidence of Pink Root Disease and *Meloidogyne graminicola* in Rice-Onion Cropping Systems

Investigators: R.T. Alberto[1], G. Galut[1], E.B. Gergon[1], C. Ravina[1], V.L. Judal[1], and S.A. Miller[2]

Abstract

A three-year study was conducted to determine the effects of rice-based cropping patterns and the most effective crop rotation scheme to suppress pink root disease incidence in rice-vegetable systems. Results showed that the use of pepper, rice and peanut as rotation crops reduces the incidence of pink root in onion. However, crop rotation did not effectively reduced nematode populations.

Objectives

1. To determine the effects of rice-based cropping patterns on the incidence of pink root disease and nematodes *Meloidogyne graminicola.*

2. To identify the most effective crop rotation scheme for reducing pink root disease and nematode populations in rice-vegetable systems.

Research Methods

1. Pink root disease

Four 4m x 5m plots were established in the field previously known to be infested with pink root and rice root knot nematode. All of the plots were planted with different crops based on the different rotation schemes formulated below. The set up was replicated 4 times. Ten onion plants and rhizosphere soil samples were collected per sampling (30, 60 and 90 DAT) for nematode and pink root assessment. All the plots were managed according to farmer's practice. The yields were taken from 2m x 3m area cut at the center of each plot at the end of the season. The experiment was conducted for three consecutive years.

Treatments (Rotation Schemes):

	Year 1		: Year 2		: Year 3	
	1	2	3	4	5	6
T1 -	Onion	Pepper	Rice	Onion	Peanut	Rice
T2 -	Peanut	Cucumber	Fallow	Pepper	Mungbean	Onion
T3 -	Mungbean	Pepper	Fallow	Onion	Peanut	Rice
T4 -	Onion	Fallow	Rice	Onion	Rice	Onion

2. Root-knot nematode

The crop rotation experiment was conducted with one of our farmer-cooperators in Bongabon, Nueva Ecija. Four different crop sequences were grown in 4 x 5 m plots with four replications in a randomized complete block design. The different crop sequences were: T1= onion-pepper-rice-onion-peanut-rice, T2= peanut-cucumber-fallow-pepper-mungbean-onion, T3= mungbean-pepper-fallow-onion-peanut-rice, and T4= onion-fallow-rice-onion-rice-onion. The field was irrigated and weeded when necessary. Fallow treatments were not maintained as clean fallow. The yield of each crop was measured on a 6 m^2 area in the center of each plot. Soil and root samples were taken one month after transplanting, at mid season of the crop, and one day before

[1] Philippine Rice Research Institute
[2] Ohio State University

harvest. The samples were processed in the laboratory for nematode extraction.

Results

1. Pink root disease

Initial data showed 70% and 100% incidence of pink root in onions with corresponding severity of 54% and 73%. Mungbean and peanut were not infected. When pepper, cucumber and rice were planted as rotation crops for two consecutive seasons, incidence levels of pink root were reduced to 9.9%, 8.9% and 14.2% in Treatments 1, 3 and 4, respectively. Consequently, the disease severity was also reduced to 45.6%, 42.2% and 58.9%, respectively. When again rotated with peanut, mungbean and rice, incidence of pink root was reduced to 30.0% in Treatment 2 and a slight increase of 22.5% from 14.3% in Treatment 4 with a corresponding decrease in disease severity of 24.8% and 19.6%, respectively. Treatment 4 was followed by fallow period, rice, onion, rice and onion in succession had the highest onion yield of 30.6 kg /10m plot in the fourth season and 22.5 kg /10m in the 6th season. Yield of 25.8 kg/10^2 was observed in Treatment 2. Onion yields in Treatments 2 and 4 were lower than the previous harvest because the crops were harvested two weeks ahead of schedule due to an approaching typhoon.

2. Root-knot nematode

The populations of *Meloidogyne graminicola* remained significantly lower in non-host crops such as peanut, mungbean, cucumber, and pepper than in onion or rice throughout the crop rotation experiment. This showed that they can reduce initial nematode population densities for the next crop. However, as observed in the first cropping season, the nematode population increased rapidly one month after transplanting when host crops such as onion and rice were planted. During the sixth cropping, nematode densities in the roots of onion grown after four resistant crops and a fallow period (cropping pattern 2) were not significantly different from those obtained in cropping pattern (CP) 4. The fourth cropping showed that yields of onion following pepper and a fallow period were significantly higher than those obtained after rice. However, in the sixth cropping, onion yields from CP 2 were not significantly different from those obtained in CP 4 (Table 1). The results indicated that crop rotation may not work effectively for *M. graminicola.*

Table 1. Cropping pattern and onion yields

Treatment	Cropping pattern					
	1	2	3	4	5	6
1	10a	2a	406a	8ab	3a	569a
2	6b	3a	15b	0b	7a	221ab
3	7b	2a	3b	11ab	3a	73
4	11a	3a	282a	17ab	9081b	130b

Impact

Reduction of pink root incidence in onion and improved yields and reduction of root-knot populations in onion crop and get higher yields.

Networking Activities

- "Workshop on Cultural Management Practices and IPM for Vegetables". PhilRice, Muñoz, N.E. July 4-15, 1999.
- "Training for Agriculture Technicians and Farmer Leaders on Rice-Vegetables with Emphasis on IPM". PhilRice, Muñoz, N.E. August 2-6, 1999.
- S. Miller traveled to PhilRice in October 1998 and February 1999 to evaluate research results and participate in planning for Year 7 experiments.

Publications and Presentations

"Management of Soil-Borne Diseases in Rice-Vegetable Systems," 30th Annual Scientific Meeting and Convention, Pest Management Council of the Philippines, May 4-6, 1999. PhilRice, Muñoz, Nueva Ecija.

"The Soil-Borne Diseases in Rice-Vegetable Systems," 30th Annual Scientific Meeting and Convention, Pest Management Council of the Philippines. May 4-6, 1999. PhilRice, Muñoz, Nueva Ecija.

"Antagonistic Effects of *Bacillus* sp. (LEP 118) Against Soil-Borne Pathogens in Rice-Vegetable Systems," 30th Annual Scientific Meeting and Convention, Pest Management Council of the Philippines. May 4-6, 1999. PhilRice, Muñoz, Nueva Ecija.

"Management of Soil-Borne Diseases in Rice-Vegetable Systems," 21st Annual Scientific Meeting. National Academy of Science and Technology . May 4-6, 1999. Manila Hotel. Manila, Philippines.

"Bacterial Wilt of Eggplant Caused by *Ralstonia solanacearum,* " Training for Agricultural Technicians and Farmer Leaders on Rice-Vegetable with Emphasis on IPM. August 2-6, 1999. PhilRice, Muñoz, Nueva Ecija, Philippines.

"Diseases of Onion and Eggplant in Rice-Vegetable Systems," Training for Agricultural Technicians and Farmer Leaders on Rice-Vegetable with Emphasis on IPM. August 2-6, 1999. PhilRice, Muñoz, Nueva Ecija, Philippines.

Project Highlights

The study showed that planting non-host crops of *Phoma terrestris* in rotation with onion can significantly reduce the disease pressure resulting in low incidence and severity of pink root infection. However, crop rotation did not seem to be effective against the root-knot nematode.

The Effectiveness of Trap Plants and Sex Pheromone Traps for *Spodoptera litura* Management

G.S. Arida[1], V.P. Gapud[1], C.V. Pile[1], B.E. Santiago[1], G.E. Balagot[1]
N.S. Talekar[2], and E. Rajotte[3]

Abstract

More than 35,000 eggs of *Spodoptera litura* were collected from castor plants planted around the field indicating that castor is an effective trap crop. However, the number of *S. litura* larvae and damaged leaves per onion plant were very low, which is probably why no significant differences were noted between plots with and without castor.

Sex pheromone traps caught moths of both species of *Spodoptera* even before seeding of onion in the field. Peaks in trap catches during the onion crop were followed in few days by peaks in the egg density of *S. litura* as monitored in castor plants. Initial results indicated that trend in sex pheromone trap catches could be a viable monitoring tool for the management of *Spodoptera* in onion.

Objectives

1. To determine if castor plant is an effective trap crop for *S. litura* management in onion field.
2. To correlate sex pheromone trap catches with eggs of *S. litura* and *S. exigua* populations in castor plants and number of larvae and its damage to onion.

IPM Constraints

Farmers normally spray the whole field when they notice damaged leaves due to defoliators like *S. litura*. An effective trap crop will reduce the area where intervention is to be directed and therefore will minimize insecticide use in onion. The lack of effective monitoring tools for efficient timing of intervention has added to insecticide misuse in onion.

Research methods

1. Trap Plant

Thirty-day-old seedlings of castor plants grown in plastic bags were planted around the designated plots, each measuring 5m x 10m in the four corners of the field. Plots with and without castor were arranged alternately with each plot replicated 4 times. Castor plants were monitored 3x a week for egg masses and larvae of *S. litura*. Collected egg masses were brought to the laboratory for egg counts. Damaged leaves and larval densities were monitored every week in onion up to 98 days after seeding (DAS).

2. Sex Pheromone

Three sex pheromone traps each for *S. litura* and *S. exigua* were installed in the field one month before seeding of onion in the study area. Castor seedlings grown in plastic bags from the greenhouse were transplanted in the study area to monitor egg masses of *Spodoptera*. Sex pheromone traps were monitored 3x a week and egg masses were counted and collected on the same period. Collected egg masses were brought to the laboratory for counting and recording. Larvae of *Spodoptera* and their damage to onion plants were recorded every week from 20 randomly selected plants per plot replicated 3 times.

Research Results

1. Trap Plant

Larval densities were slightly higher in plots without castor plant up to 70 DAS. It was noted that several species of defoliators were present in the field although their populations were low. Highest larval density was recorded at 0.6 larva/plant.

Generally the number of damaged leaves and larvae in both treatments were too low to cause significant loss in yield (Fig. 1). Total count of *S. litura* eggs collected throughout the season in all the castor plants exceeded 35,000 indicating that castor plant is effective in trapping the insect for oviposition. Mean yield from both treatments showed no significant differences.

[1] Philippine Rice Research Institute
[2] AVRDC
[3] Penn State University

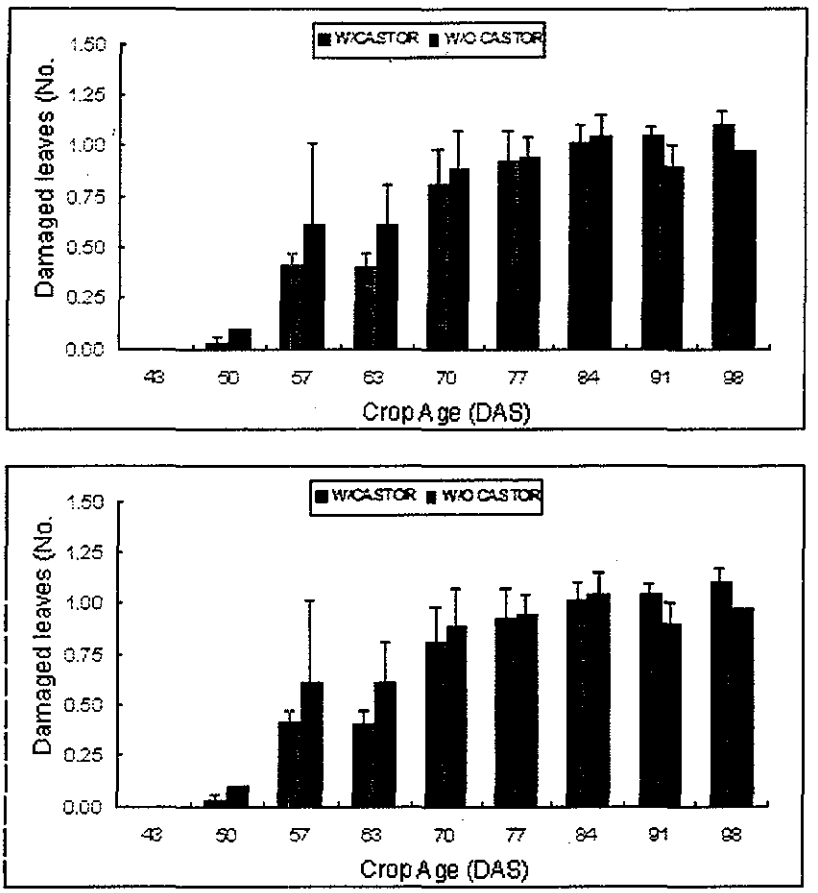


Fig. 1. Damaged leaves and number of larvae monitored from onion fields with and without castor plants. Bongabon, Nueva Ecija. 1999 Season

2. Sex Pheromone

Sex pheromone traps detected both species of *Spodoptera* in the study area even before seeding of onion in the field. The trend in trap catches showed more *S. litura* than *S. exigua* at the start of the season. However, the opposite was noted starting at the middle of the season until harvest (Fig. 2).

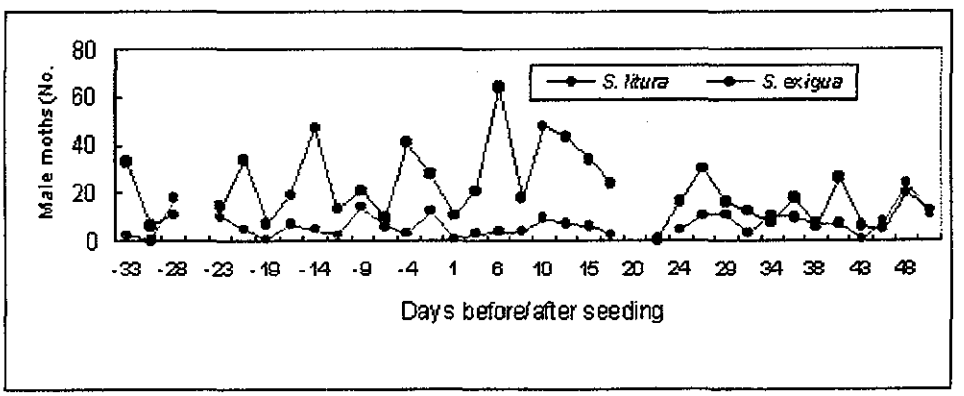


Fig. 2. Number of male *Spodoptera* spp. moths caught in the sex pheromone traps before and during the crop period. Bongabon, Nueva Ecija. 1999 Season

Peaks in sex pheromone trap catches of *S. litura* were recorded at 56 and 75 days after seeding (DAS). This was followed in a few days by peaks in density of *S. litura* eggs as monitored in castor plants. It was estimated that the peak in trap catches coincided with the peak in mating activity in the field. This initial result indicated that the trend in trap catches could be used as a monitoring tool in the management of *S. litura*. For a successful pest management program, it is important that a monitoring system be developed for efficient timing of interventions against a target pest.

Impacts

Reduced area in managing *S. litura* that can result in reduction in cost. An effective monitoring and surveillance system will result in reduced insecticide use in onion.

Networking Activities

Arida, G.S., Gapud, V.P., Pile, C.V., Santiago, B. E., Talekar, N.S., and Rajotte, E. 1999. Monitoring Adult Densities of *Spodoptera spp.* in onion with Sex Pheromone Traps. Poster Paper presented during the 30th Annual Scientific Meeting of the Pest Management Council of the Philippines. May 4-6, 1999. Philippine Rice Research Institute, Muñoz, Nueva Ecija.

Highlights

Castor is an effective trap crop for *S. litura* in onion field as shown by the high population of eggs collected throughout the season.

Sex pheromone traps detected *Spodoptera litura and S. exigua* even before seeding of onion crops. Peaks in sex pheromone trap catches were followed in a few days by peaks in egg density of *S. litura* as monitored in castor plant. It is possible that trap catches could be used as a monitoring tool for efficient timing for interventions in the field thus resulting in reduced costs and insecticide usage in onion.

Field Evaluation of Damaged Fruit Removal as an Alternative to Insecticide Sprays for Control of Eggplant Shoot and Fruit Borer (*Leucinodes orbonalis*)

Investigators: V.P. Gapud[1], C.V. Pile[1], G.S. Arida[1], B. Santiago[1], G. Balagot[1], and E.G. Rajotte[2]

Abstract

The effectiveness of damaged shoot and fruit removal at varying frequencies was compared with insecticide application at three weeks interval throughout the eggplant season was evaluated in farmer's field (San Jose) and at the experimental field (PhilRice) during the 1998-1999 dry season. In both study sites, highest yields of healthy (undamaged) fruits, in terms of number and weight were obtained from plans where damaged shoots and fruits were removed every week. Plants sprayed every three weeks and the untreated control plants gave low yields.

Although fruit damage was highest in untreated control plots, the differences did not appear significant, except when compared to the weekly removal treatment. The weekly removal of damaged shoot and fruits appeared to be the best treatment over other removal frequencies and insecticide application every three weeks and is optimally beneficial to farmers if the treatment coincides with the regular harvesting schedule of farmers. In effect, the reduction in pesticide use has been tremendous with the simple removal of damaged shoots and fruits, the latter being cost-effective if applied together with the harvesting schedule of the farmer.

[1] Philippine Rice Research Institute
[2] Pennsylvania State University

Objectives

1. Determine appropriate frequency of application of commonly used insecticides against *Leucinodes orbonalis.*
2. Determine the frequency of damaged shoot and fuit removal as an alternative to insecticide use.

IPM Constraints

1. Biological control agents are lacking in most parts of the Philippines. Because of its exotic nature, *L. orbonalis* (introduced from mainland Asia) natural enemies and biocontrols are lacking and the pest has become highly destructive.
2. The lack of alternatives to insecticide use encourages farmers to spray intensively.

Research Methods

Farmers' and experimental fields were used to compare and evaluate the effectiveness of Brodan and simple damaged shoot and fruit removal throughout the eggplant season for the management of *L. orbonalis*. Since the appropriate frequency of Brodan application has been established at every three weeks from the previous experiment (1997-98), only the appropriate frequency of damaged shoot and fruit removal (DSFR) was determined this year.

Both farmer's field in Abar 1st, San Jose, Nueva Ecija and PhilRice experimental field in Maligaya, Munoz, Nueva Ecija were laid out in 4 x 5 m plots in an RCBD pattern, with four replications for each treatment per crop. The treatments used were: (a) Brodan, applied once every three weeks; (b) damaged shoot and fruit removal (DSFR) every week ; (c) DSFR every two weeks; (d) DSFR every three weeks; and (e) untreated control. Treatments were initiated 30 days after transplanting (DAT). Fruits were harvested according to the farmer's schedule (every 4-5 days) and were used for yield comparison among the treatments over a 5-month period. The number of *Leucinodes* larvae per fruit were estimated based on the damage levels and the previous estimates on number of larvae per fruit (average of one per fruit is a conservative estimate).

Research Results

The total fruit yield ranged from 16.6 t/ha (T1, spray every 3 weeks) to 23.2 (control plots) (Table 1). In terms of marketable (undamaged) fruits, however, yields were highest in plots treated with weekly removal (T2) at 17.2 t/ha, followed by plots with removal every two weeks at 14.2 t/ha, and plots with removal every three weeks at 13.2 t/ha, with both sprayed and control plots having similar healthy yields of 11.7 and 11.6 t/ha, respectively. The percent fruit damage was lowest in plots with weekly removal of damaged shoots and fruits (22.3%) and was highest in control plots (34%). Plots treated with insecticide (T1) incurred fruit damage of 31.4%.

Table 1. Effects of insecticide application and frequency of shoot and fruit removal on eggplant borer and fruit yields, Abar, San Jose, Nueva Ecija, DS 1998-99 (based on 4 x 5 m plots).

Treatment	Total Harvestable Fruits/ha	No. of Damaged Fruits/ha	Total Wt of Harvested Fruits (t/ha)	Wt. Of Undamaged Fruits (t/ha)	Wt. of Damaged Fruits (t/ha)	Percent (%) Damaged Fruits
T1, Spray Every 3 wks	300,780	90,750	16.61	11.71b	4.97b	31.38
T2, Weekly Removal	330,070	68,750	22.10	17.20a	4.90b	22.32
T3, Removal Every 2 wks	309,070	75,925	19.53	14.23ab	5.30b	26.02
T4, Removal Every 3 wks	298,985	77,430	18.53	13.21ab	5.32ab	27.29
T5, Control	300,910	201,675	23.20	11.60b	11.60a	33.99

At the PhilRice experimental field, total fruit yields were slightly higher but the levels of fruit damage were also very high (44-58%). In terms of total harvestable fruits, both T2 (weekly removal) and T5 (control) plots had similar yields, 22.8 and 22.56 t/ha, respectively, but the marketable (undamaged) fruits were much higher in T2 plots than in T5 plots, as reflected in their respective fruit damage levels of 43.6% and 57.7%. Plots with removal every three weeks (T4) had the lowest marketable fruits (8.9 t/ha), followed by insecticide-treated plots (T1).

Table 2. Effects of insecticide application and frequency of shoot and fruit removal on eggplant borer and fruit yields, PhilRice Central Experiment Station, Maligaya, Muñoz, Nueva Ecija, DS 1998-99 (based on 4 x 5 m plots).

Treatment	Total Harvestable Fruits/ha	No. of Undamaged Fruits/ha	Total Wt of Harvested Fruits (t/ha)	Wt. of Undamaged Fruits (t/ha)	Wt. of Damaged Fruits (t/ha)	Percent (%) Damaged Fruits
T1, Spray every 3 wks	259,500	147,825a	18.03	9.23a	8.80a	56.97
T2, Weekly Removal	300,625	131,125a	22.84	14.25a	8.59a	43.62
T3, Removal every 2 wks	274,500	131,250a	20.00	11.38a	8.62a	47.81
T4, Removal every 3 wks	256,375	140,500a	17.40	8.90a	8.50a	54.80
T5, Control	331,625	191,250b	22.46	10.76a	11.70a	57.67

In both farmer's and experimental fields, the treatment of weekly removal of damaged shoots and fruit was consistently better than other treatments and also implies a pruning effect of the removal process. The advantage of the treatment is that it serves not only as an option for insecticide use reduction but completely replaces the insecticide option for managing *L. orbonalis*.

The levels of fruit damage in farmer's field and PhilRice experimental field were estimated both by selecting 20 plants from each plot for the duration of the crop from which fruit yields were monitored, and by obtaining the total harvest from each of the 4 x 5-m plots, with 4 replications for each treatment. Table 3 shows the similarity in percent fruit damage in farmer's field from both estimates, while the percent damage levels were slightly higher in the unit area estimate than on the per plant estimate, except the control plots. The use of a representative number of plants for each plot is, therefore, considered acceptable and can be recommended in place of whole plot harvest measurements to estimate the level of fruit damage. However, the number of sampled plants (sample size) could be increased by 25 per plot for better results. On a hectare basis, however, the sample size for estimating the extent of fruit damage will have to be determined, using selected 4 x 5 m plots across the field and taking measurements from 20-25 plants per plot.

Regardless of sampling method, using plants per plot or unit area, the weekly removal treatment consistently showed the lowest percent fruit damage in both farmer's and experimental fields, with slightly higher levels in the third treatment (removal every two weeks), followed by the fourth treatment (removal every three weeks). The highest damage levels were expected to be in the untreated control plot, followed by the insecticide-treated plots. Consistent also were the much higher damage levels in the experimental field than in farmer's field.

Table 3. Measurements of percent fruit damage based on fruit harvest per unit area and on number of plants (replicated 4 times), DS 1998-1999.

Treatment	% Damage based on 4 x 5 m plot		% Damage based on 20 plants/plot	
	San Jose	PhilRice	San Jose	PhilRice
T1, Spray every 3 weeks	31.38	56.97	27.94	53.74
T2, weekly removal	22.32	43.62	22.06	41.07
T3, removal every 2 weeks	26.02	47.81	27.51	46.12
T4, removal every 3 weeks	27.29	54.80	27.05	52.10
T5, Untreated Control	33.99	57.67	34.80	58.01

Impact

The impact of the study shows the great possibility of drastically reducing, if not totally eliminating, insecticide use in eggplant fields, by replacing it with properly timed removal of damaged shoots and fruits, together with the already existing sanitation measures (disposal of damaged fruits from the field) which the farmers are assumed to be

doing now, along with the harvesting schedule of farmers. Where before, insecticide spraying could be as high as 40 times in a 5-month crop, it is now possible to reduce it to 7 times (every three weeks). In this regard, the effect is tremendous in terms of improved environmental quality and savings attributed to insecticide use. The labor costs of removal are eventually incorporated into the labor cost for harvesting.

Networking Activities

- Helped plan, participated in and served as resource person in a workshop for the development of a training module for IPM in rice-vegetable systems
- Fact sheets developed on eggplant insect pests, *Leucinodes orbonalis* Guenee, *Amrasca biguttula* (Ishida), and *Henosepilachna doryca philkippinensis* (Dieke).

Project Highlight

Removal of damaged shoots and fruits of eggplant is a viable alternative to insecticide application for the management of *Leucinodes orbonalis*. If implemented at the same time with the harvest schedule of farmers, labor costs can be cut down drastically. With the drastic reduction or non-use of insecticides, great saving will be realized, leading to high economic returns to farmers.

Preliminary Study on Net Barrier for Eggplant Fruit and Shoot Borer *Leucinodes orbonalis* Management

Investigators: G.S. Arida[1], V.P. Gapud, C.V. Pile[1], N.S. Talekar[2], and E. Rajotte[3]

Abstract

The number of damaged shoots and larvae of *Leucinodes orbonalis* was monitored inside a field with net barrier and compared with adjacent field without barrier. A higher incidence of damaged shoots and number of larvae were recorded from plants in the open field than from plants inside the barrier up to 15 weeks after transplanting. This is a preliminary study and further tests will be conducted in the coming season.

Objective

To determine the effect of net barrier on the density of the eggplant fruit and shoot borer, *L. orbonalis*, and the resulting short change.

IPM Constraints

Farmers usually spray insecticides several times during the season due to eggplant fruit and shoot borer. An alternative management strategy is badly needed to address this problem that would result in the reduction of insecticide use in eggplant.

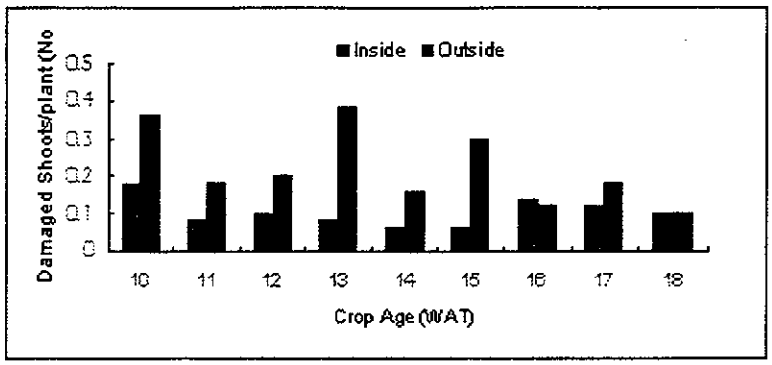
Research Methods

One-month-old seedlings of eggplant were transplanted into a field inside the Central Experiment Station (CES), PhilRice. The field was divided into 2 plots, one with a net barrier and the other left open. Damaged shoots and number of *L. orbonalis* larvae were monitored weekly on 50 plants per plot starting at 2 weeks after transplanting (WAT).

Results

The number of damaged shoots and larvae per plant were higher outside than inside the net barrier up to 15 weeks after transplanting (Fig. 1). No difference was noted at 16-18 WAT. This was probably due to damage of the net barrier caused by heavy rain and strong winds during the later part of the study. This is a preliminary study and a modified experimental design will be conducted in the coming season.

[1] Philippine Rice Research Institute
[2] AVRDC
[3] Penn State University



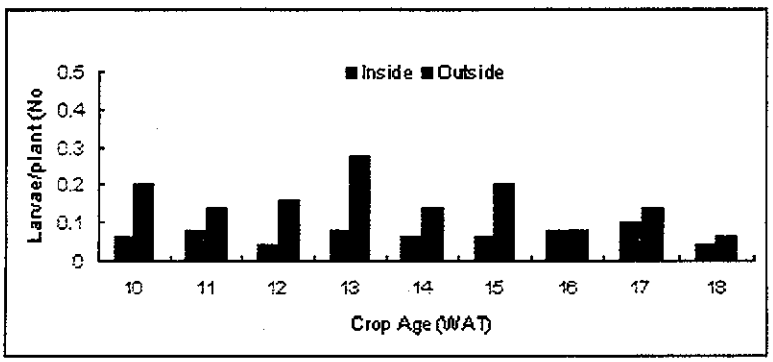


Fig 1. Number of damaged shoots and larvae per plant at different crop ages, PhilRice CES, Nueva Ecija

Networking Activities

- E. Rajotte traveled to PhilRice in October 1998 to evaluate research results and participate in planning for Year 7 experiments. N. S. Talekar also participated in these discussions in October 1998.

Project Highlights

Installation of a net barrier significantly reduced the infestation of *L. orbonalis* as shown by the low incidence of damaged shoots and number of larvae on the eggplant protected by the net.

Host Plant Resistance of Eggplant, *Solanum melongena* L. to the Leafhopper, *Amrasca biguttula* (Ishida), and the Eggplant Borer, *Leucinodes orbonalis* Guenee

[Resistance Screening of Farmers' and Commercial Varieties of Eggplant Against the Cotton Leafhopper, *Amrasca biguttula* (Ishida)]

Investigators: M.C. Lit[1], V.P. Gapud[2], C.V. Pile[2], B.A. Santiago[2], G.E. Balagot[2], N.S. Talekar[3], E. Rajotte[4]

Abstract

Leafhopper infestation in the field followed the same pattern as that observed during the 1998 dry season trial. Adult and nymph populations peaked at 60 days after transplanting (DAT). More leafhoppers infested the 5th leaf from the growing tip. Based on over-all counts, the varieties Jackpot and Bulakeña were most preferred by both adults and nymphs; variety IPB GS 1 was least preferred.

Overall damage rating showed that the variety SRO2 had the least yellowing and cupping symptoms. Among the varieties tested, Bulakeña and Jackpot were susceptible at 60 DAT. Dumaguete Long Purple and Abar were the tallest varieties at vegetative and reproductive stages, respectively. Abar had the longest leaf while IPB GS1, the smallest. Both varieties were tolerant but whether these plant characters can affect leafhopper preference has not been established. Variety SRO2 had the highest number of trichomes per 40 sq. mm while Abar had the longest trichomes. This suggests that the dense trichomes in SRO2 could have deterred leafhopper feeding and oviposition. IPB GS1 yielded the healthiest fruits. The yield of Jackpot and Dumaguete Long Purple was comparable to IPB GS1. Bulakeña had the lowest number of healthy fruits.

Damaged fruits due to borer infestation were counted and expressed as percentage of the total number of healthy and damaged fruits. During the four harvest periods, Abar had the highest percentage of damaged fruits while IPB GS1 had the lowest percent infestation. SRO2 was resistant to leafhopper at vegetative and reproductive stages while Abar was tolerant to leafhopper until the last harvesting period. Jackpot was tolerant and yielded high despite the high leaf yellowing rating. Bulakeña was the most susceptible variety showing distinct leaf cupping before the yellowing symptoms of leafhopper damage.

Objectives

(1) To screen and confirm the reaction of selected commercial and farmers' eggplant varieties for resistance or susceptibility to the cotton leafhopper.
(2) To determine the impact of leafhoppers on the yield of eggplant.
(3) To select the varieties that have resistance or tolerance to this pest and determine the mechanism of plant resistance to the pests in the genotypes identified.

IPM Constraints

(1) Lack of available sources of resistance to the cotton leafhopper for improving the resistance of improved varieties.
(2) No available resistant germplasm sources of eggplant against the eggplant borer.

Research Methods

General Screening

Seven selected varieties of eggplant were sown in seedbeds. After 2-3 weeks, the seedlings were pricked on plastic trays and maintained inside the greenhouse. After a month (seedlings reaching 10-15 cm length), they were planted in 4m x 5m field plots with four replications in RCBD at PhilRice Central Experimental Station during the 1999 dry season (January) and maintained following standard cultural management practices for eggplant production. Two eggplant entries are farmers' varieties (SRO 2 and Abar), the four entries came from different private seed companies (Jackpot, Bulakeña, Long Violet), while IPB GS 1 is an

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improved line (genetic stock) developed at the Institute of Plant Breeding, which has increased resistance against the leafhopper.

Leafhopper populations and leaf damage were monitored for each variety at 30 days after transplanting (DAT) and every two weeks thereafter until 135 DAT. Leafhopper damage was recorded using a 1-9 rating scale on yellowing and cupping, based on the 4th and 5th fully expanded leaf. Other insect pests such as thrips, mites, aphids and natural enemies were also counted.

Morphological and horticultural features were measured from 45 to 105 DAT. Trichome density and length were measured at 45, 90, and 105 DAT. Dried leaf samples of each variety were taken to the Analytical Laboratory of the Institute of Plant Breeding for proximate analysis and other specific chemical tests including analysis of fat, sugar and amino acid content.

Fruit yields were determined weekly for each variety. Fruits infested with the eggplant borer (damaged fruits) and healthy (undamaged) fruits were counted and weighed.

Results

Leafhopper populations

Leafhopper infestation levels in the field followed the same trend as that observed during the 1998 dry season trial. Adult leafhoppers counted on the 4th and 5th leaves started to increase at 45 DAT, peaked at 60 DAT and declined from 75 DAT and thereafter as the plants matured. Two-month old plants (60 DAT) were consistently susceptible to leafhopper under field conditions. Generally, more leafhoppers were present on the 4th and 5th leaves of Jackpot than on other varieties. Nymph populations peaked at 60 DAT, declined at 75 DAT and increased again at 90 DAT and thereafter. More nymphs preferred to aggregate on the 5th leaf from the top, especially on Jackpot and Long Violet. The least number of nymphs and adults were observed in the 4th and 5th leaf samples of SRO2.

Other Insect/Arthropod Pests and Natural Enemies

Thrips were found significantly abundant from 30 to 75 DAT on both 4th and 5th leaves, and declined thereafter (data not shown). Aphids were also found attacking the different eggplant varieties at early vegetative stage but numbers did not differ among varieties. Red spider mites became abundant from 45 DAT and decreased after 75 DAT on both leaves. The spider populations did not differ significantly among the eggplant varieties. Mirid bugs were also present at the early reproductive stages and coccinellids were observed between 120 and 135 DAT. However, they did not differ significantly in their numbers among the eggplant varieties.

Damage Response

Yellowing was more pronounced on the 5th leaf compared to the 4th especially towards the later part of the sampling periods. This was expected as the leafhoppers on the 4th leaf were fewer and physiologically younger than on the 5th. Jackpot showed the highest mean yellowing rating from 60 DAT onwards while IPB GS 1 showed the lowest mean yellowing rating throughout all rating periods except at 90 DAT, when both SRO2 and Abar had the least leaf yellowing. On the other hand, SRO2 variety showed a relatively low cupping mean rating of 1.08 and 1.78 at 105 DAT and 120 DAT, respectively, compared with Jackpots' 4.35 at 60 DAT, which had the highest rating among all varieties up to the last rating period. Bulakeña was the second most susceptible variety and showed distinct leaf cupping. IPB GS 1 and Abar variety were least susceptible between 105 and 120 DAT.

Morphological/Horticultural Characteristics

The tallest variety was IPB GS1 during the vegetative stage (45 DAT) and Abar during the reproductive and fruiting stages. Long Violet was the shortest at 75 DAT and SRO2 at 105 DAT. Abar variety was the largest in both 4th and 5th leaves in all sampling dates. Dumaguete Long Purple had the second largest leaves. IPB GS 1 had the smallest leaf area on the 4th leaf from 90 to 105 DAT.

Trichome characters

To confirm the antixenotic and tolerance mechanisms of field resistance demonstrated by some eggplant varieties, trichome characters were measured. All eggplant varieties had the dendritic or arboriform type of trichomes. Results showed that SRO2 had the highest number of trichomes per 40 sq. mm in all three sampling dates. This probably suggests that the trichome density in SRO2 could be the resistance factor that deters leafhopper feeding and oviposition on both 4th and 5th leaves of eggplant. Longer trichomes were observed on Abar from Nueva Ecija, followed by Dumaguete Long Purple in all sampling periods. Tolerance of Abar to leafhopper infestation could be due to longer trichomes of this eggplant variety. IPB GS 1 had the shortest trichomes at 45 and 105 DAT and Jackpot at 90 DAT. Trichome characters in IPB GS1 probably do not confer tolerance or resistance mechanism as trichome density and length were lowest in this variety in all three sampling dates. The result shows that trichome characters can serve as resistance factors in some eggplant varieties and probably a combination of trichomes and chemical factors on the surface of the leaves in other eggplants.

Yields of Healthy Fruits

The yields of several eggplant varieties differed significantly from one another at various sampling periods. As in the previous season, IPB GS 1 yielded the healthiest fruits at 75

and 82 DAT. Jackpot and Dumaguete Long Purple yielded high at 89 DAT which was comparable to the yield of IPB GS 1 in terms of the number and weight of fruits. Bulakeña, SRO2 and Abar yielded low in terms of the mean number of healthy fruits in all harvesting periods. The mean number of borer damaged fruits was highest on DLP followed by Abar and Jackpot, starting from 95 DAT harvesting. Bulakeña and SRO2 had the lowest number of borer-damaged fruits in all sampling periods. The weights of healthy fruits were highest for Jackpot followed by IPB GS1 starting from 85 DAT up to 105 DAT.

Chemical Analyses

Proximate analyses of dried leaf samples of the different eggplant varieties collected at 60 DAT is shown in Table 1. The percent protein differed significantly among the eggplant varieties, with SRO2 having the highest amount. It is possible that these protein compounds are secondary metabolites that are considered defense substances in plants against herbivory. The pigments (also known as flavonoids) may have been present in the trichomes of some of these varieties such as IPB GS1. The biochemical basis of leafhopper resistance among the different eggplant varieties will be an interesting topic to pursue.

Table 1. Proximate analysis of farmers' and commercial varieties of eggplant for resistance to the leafhopper, *Amrasca biguttula* Ishida.

Treatment	% Crude Fat	% Protein	% Ash	% Crude Fi	% TFS	% Starch
Jackpot	16.99	24.20	9.98	23.10	14.00	28.40
DLP	17.01	24.18	9.98	24.57	12.13	29.37
Abar	17.13	27.50	9.70	25.73	12.73	32.58
SRO2	16.34	30.83	11.03	26.06	14.30	28.89
Bulakeña	16.11	26.50	9.34	27.06	14.76	27.03
L Violet	15.71	39.75	10.08	25.24	13.56	30.99
IPB GS1	16.60	27.78	10.01	22.29	13.11	29.83

Samples taken at 60 DAT; for analysis – 2 samples per replicate, three replications in the three inner 5m rows.

Relationship of damage rating, leafhopper population and plant characters

A significantly positive correlation was obtained between leaf yellowing and mean weight of fruit yield, while no significant relationship was observed with the mean number of fruits (Table 2). When the leafhopper populations were correlated with damage rating, a highly positive significant correlation was observed using the leaf yellowing rating (Table 3). No significant correlation was observed between leafhopper population and plant characters, with the exception of leafhopper damage rating and trichome density (Table 4). Over-all, based on these results, the leafhopper population, leafhopper damage rating, fruit yield and trichome density are potential parameters for resistance evaluation which can be reliable indicators for selecting eggplant varieties with tolerance or resistance against a pest.

Table 2. Relationships of damage rating, leafhopper population and plant characters with the mean number and weight of healthy fruits. PhilRice-CES, Maligaya, Muñoz, Nueva Ecija Philippines, 1999 dry season.

Parameters	Correlation (R)	
	No. of Fruits	Weight (kg)
Damage Rating		
Leaf Yellowing	0.272	0.766
Leaf Cupping	-0.044	0.499
Leaffolder population		
Nymph	0.054	0.519
Adult	0.129	0.587
Plant Characters		
No. of trichomes	-0.531	-0.378
Length of trichomes	-0.519	-0.289
Leaf Area	-0.287	-0.191
Leaf Length	-0.383	-0.217
Leaf Width	0.039	-0.102
Plant Height	0.200	0.174

Table 3. Relationship of damage rating and plant characters with the mean number of nymph and adult leafhoppers, PhilRice-CES, Maligaya, Muñoz, Nueva Ecija, Philippines, 1999 DS.

Parameters	Correlation Coefficient (R)	
	Nymph	Adult
Damage Rating		
Leaf Yellowing	0.733	0.603
Leaf Cupping	0.573	0.263
Plant Characters		
No. of trichomes	-0.399	-0.268
Length of trichomes	0.289	0.479
Leaf Area	0.194	0.509
Leaf Length	0.106	0.441
Leaf Width	0.476	0.383
Plant Height	0.113	0.464

Table 4. Relationship between damage rate and plant characters. PhilRice-CES, Maligaya, Muñoz, Nueva Ecija, Philippines, 1999 dry season.

Parameters	Correlation Coefficient (R)	
	Leaf Yellowing	Leaf Cupping
Plant Characters		
No. of trichomes	-0.71	-0.480
Length of trichomes	-0.163	0.029
Leaf Area	-0.296	-0.272
Leaf Length	-0.274	-0.312
Leaf Width	-0.053	0.133
Plant Height	-0.131	-0.346

Impact

Some morphological characters such as trichome density and length influenced Field preferences of adults and nymph leafhoppers among the different varieties of eggplant initially. The farmers' variety SRO2, from the Ilocos region, was densely covered with the arboriform or dendritic trichomes which initially inhibited leafhopper feeding and oviposition, as shown by the lowest number of nymphs and adult population counts all throughout the sampling periods. On the other hand, IPB GS1, an improved resistant/tolerant line from the Institute of Plant Breeding, was not densely covered by these arboriform trichomes but showed resistance or tolerance to leafhopper damage. Proximate analyses did not show any significant findings except for percent proteins. A closer look at the chemical nature of the leaf undersurface might reveal that this variety has increased resistant chemical substances, which possibly prevented the leafhoppers from feeding and oviposition. For resistance evaluation purposes, correlation studies showed that leafhopper counts, leafhopper damage rating, fruit yield and trichome density are good and reliable parameters. Jackpot, a commercial variety, is considered tolerant because it yields high in spite of the higher leafhopper damage at vegetative stage. The use of resistant or tolerant eggplant varieties is a promising alternative to reduce crop loss, increase farmer income and reduce pesticide use as shown by the differential varietal responses of several eggplant varieties against the leafhopper.

Networking Activities

- Lecture materials and posters as part of the Training Manual prepared by the IPM-CRSP group during Farmer's Forum and Trainers Training.
- Live Exhibits of the cotton leafhopper and the eggplant borer and their damage to eggplant. Presented during the Farmer's Forum.
- E. Rajotte traveled to PhilRice in October 1998 to evaluate research results and participate in planning for Year 7 experiments. N. S. Talekar also participated in these discussions in October 1998.

Publications and Presentations

M. Caasi-Lit, V. P. Gapud, B. A. Santiago, C. V. Pile, G. E. Balagot, N. S. Talekar and E. Rajotte. "Major insect pests of eggplant, *Solanum melongena* L., and their natural enemies". Poster paper during the Annual Scientific Meeting of the Pest Management Council of the Philippines, May 6, 1999, PhilRice, Maligaya, Muñoz, Nueva Ecija.

M. Caasi-Lit, V. P. Gapud, B. A. Santiago, C. V. Pile, G. E. Balagot, N. S. Talekar and E. Rajotte. "Resistance screening of farmers' and commercial varieties of eggplant against the leafhopper, *Amrasca biguttula* (Ishida). Poster paper presented during the Farmer's Forum "Presentation of IPM CRSP Research/Technologies in Collaboration with NOGROCOMA Farmer Members". July 30, 1999, PhilRice, Maligaya, Muñoz, Nueva Ecija.

Training Output

Pest Management of Eggplant/ Tomato Insect Pests during the Trainers Training, September 29-30, 1999, PhilRice, Maligaya, Muñoz, Nueva Ecija.

Highlight

Several farmers' and commercial varieties of eggplant were resistant or tolerant to the leafhopper. The farmer's variety SRO2 has dense trichomes that prevented leafhoppers from feeding and oviposition. IPB GS 1, an improved line, has few trichomes but is resistant to leafhopper and yields high. The use of these varieties significantly cut production costs as no pesticide inputs were added. This was coupled with the abundance of natural enemies, which helped reduce and manage leafhopper and borer populations below damaging levels.

Movement of Arthropod Predators

Investigators: K.L. Heong[1], L. Sigsgaard[1], V.P. Gapud[2], G.S. Arida[2], and E. Rajotte[3]

Abstract

The objective of the project is to quantify movements of predators between habitats in rice-onion cropping systems. Our hypothesis is that generalist predators can be found in rice-onion systems that play a role in maintaining control of insect pests. Habitats adjacent to the rice-onion system serve as reservoirs of generalist predators of insect pests. We have monitored arthropod predator activity-density and directional movement between habitats in the fallow and rice-onion system at four different farms in the province of Nueva Ecija and at one location at IRRI. We are assessing species density and composition in the field edge and at increasing distance from the field edge. This serves as a control of the catches in the pitfall traps. At the location at IRRI the spatial distribution within a whole field has been followed over two cropping seasons. In all localities the flora composition in the bunds have also been assessed. Directional pitfall traps placed in the bunds serve to assess the movement of walking predators. Sticky boards and window traps serve to assess the movement of flying predators. We are currently analyzing the temporal patterns of the movements in and out of the fields from diurnal samplings in the 1998-99 dry season. Preliminary results show a clear effect of crop age as well as farm operation upon the catches in the pitfall traps. There are trends of movement of *Pardosa pseudoannulata* females with young into the field early in the season, a trend that is later reversed. Farm operations affect movements of spiders, carabids and ants, as well as predator activity-density in the bunds. The importance of bunds as a refuge is stressed by the fact that walking generalist predators predominate during the early crop stages. A walking predator such as *P. pseudoannulata* needs favorable conditions for survival near the field to provide good biological control. Later flying predators, as the ballooning spider *Atypena formosana* arrive. Flying predators may be less dependent on refuges close to the field. The spiders *A. formosana* and *P. pseudoannulata* have been selected for more detailed study based on their early occurrence and high abundance in the pitfall traps and/or in the field. *P. pseudoannulata* is the most common spider caught in the pitfall traps, and occurs very early in the season and thus is an important early predator. Shortly after (2 weeks), *A. formosana* is also found in the field. It does enter the field walking (as seen from our pitfall traps), but entry by ballooning is much more important based on our window-trap and sticky trap catches. Functional response and density dependent predation were assessed for *A. formosana*. Results indicate a type two response, as well as a very high predation level. Development time and fecundity of *A. formosana* on different diets were negatively affected by a pure diet of brown planthopper or green leafhopper as compared to a more varied diet.

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Objectives

(a) To quantify movements of predators between habitats in rice-onion cropping systems in space and time.
(b) To identify the predator species moving between the habitats.
(c) To assess the impact of predators on pest abundance.

IPM Constraints

Limited understanding of natural biological control in the field and how natural enemies are maintained in the field. The lack of information on the usefulness of bunds for pest management. Both concerns are addressed in the study.

Research Methods

Arthropod predators and their movement between habitats in the rice-onion system, were sampled and measured respectively, by directional pitfall traps placed in the bunds of rice-onion fields. Four localities were sampled weekly with these directional pitfall traps. In each locality, five traps were placed. Each trap included two pitfall traps divided by a 40 cm wide barrier for walking insects. In two of the localities there were window traps to follow trends in the movement of flying insects over the season. Density of predators and their prey in the bunds and field were also assessed by suction sampling. Finally the plant community of the bunds was also sampled.

Although we put special emphasis on spiders and coleopterans, catches of coleopterans were very low. Temporal patterns of these arthropods' activity-densities and directional movements are being analyzed by comparing catches over time and by comparing catches in the half of the directional trap facing the field with the part facing other vegetation. As a control of the farm located experiments we did a parallel experiment at one location at IRRI farm. At IRRI the diurnal pattern of movements across the bunds was studied following an intense sampling scheme.

In addition, detailed biology and ecology of *A. formosana* and *P. pseudoannulata,* the two most common spiders early in the season, are being quantified in a combination of field and lab studies. These include detailed studies of the hunger level of *A. formosana* and *P. pseudoannulata* in the field across the season, the functional response of *A. formosana*, its prey preference and development time, and fecundity on different diets.

Results

Information on the dynamics of generalist predators and their possible roles in maintaining control of pests. Our insect samples for 1998 covering the onion-fallow and the rice crop have now been keyed out and are currently being analyzed. Sampling for 1999 has been completed, approximately half of the samples from 1999 are keyed out, and these are presently being formatted for further analysis.

The IRRI farm control showed a clear effect of farm operation upon the catches of several groups of generalist walking predators in the pitfall traps. There are trends of movement of *P. pseudoannulata* females with young into the field early in the season, a trend that is later reversed, indicating that the maturing field can serve as a source of predators for other crops. To better understand the observed trends of movement, and a possible diurnal effect on movement patterns not detected by our 24-hour sampling pattern, we have completed a series of diurnal samplings through the dry season 1998-99 to investigate the diurnal pattern of these movements further. These data are currently being prepared for further analysis.

Detailed biology of one or two selected generalist predators. Two spiders *A. formosana* and *P. pseudoannulata* have been selected for further studies in the laboratory based on their high abundance in the pitfall traps and/or in the field. *P. pseudoannulata* is the absolutely most common spider caught in the pitfall traps, and is interesting because it occurs so early in the season that it has a good chance of keeping early pests at a reduced level. Shortly after (2 weeks), *A. formosana* is also found in the field. It does enter the field walking (as seen from our pitfall traps), but entry by ballooning is much more important based on our window-trap and sticky trap catches. A walking predator such as *P. pseudoannulata* needs favorable conditions for survival near to the field to provide good biological control whereas the ballooning *A. formosana* may be able to add to the biological control also when conditions for predators near the field are not optimal. Functional response and density dependent predation were assessed for *A. formosana.* Results indicate a type two response, as well as a surprisingly high predation level by this little spider. Our study on the development time and survival of *A. formosana* on different diets is completed. Though the predation on BPH and GLH in the functional response experiments was high, both development time and fecundity were negatively affected by a pure diet of BPH or GLH as compared to a more varied diet.

Impact

The study will add to the information on the role these generalist predators play in enhancing natural biological control of pests in onion and rice and suggest times where the bunds may have particular importance. This activity should further provide information to help refine the timing of pesticide spray recommendations developed in other projects to reduce negative impact on predators.

Networking activities

The project involves collaboration between PhilRice and IRRI. We are also collaborating with Dr. Rajotte from the USA. E. Rajotte visited IRRI and PhilRice in October, 1998

and February 1999 to discuss results of this work and future experiments with cooperators.

Publications and presentations

Sigsgaard, L. and S. Villareal, 1999 Predation rates of *Atypena formosana* (Arachnidae: Linyphiidae) on brown planthopper, and green leafhopper, International Rice Research Notes (In press).

Sigsgaard, L. , S. Villareal, , V.P. Gapud, and E. Rajotte. (1999) Directional Movement of Predators Between The Irrigated Rice Field and Its Surroundings. In: Biological Control in the Tropics, Towards efficient biodiversity and bioresource management for effective biological control. Proceedings of the Symposium on Biological Control in the Tropics. Loke Wai Hong, Soetikno S. Sastroutomo *et al.* (Eds). The National Council for Biological Control (NCBC in collaboration with CAB International, South East Asian Regional Centre, Malaysia. MARDI Training Centre, Serdang, Malaysia from 18-19 March 1999, p. 43-47.

Sigsgaard, L., S. Villareal. (1999) Functional response of *Atypena formosana* (Aranea: Linyphiidae) to nymphs of brown planthopper, and green leafhopper. IVXth International Conference of Plant Protection, Jerusalem, Israel, July 25-30, 1999, Kenes, Organizers of Congresses and Tour Operators. p. 42.

Training output

The research assistant at PhilRice received a ten day long intensive training course in spider identification at IRRI in mid 1998.

Highlights

Early pest control in rice mostly depends on walking predators. Predators include spiders, ants, Dermaptera and carabids, the most important single predators being *Pardosa* spiders. These early predators rely on refugia within walking distance from the rice fields to provide this early biological control. The bunds are the closest refugia. The age of the crop as well as farm operations affect predator movement across bunds. In the young crop *Pardosa* females with eggs or young show a trend of movement from or across the bund and into the field. This trend is later reversed so that the older crop may serve as a source of spiders to neighboring crops. During farm operations, such as harrowing, predators escape into the bunds. Later other groups of predators arrive and become more numerous than the walking predators. One of the first is ballooning spiders, later followed by, among others, a high number of aquatic hemipteran predators. During fallow collembolans and dipterans provide important alternative prey for the predators, thus allowing many predators to survive in and around the field. After the crop is planted, numbers of alternative prey fall dramatically, producing a perfect timing with many hungry spiders at the time of early pest attack.

Biological Control of Soil-Borne Pathogens in Rice-Vegetable Systems

Investigators: R.T. Alberto[1], E. Gergon[2], M.V. Judal[2], M.V. Duca[2], J.P. Rillon[2], H.X.T ruong[2], S.A. Miller[3], L. Padua[4], R.M. Gapasin[5], J. Halbrendt[6]

Abstract

The *Bacillus* sp. strain LEP 118 lowered the incidence of bulb rot due to *Phoma terrestris* and three species of *Fusarium* compared to *Sclerotium* and *Rhizoctonia*. Roots dipped in bacterial suspension had significantly lower bulb rot incidence than drenched plants. *Trichoderma viride* and the *Trichoderma* sp. isolated from onion (T5) were identified as potential biological control agents against the damping-off pathogens of onion in a dual culture technique conducted in the laboratory. Likewise, *T. viride* and T5 in a second trial conducted in the greenhouse revealed their suppressive efficacy against *Rhizoctonia* and *Sclerotium*. Application of two strains of *Bacillus thuringiensis*, PSB9113 and G8, lowered the number of nematode juveniles.

Objectives

1. To evaluate selected bacterial antagonists against soil-borne fungal pathogens of onion.
2. To develop bioassay technique for evaluation of bacterial antagonists against soil-borne fungal pathogens of onions.
3. To develop system(s) of delivery of the biological control agent to onion seeds and seedlings.

Research methods

1. Bacterial antagonist

The potential of *Bacillus* sp. (LEP 118) as biological control agent against soil-borne fungal pathogens and the best delivery system were tested using three methods:

- Seed Coating - onion seeds were coated with bacterial suspension prior to seeding.
- Soil Drenching - pouring of bacterial suspension into the soil at approx. 2 cm away from
- Root Dipping - roots of the onion seedlings were soaked into the bacterial suspension before transplanting.

All the three methods of delivery were tested in Yellow Granex while soil drenching and root dipping were tested in Tanduyong. On seed coating experiment, seeds were assessed for incidence of pre-emergence and post-emergence damping-off at 1 week and 2 weeks after seeding, respectively. Bulb rotting and pink root incidence in soil drenching and root dipping experiments were assessed at 30, 60 and 90 days after transplanting (DAT).

2. *Trichoderma* studies

a) Laboratory experiments

Five species/isolates of *Trichoderma (T. aurioviride, T. glaucum, T. harzianum, T. viride* and T5 (onion isolate) were evaluated for their biocontrol efficacy against pathogens in onion causing bulb rot (*Fusarium*), seedling rot (*Rhizoctonia* and *Sclerotium*).

To test their control efficacy the dual culture (*in vitro*) method was used. The biological control agents and pathogens were first separately grown in petri dishes and after one week plugs cut from the edge of actively growing fungal colonies were transferred to PDA medium in petri dishes and paired with the agents. The plates with the organisms were incubated for 6 days. The degree of antagonism by the *Trichoderma* species was measured using the following rating scale (Bell *et.al*, 1982): **1**- Antagonist completely overgrew the pathogen and covered the entire medium; **2**- Antagonist overgrew at least two-thirds of the medium surface; **3**- Antagonists and pathogen each colonized approximately 1/2 of the medium surface (more than 1/3 and less than 2/3); **4**- pathogen colonized at least 2/3 of the medium surface and appeared to withstand encroachment by antagonist; and **5**- Pathogen completely overgrew antagonist species and occupied the entire medium surface.

b) Greenhouse Experiment

T. viride and *Trichoderma* sp. (T5, onion isolate) were evaluated against *Fusarium, Rhizoctonia and Sclerotium* causing damping off of onion in the greenhouse. The *Trichoderma* species were cultured in sawdust-rice bran mixed media while *Rhizoctonia* and *Sclerotium* were grown

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in rice grain-rice hull mixed medium. The *Fusarium* species were grown in PDA cultures placed in flat bottles. Sterile soil was placed in 8-inch dia clay pots and later infested with the three pathogens. 25 g of the rice grain-rice hull mixed culture of *Rhizoctonia* and *Sclerotium* were inoculated to the pots while the spore density of 10^3 was inoculated for *Fusarium* species. After one week, 100 g of *Trichoderma* culture were mixed in the potted soil and later 50 seeds of onion (cv. Yellow Granex) were evenly sowed in the pots.

3. Bt against Root-knot Nematode

The following biocontrol agents were evaluated for efficacy against *M. graminicola: Bacillus thuringiensis* strains (isolated by L. Padua,UPLB), *B. pumilus* (10 strains, by H. Truong), *B. macerans* (three strains, by H. Truong), and *Eclipta prostrata* extracts.

Bacterial strains were grown in nutrient agar for a week. Three loops of bacterial cells were taken from the tube and mixed in water. One hundred J2 juveniles of *M. graminicola* were incubated in control medium and bacterial suspension for 1, 2, and 3 days. After incubation, the nematodes were transferred in a modified Baermann funnel, for 24 hours and then collected in test tubes. The number of juveniles that passed through the several layers of facial tissue in the funnel was counted under a stereomicroscope.

Results

1. Bacterial Antagonist

Low bulb rot incidence (3.1%) was obtained at 30 DAT when the roots of Tanduyong onions were dipped in LEP 118. Highest rotting incidence of 9.4% was recorded in plants infected with *Fusarium* 3. No pink root infection was observed on plants inoculated with *Phoma terrestris*. At 60 DAT although the *Rhizoctonia* inoculated plants had the highest bulb rotting incidence, differences among treatments were not significant. However, at 90 DAT, *Sclerotium* and *Rhizoctonia* infected treatments had high incidences of bulb rot, ranging from 77.1% to 83.9%, respectively. Incidence levels were significantly lower on those infected with the three species of *Fusarium*. No infection of *P. terrestris* was recorded. The same trend was observed under soil drenching method. Results show that LEP 118 has minimal activity against *Sclerotium* and *Rhizoctonia* under greenhouse conditions, which confirms the laboratory assay results. Based on the two methods of delivery, the dipping method showed significantly lower bulb rot incidence (1.58%) than the soil drenching method (1.80%) at 30 DAT. Similar trends were observed even at 60 and 90 DAT. The presence of bacterial antagonists right on the surface of the roots provides immediate protection from the soil pathogens resulting in lower incidence of bulb rotting than those plants tested using soil drenching method. Results on tests on Yellow Granex variety will be available a month from now.

2. *Trichoderma* Studies

The second trial conducted under the laboratory further confirms the efficacy of *Trichoderma viride* and T5 as potential biocontrol agents against the pathogens tested, with average ratings of antagonism of 1.6 and 1.4, respectively after 6 days incubation (Table 1). Greenhouse experiments showed that *T. viride* was effective against *Rhizoctonia* with 51% suppression (Table 2).

Table 1. Antagonism of *Trichoderma* species against pathogens causing diseases in bulb onion (var.Yellow Granex).

	PATHOGEN				
Antagonist	*Fusarium* (cream)	*Fusarium* (orange)	*Fusarium* (purple)	*Rhizoctonia solani*	*Sclerotium cepivorum*
T. auroviride	2	2	2	3	3
T. glaucum	2	2	2	3	3
T. harzianum	1	1	2	1	3
T. viride	2	1	2	1	2
T. (onion) 5	1	1	1	1	3
Fungicide (Maneb)	5	5	5	5	5

The degree of antagonism by the *Trichoderma* species was measured using the rating scale developed by Bell et al. (1982).

Table 2. Effect of *Trichoderma viride* and *Trichoderma* sp (*T5*) on damping off of onion (cv. Yellow Granex) caused by *Fusarium, Sclerotium,* and *Rhizoctonia spp.* 14, 21 and 28 days after inoculation. (Trial 2)

Treatment	Percent Damping-off (days) 14	21	28	% Suppression
Fusarium (Purple) alone	17.77	41.87	83.61	-
Fusarium (Purple) + *T5*	11.93	28.17	57.48	26
Fusarium (Purple) + *Tv*	13.66	24.53	61.28	27
Fusarium + Maneb	5.96	14.77	40.62	51
Rhizoctonia alone	20.53	47.08	80.78	-
Rhizoctonia + *T5*	9.83	21.67	60.74	25
Rhizoctonia + *Tv*	10.90	16.41	39.73	51
Rhizoctonia + Maneb	40.80	82.89	91.70	(-)
Sclerotium alone	11.62	19.56	42.74	-
Sclerotium + *T5*	4.30	17.94	39.24	8
Sclerotium + *Tv*	6.94	18.86	40.62	4
Sclerotium + Maneb	7.06	14.05	35.12	17
Uninoculated (control)	0.00	0.00	0.00	-
LSD (.05)	11	11	17	
LSD (.01)	14	15	22	

Tv - *Trichoderma viride;* T5- *Trichoderma* (onion isolate); %Suppression = pathogen alone - pathogen + *Trichoderma* / pathogen alone X 100

2. *Bacillus* spp. against Root-knot Nematode

A total of 23 isolates from Dr. H. Truong and 16 isolates from Dr. Padua were initially tested *in vitro* against *M. graminicola* juveniles. Among Dr. Troung's isolates, three strains of *Bacillus megaterium* and a strain of *B. subtilis* were selected based on the lowest number (77-94) of juveniles that passed through the modified sieves. From Dr. Padua's isolates, PSB 9113 and G8 were selected, both of which were strains of *B. thuringiensis.*

Analysis of exposure time indicated that the pathogens must be exposed for at least three days to the biological control agents to determine their effectiveness (Table 3). In our second trial using the selected isolates, isolate PSB 9113 gave the highest control of *M. graminicola* (Table 4). These isolates will be further tested *in vivo* to confirm their potency.

Table 3. Number of live juveniles of *Meloidogyne graminicola* recovered 1, 2, and 3 days after exposure to bacterial cells and root and stem extract of *Eclipta prostrata* (L)L.

Exposure time	No. of nematodes (n=40/exposure)
1 day	114a
2 days	114a
3 days	96b

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT significantly different at the 5 % level by DMRT.

Table 4. Number and percentage control of *Meloidogyne graminicola* J2 by *Bacillus* sp and extract from *Eclipta* sp.(T7-T9) after three days of exposure

Treatment	No. recovered	Control
1 = 0.5 ml *Bacillus megaterium* #2 + 0.5 ml Mg suspension	86 ab	26.9
2 = 0.5 ml *Bacillus megaterium* #3 + 0.5 ml Mg suspension	88 ab	25.2
3 = 0.5 ml *Bacillus megaterium* #5 + 0.5 ml Mg suspension	88 ab	25.2
4 = 0.5 ml *Bacillus subtilis* #7 + 0.5 ml Mg suspension	101 ab	13.5
5 = 0.5 ml PSB 9113 + 0.5 ml Mg suspension	66 b	44.0
6 = 0.5 ml G8 + 0.5 ml Mg suspension	100 ab	14.7
7 = Root extract of *Eclipta* sp. (0.5 ml) + 0.5 ml Mg suspension	116 a	0.9
8 = Stem extract of *Eclipta* sp.(0.5 ml) + 0.5 ml Mg suspension	97 ab	15.5
9 = Root and stem extract of *Eclipta* sp. (0.5 ml) + 0.5 ml Mg suspension	100 ab	14.3
10 = Distilled water (0.5 ml) + 0.5 ml Mg suspension (Control)	117 a	0.0

In a column, means followed by a common letter are not significantly different at the 5% level by DMRTsignificantly different at the 5 % level by DMRT.

Studies on the biology of *M. graminicola* showed that under well-drained conditions, the second stage juveniles (J2) penetrated the roots 2 days after inoculation with an average of 5% penetration rate. J3 and J4 were observed 5 days after inoculation; young females without eggs, 13 days after; and mature females with eggs as early as 17 days. Galls on the

roots became evident one week after inoculation. On the average, there were 54 eggs per egg mass, 9 mature females per gall, and about 39 galls per root system.

Impact

The potential of non-chemical management strategies like plant antagonists, biological control agents, and animal manure against nematode, pink root and bulb rot pathogens were identified.

The use of antagonists against damping off pathogens may be feasible with the discovery of *Trichoderma* species that are very effective and suppressive. While we understand their limitations these biological control agents should be tried in the field especially during the seedling stage of onion. Their use should compliment the use of chemicals. Continued efforts must be made in discovering other antagonists especially from other organic waste materials and in soil rich in organic matter.

The use of chicken and cow manure alone at 5 tons per hectare can significantly reduced nematode development and population density in roots and soil. Combining chicken and cow manure with VAM can further reduced the nematode especially when VAM and the manure are applied ahead of the nematode. While we see the limitations of this method of managing the nematode, especially the availability of manure, this may be an appropriate alternative method. Likewise this can be used on small farms in which onion is grown.

Plant extracts with nematicidal activity can be used as an alternative method against *M. graminicola*. This is feasible and more economical because these plants are abundant and locally available.

Networking Activities

- "Workshop on Cultural Management Practices and IPM for Vegetables". PhilRice, Muñoz, N.E. July 14-15, 1999.
- "Training for Agriculture Technicians and Farmer Leaders on Rice-Vegetables with Emphasis on IPM". PhilRice, Muñoz, N.E. August 2-6, 1999.
- S. Miller traveled to PhilRice in October 1998 and February 1999 to evaluate research results and participate in planning for Year 7 experiments.

Presentations

"Management of Soil-Borne Diseases in Rice-Vegetable Systems," 30th Annual Scientific Meeting and Convention, Pest Management Council of the Philippines, May 4-6, 1999, PhilRice, Munoz, Nueva Ecija

"The Soil-Borne Diseases in Rice-Vegetable Systems," 30th Annual Scientific Meeting and Convention, Pest Management Council of the Philippines. May 4-6, 1999. PhilRice, Muñoz, Nueva Ecija.

"Antagonistic Effects of *Bacillus* sp. (LEP 118) Against Soil-Borne Pathogens in Rice-Vegetable Systems," 30th Annual Scientific Meeting and Convention, Pest Management Council of the Philippines. May 4-6, 1999. PhilRice, Muñoz, Nueva Ecija.

"Management of Soil-Borne Diseases in Rice-Vegetable Systems," 21st Annual Scientific Meeting. National Academy of Science and Technology . May 4-6, 1999. Manila Hotel. Manila, Philippines.

"Bacterial Wilt of Eggplant Caused by *Ralstonia solanacearum*," Training for Agricultural Technicians and Farmer Leaders on Rice-Vegetable with Emphasis on IPM, August 2-6, 1999, PhilRice, Muñoz, Nueva Ecija, Philippines.

"Diseases of Onion and Eggplant in Rice-Vegetable Systems," Training for Agricultural Technicians and Farmer Leaders on Rice-Vegetable with Emphasis on IPM, August 2-6, 1999, PhilRice, Muñoz, Nueva Ecija, Philippines.

Project Highlight

This research has shown that the bacterial antagonist LEP 118 has the potential controlling the pink root and other soil-borne pathogens in rice-onion systems and can be more effective if applied as protective coating on the root surface.

Characterization of Purple Nutsedge (*Cyperus rotundus* L.) in Rainfed Rice-Onion Systems

Investigators: M. C. Casimero[1], E.C. Martin[2], F. Bajo[1], Jr., S.R. Obien[1], A. M. Baltazar[2], and S. K. De Datta[3]

Abstract

Morphologic and genetic variations of upland and lowland ecotypes of purple nutsedge were determined in laboratory and greenhouse studies. Tubers of upland and lowland ecotypes of purple nutsedge were collected from three villages in Nueva Ecija province, Philippines where the weed was observed to grow in both wet and dry seasons in the same field. The tubers were sprouted and grown in the greenhouse to determine if morphologic and genetic variation between the two ecotypes exists. Morphologic characterization of the two ecotypes showed significant variation. The lowland ecotype was significantly taller, had more offshoots, more seeds per inflorescence and flowered later than the upland ecotype. Tuber number and tuber weight were, however, significantly higher in the upland ecotype. Genetic analysis using RAPDs technique showed distinct variation between the upland and lowland ecotypes in two villages. The lowland ecotype either possessed one additional DNA band or a band in a different position or absence of a band, with each of the tested primers. Cluster analysis revealed variability between the upland and lowland ecotypes particularly in the two villages where the rice-onion rotation is done continuously. These variations in the morphologic and genetic characteristics between the upland and lowland ecotypes may have resulted from the alternate wet and dry regimes over the years which favored the selection of a type of purple nutsedge that can adapt to both upland and lowland conditions. This has significant implications in the management of purple nutsedge, which is the dominant weed in rice-onion rotation systems.

Objective

This study was conducted to determine the morphologic and genetic variations in the upland and lowland ecotypes of purple nutsedge.

Research Methods

Collection of tubers

Tubers of purple nutsedge were collected from 12 fields where the weed was observed to grow in both wet and dry seasons in three villages namely, Abar 1st, Santo Tomas and Palestina, in San Jose, Nueva Ecija province. Tubers of purple nutsedge growing in rice paddies collected during the 1997 wet season were used for the lowland setup. For the upland setup, tubers were collected during the fallow period following onion in the 1997- 1998 dry season.

Morphologic variation

Uniformly sized tubers were sprouted in petri dishes then transferred to plastic bags lined with moist filter paper to germinate until the seedlings reached one cm. For the upland setup, size #12 clay pots were filled with clay loam soil obtained from the PhilRice Central Experiment Station. For the lowland setup, size #12 clay pots without holes were filled with Maligaya clay soil (fine montmorillonitic isohyperthermic Ustic Epiaquerts). Three seedlings were planted in each pot then thinned to one plant per pot when the seedlings reached 4-5 cm. In the upland setup, the soil moisture was maintained at saturation until harvest. Water was maintained at 3-5 cm simulating flooded condition in the lowland setup until harvest. Plants were grown in natural environmental conditions from September to December 1997 (lowland set up) and from March to July 1998 (upland). Each treatment was replicated four times and arranged in completely randomized design. Plant height, number of off shoots and number of leaves were recorded biweekly. The number of days to flowering was determined when 50% of the florets had emerged. Plants were harvested at 120 days after emergence (DAE). Fresh weight of tubers, tuber number, and number of rays/inflorescence and number of seeds/inflorescence were recorded.

Genetic variation

Plants were sprouted and grown as in the morphologic variation study. Freshly harvested leaves of 40-45 day old purple nutsedge were cleaned and cut into small pieces. A sample of 8 g from each plant was ground in mortar and pestle with liquid nitrogen. The finely ground tissue was

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placed in plastic tubes and added with 20 ml of previously boiled 1.5X CTAB extraction buffer composed of 1.5% CTAB (alkyltrimethyl ammonium bromide), 0.075 M Tris-HCl pH 8.0, 15 mM EDTA pH 8.0, 1.5 M NaCl (w/v). The samples were incubated in a water bath at 56°C for 20 min with mild shaking then extracted with 20 ml (1 vol) chloroform isoamyl alcohol (24:1; v/v). The mixture was again incubated for 30 min at room temperature with mild shaking in a rotary shaker then centrifuged at 2800 rpm for 30 min. The upper layer (aqueous phase) was collected and transferred into a new tube and added with 2 ml of 10% CTAB and mixed gently. Twenty ml (1 vol) of chloroform isoamyl alcohol (24:1, v/v) was added and mixed using a rotary shaker at room temperature for 20 min then centrifuged at 2800 rpm for 30 min. The upper layer was again collected and added with 20 ml (1 vol) CTAB precipitation buffer made up of 1% CTAB, 50 mM Tris-HCl pH 8.0, and 10 mM EDTA pH 8.0. The mixture was mixed slowly using a rotary shaker until DNA precipitate formed then stored overnight at 4°C to make a more fibrous DNA clot. The mixture was centrifuged at 2800 rpm for 20 min to separate the DNA clot. The supernatant was discarded by inverting the tube in a paper towel to get rid of the excess liquid. Five ml of 1M NaCl with 5 µl RNAse (stock:10 mg/ml) was added to the DNA precipitate. The mixture was incubated in 56°C water bath until the DNA was dissolved completely then added with 10 ml of 99.5% cold ethanol. The DNA was collected by swirling the sterile bent pipette until the DNA adhered to the tip. The DNA was washed by immersing in a tube with 70% EtOH for 7 min, then transferred to another tube with 70% EtOH for 30 min and then in a tube with 99.5% EtOH for 5 min. The DNA was air dried for 2 min, re-dissolved in 2 ml of 10% TE buffer and stored at 4°C.

Random Amplified DNA (RAPD) analysis

The standard RAPDs protocol developed by Williams et al (1990) was optimized to obtain good amplification of purple nutsedge genomic DNA. DNA concentrations ranging from 2, 5, 10 and 15 ul were tested to determine the optimum concentration. Different concentrations of magnesium chloride, deoxy nucleotide triphosphates (dNTPs) mix and PCR buffer were tested in the optimization process. The Polymerase Chain Reaction (PCR) mixture which gave the best amplification was composed of 6.8 ul sterile distilled water, 2.0 µl 10x PCR buffer, 0.4 µl 5mM dNTPs, 3.8 µl 10 mM MgCl2, 1 µl random decamer primer manufactured by Operon Technologies Inc. (Alameda, CA), 1 µl of homemade Taq polymerase to yield 15 µl of PCR mixture. Five µl of genomic DNA (adjusted to a concentration of 5 ng/µl) was transferred to plastic thermocycler wells and 15 µl of the PCR mixture was added. One drop of mineral oil was overlaid to the mixture to prevent evaporation. Properly labeled samples were placed in automated thermocycler (PTC-100 Programmable Thermal Controller, MJ Research, Inc.) programmed to pass 45 cycles, each consisting of 5 min at 95°C (initial denaturation), 1 min at 95°C (annealing), 1 min at 36°C (extension) and 1 min at 72°C (denaturation). At the end of 45 cycles, a final extension step was allowed to proceed at 72 °C for 7 min.

Five µl of the loading dye was added to the amplified DNA products prior to gel electrophoresis. The gel was prepared by using 2% agarose gel in 1X TAE buffer. Ethidium bromide (5 mg/ml) was added to stain the DNA bands. Fifteen µl sample was taken out of the plastic thermocycler wells and loaded to the wells of the gel. The voltage was set at 90 volts for 4 hr. The gel was viewed in a UV transilluminator then photographed using a Polaroid camera.

To ensure that the amplification products were consistent and reproducible, the DNA extracts were subjected to three PCR runs for each primer at different times. Different batches of PCR cocktails were used in each PCR run. A control without the DNA extract was included in each run. Only those bands that appeared consistently in all trials were included in the scoring. Bands generated in RAPDs were scored either as present or absent designated as 1 and 0, respectively. Genetic variation between populations of lowland and upland ecotypes of purple nutsedge was determined using the Nei's distance formula (Nei, 1972). A dendogram was created using the unweighted pair group method with arithmetic averages (UPGMA) cluster analysis. All genetic distance calculations and the dendogram were made with the aid of NTSYS-pc version 1.8 (Rohlf, 1993).

Results

Morphologic variation

The morphologic parameters measured are summarized in Table 1. Plant height and number of offshoots of the lowland ecotype were significantly higher in Abar 1st and Palestina compared to the upland ecotype. The number of leaves and inflorescence per plant and rays per inflorescence did not significantly vary between the lowland and upland ecotypes in all three sites. Significantly more and bigger tubers were observed in the upland ecotypes from Santo Tomas and Palestina. More seeds per inflorescence were obtained from the lowland ecotype than from the upland ecotype. However, only the lowland ecotype from Abar 1st showed significantly more seeds per inflorescence. The lowland ecotype flowered significantly longer by 12-14 days in Abar 1st and Santo Tomas compared to Palestina. Initial morphological characterization showed that the lowland ecotypes were taller and had 60% more biomass than the upland types. When submerged in 5 cm water, tubers of the lowland ecotype grew as well as the upland ecotype (Baltazar et al, 1997b).

Table 1. Growth parameters measured in upland and lowland purple nutsedge collected from three sites.

Growth Parameters	Abar 1st [a]			Sto. Tomas [a]			Palestina [a]		
	Low land	Up land	Diffe rence	Low Land	Up land	Differ ence	Low land	Up land	Diffe rence
Plant height (cm)	106	93	13*	99	103	4	83	63	20**
No. of offshoots	18	7	11*	13	9	4	13	7	6*
No. of leaves	315	221	93	282	386	104	275	294	19
No. of Inflorescence	8	10	2	9	10	1	8	7	1
No. of rays / Inflorescence	47	48	1	71	79	8	49	48	1
No. of tuber/plant	27	36	9	38	56	18*	37	66	29**
Wt. of tuber/plant (g)	18	27	9	22	38	16*	23	51	28**
No. of seed/ Inflorescence	56	0	56**	51	28	11	35	23	18
Days to flower	44	30	14**	36	24	12**	27	28	1

[a] Average of four replications
* Significant at 5* level, ** Highly significant at 5% level

Genetic variation

The upland and lowland ecotypes showed genetic variation in 42 out of the 65 primers that produced polymorphic DNA bands. Differences were seen in the number and position of DNA bands of lowland and upland ecotypes (Figure 1). The lowland ecotypes either possessed an extra band or had missing bands or possessed a band in a different position compared to the upland ecotypes as shown in the polymorphic bands amplified with OPAO-02. Polymorphic bands amplified with the primer are indicated by arrows labeled a, b, c, d. DNA bands generated with OPAO-02 showed variable polymorphism in most sites as shown by the differences in RAPDs product patterns.

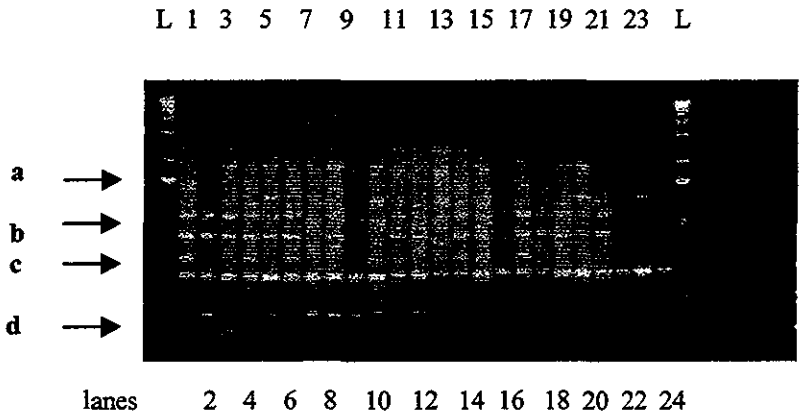

Figure 1. Genomic DNA fragments from 24 populations of upland and lowland ecotypes of purple nutsdege amplified with OPAO-02 primer. Lanes: L, DNA size marker; 1, Field 1 Abar 1st lowland (L); 2, Field 1 Abar 1st upland (U) ; 3, Field 2 Abar 1st U; 4, Field 2 Abar 1st L; 5, Field 3 Abar 1st U; 6, Field 3 Abar 1st L; 7, Field 4 Abar 1st L; 8, Field 4 Abar 1st U; 9, Field 1 St. Tomas U; 10, Field 1 Sto. Tomas L; 11, Field 2 Sto. Tomas U; 12, Field 2 Sto. Tomas L; 13, Field 3 Sto. Tomas U; 14, Field 3 Sto. Tomas L; 15, Field 4 Sto. Tomas L; 16 Field 4 Sto. Tomas U; 17, Field 1 Palestina L; 18, Field 1 Palestina U; 19, Field 2 Palestina U; 20, Field 2 Palestina L; 21, Field 3 Palestina U; 22, Field 3 Palestina L; 23, Field 4 Palestina U; 24 Field 4 Palestina L.

Genetic dissimilarity distance was obtained using the bands generated with RAPDs. The genetic distance ranged from 0.15 to 0.45 with the majority of the gene frequency occurring at 0.23 to 0.36 (Figure 2). The data indicate genetic variability among the different populations of lowland lanes and upland ecotypes of purple nutsedge. A dendogram (Figure 3) for the 24 populations of upland and lowland ecotypes of purple nutsedge was generated using UPGMA cluster analysis. Several branches were present on the dendogram with the lowland and upland ecoytpes in all fields in Palestina forming a single broad cluster. This observation is expected as the rice farms in Palestina are sometimes left fallow during the wet season resembling an upland condition. Two distinct and separate clusters were formed for Sto. Tomas and Abar 1st. The lowland ecotype from three fields in Abar 1st was distinctly separated from the upland ecotype. Similarly, the lowland ecotypes from two fields were separated from the cluster formed by the

upland ecotype from Santo Tomas. These results indicate genetic variation between the lowland and upland ecotypes of purple nutsedge particularly in Abar 1st and Santo Tomas. A more systematic sampling from a small area might lead to a more distinct clustering that separates the lowland ecotype from the upland ecotype.

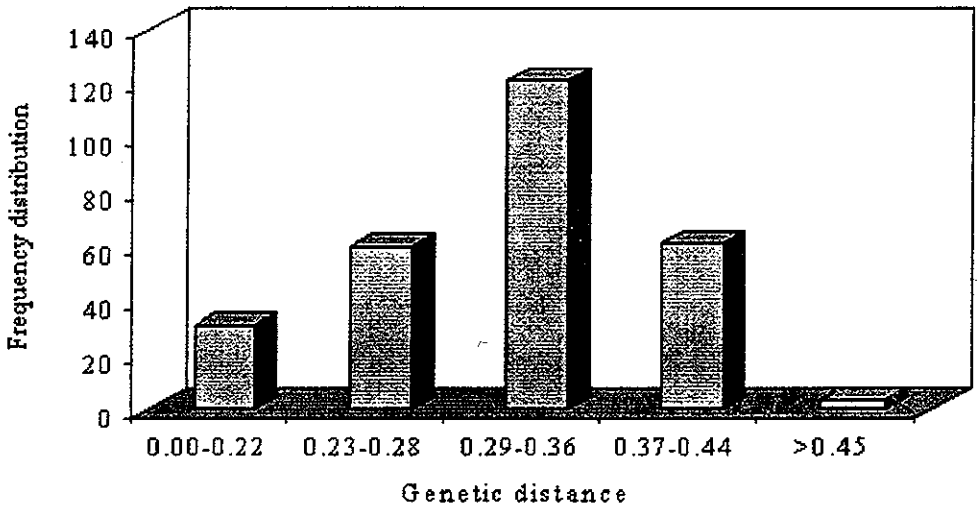

Figure 2. Frequency distribution of genetic dissimilarity distance of upland and lowland ecotypes of purple nutsedge collected from three villages.

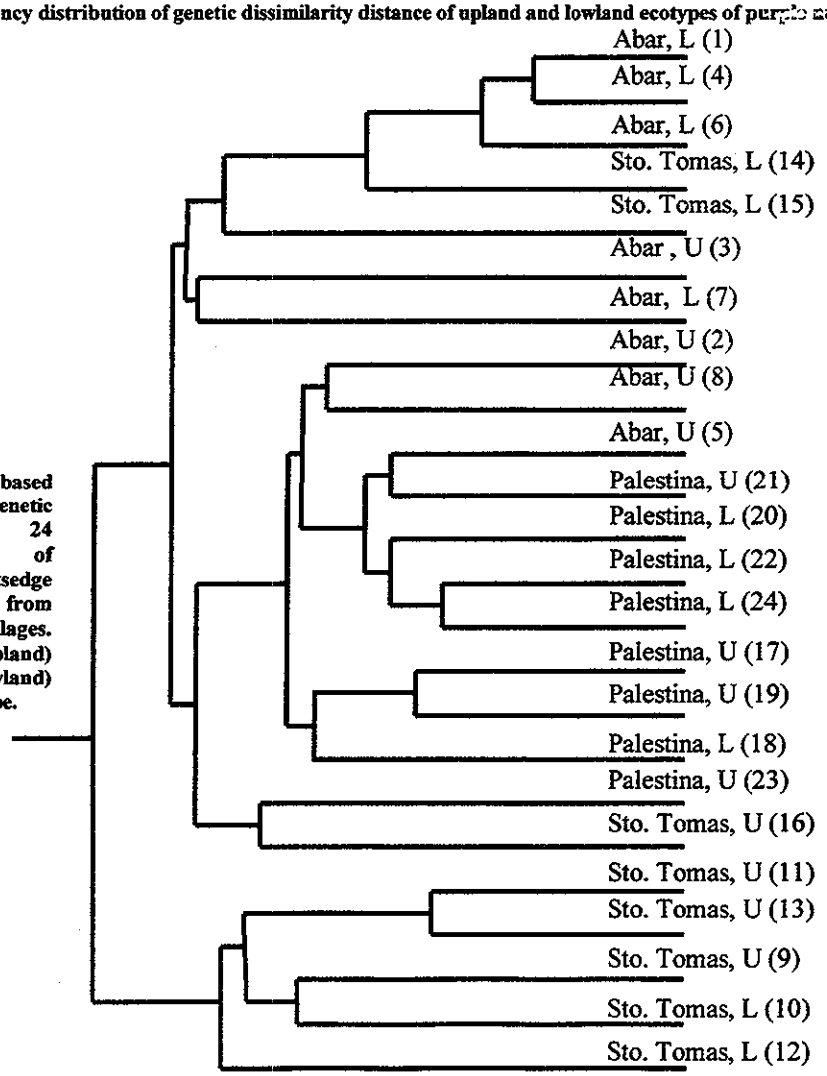

Figure 3. Dendogram based on Nei's genetic distance for 24 populations of purple nutsedge collected from three villages. Letters U (upland) and L (lowland) indicate ecotype.

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Impact

The occurrence of *C. rotundus* in both onion and rice crops poses more problems to farmers. Results of the study show morphologic and genetic variations between the upland and lowland ecotypes of *C. rotundus*. The observations made in this study will be used as a basis in the development of management strategies to control *C. rotundus* in rainfed rice-onion systems. The lowland and upland types of *C. rotundus* may respond differently to herbicide treatments, hence, cultural management strategies have to explored to manage the weed.

Networking Activities

S. K. DeDatta traveled to PhilRice in October 1998 to evaluate research results and participate in planning for Year 7 experiments.

Project Highlight

Morphologic and genetic variation was observed between the lowland and upland types of *C. rotundus*. The results of this study will serve as a basis in formulating short-term and long term integrated weed management strategies in rice-onion rotation systems.

Evaluation of the Feasibility of Bt Transgenic Eggplant Production for South Asia

Investigators: L. Sebastian[1], N. S. Talekar[2], G. Jelenkovik[3], S. Miller[4], E. Rajotte[5]

Abstract

Development of Bt transgenic Asian eggplant varieties was determined to be feasible. A strategy for such development was defined, and a proposal written by Dr. Jelenkovic. However, further work is currently limited due to funding constraints. Availability of Asian eggplant varieties resistant to the fruit and shoot borer could result in significant reductions in insecticide use in South and Southeast Asia.

Objectives

To investigate the feasibility of developing transgenic pest-resistant eggplants for use in South and Southeast Asia. Specifically, the objectives are (1) to evaluate eggplant production practices and assess available production material and lab/field facilities, and (2) to construct a strategy for developing and testing Bt transgenic eggplants in Asia.

Research Methods

For the last several years Dr. Goiko Jelankovic, a research horticulturist at Rutgers University in New Brunswick, New Jersey, has been developing transgenic eggplants to resist damage by Colorado potato beetle using *Bacillus thuringiensis* (Bt). Transgenic plants have been successfully tested in the field in New Jersey. In Year 6, E. Rajotte visited with Dr. Jelankovic to discuss a similar transgenic approach to controlling eggplant fruit and shoot borer in Asian eggplant varieties. As part of that process Dr. Jelankovic visited the Asian Vegetable Research and Development Center in Taiwan as well as UPLB and PhilRice in the Philippines to meet counterpart scientists, collect eggplant seeds and evaluate Asian growing conditions. Greenhouse production of Asian eggplants has been initiated at Rutgers. A proposal to develop transgenic Asian eggplants has been developed and is still under consideration primarily because it is too expensive to be done under the auspices of IPM-CRSP at this time.

Impact

This type of research extends the possibility of greatly improving Asian eggplant yields and reducing pesticide use.

Networking Activities

G. Jelenkovic visited AVRDC, UPLB, and PhilRice and interacted with counterpart scientists to develop a strategy for production of Bt-transgenic Asian eggplant.

Project Highlight

Development of transgenic Asian eggplant varieties is feasible but currently limited by funding constraints. However, availability of varieties resistant to the fruit and shoot borer could result in highly significant reductions in pesticide use.

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[3] Rutgers University
[4] Ohio State University
[5] Penn State University

Interaction Effects of *Phoma terrestris*, *Fusarium* spp. and *Meloidogyne graminicola* on Pink Root Bulb Rot Severity of Onion
(special project)

Investigators: R.T. Alberto[1], S.E. Santiago[2], E.B. Gergon[2], V.L. Judal[2], M.S. Castro[2], J.R. Casayuran[2], M.C.B. Falla[2], L.S. Sebastian[2], and S.A. Miller[3]

Abstract

Tests were conducted for seven soil-borne pathogens in the laboratory and for *Phoma terrestris*, three species of *Fusarium* and their combinations in greenhouse experiments to determine the capability of the isolates to cause disease in onion bulbs and roots. Tests for pathogenicity under laboratory conditions showed lesion formation on onion scales by all of the soil-borne pathogens tested except *Phoma terrestris*. Under greenhouse conditions, *P. terrestris*, in combination with *Fusarium* 1, 2, or 3 can cause high incidence of post-emergence damping-off and bulb rotting. *Phoma* if inoculated alone does not cause pink root infection. Results on the interaction effects of *Fusarium* spp., *P. terrestis*, and *Meloidogyne graminicola* showed that all the inoculated plants were positive to *M. graminicola* but not to pink root and bulb rot infections.

A rapid and efficient method of detection for *P. terrestris* in onion roots using PCR technology was tried. The Pt primers developed in OSU-OARDC did not amplify the DNA of local *P. terrestris* isolates nor its presence in onion roots taken from different onion fields. Differences in DNA sequence of both the Pt primers and the DNA of local *Phoma* isolates could be one of the reasons for the failure. A new set of primers should be developed and its sequence should be based on the DNA of the local *Phoma* isolates.

Objectives

1. To determine the single and combined effects of *P. terrestris, Fusarium* spp. and *Meloidogyne graminicola* on the severity of root knot, pink root, and bulb rot diseases of onion;
2. To determine the nematode/spore densities that can cause significant yield reduction in onion; and
3. To develop a rapid and efficient method of detection for *P. terrestis* in onion root tissues.

Research Methods

1. Pathogenicity Tests of *P. terrestris* and *Fusarium* spp.

Laboratory

Pathogenicity of the different soil-borne fungal pathogens was tested in segments of Yellow Granex and Tanduyong onions using scale inoculation technique. Diameter of lesions on onion segments was determined 7 days after inoculation.

Greenhouse

Pathogenicity of *P. terrestris* and *Fusarium* spp. was tested in Yellow Granex and Tanduyong onions. The soils were inoculated with the fungal spores before seeding (Yellow Granex) and transplanting (Tanduyong). Incidence of pre-emergence damping-off was taken in Yellow Granex 1 week after seeding. Bulb rotting and pink root incidence were monitored at 30, 60 and 90 days after transplanting. Incidence of bulb rotting and pink root in Tanduyong were assessed at 30, 60 and 90 DAT.

- Molecular detection of *Phoma* using PCR assay.

Fungal Isolates

P. terrestris, Fusarium sp. 1,2 and 3, *Sclerotium rolfsii* and *Rhizoctonia solani* were mass- produced in potato dextrose broth. Fungal mycelia were harvested from the broth and dried using sterilized absorbent tissue paper. The mycelia were further dehydrated using liquid nitrogen before grinding. DNA's of the fungal isolates were extracted following the methods of Lee and Taylor (1990). DNA's were amplified in thermocycler using specific primers (ITS and Pt) developed in OARDC and 100 RAPD primers. The amplified DNA's were run in agarose Gel Electrophoresis and the DNA bonds were detected under UV light.

Onion Roots

Healthy and pink root infected onion roots were ground using a conical grinder. DNA of healthy onion roots was

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extracted using the CTAB method and methods of Lee and Taylor (1990). The extracted DNA's were amplified in thermocycler using specific primers developed in OARDC. The amplified DNA's were run in Agarose Gel Electrophoresis and the DNA bonds were detected under UV light.

3. Fungal pathogens and nematodes

A greenhouse study was conducted on the combined effects of *M. graminicola, P. terrestris,* and *Fusarium spp.* on the pink root and bulb rot severity of onion. *P. terrestris* and the three species of *Fusarium* were mass-produced in sand corn meal agar and *M. graminicola* in potted onion plants. Fifty grams of two-week-old cultures of *P. terrestris, Fusarium* spp. 1, 2, and 3 and their possible combinations and different juvenile densities of M. graminicola were inoculated in direct seeded and transplanted onion (45 days old). Plants were sampled at 50 and 120 DAS for direct seeded onion and 120 DAT in transplanted onion to assess the incidence and severity of pink root, bulb rot and root galling. Presence of *Fusarium* in the soil was checked and re-isolated using a soil-dilution technique.

Results

1. Pathogenicity

Laboratory

The first trial of the experiment using Yellow Granex as test variety showed that the onion scales inoculated with *Sclerotium* gave the highest average lesion diameter of 20.75 mm followed by *Fusarium* 3,2 and *Rhizoctonia* with average lesion diameters of 3.5mm, 3.5mm and 3.0mm, respectively. No infection or lesion was recorded on scales inoculated with *Phoma* and the uninoculated control. The trend was similar when the pathogens were tested in Tanduyong variety except that the lesions produced by the three species of *Fusarium* and *Rhizoctonia* were slightly larger. Results of the second trial showed high aggressiveness of *Sclerotium* in both varieties tested with average lesion diameter of 69.37mm and 56.25mm, respectively. Low aggressiveness was recorded on other pathogens with lesion diameters ranging from only 1.25mm to 5.75mm in both varieties. For the second trial, no infection or lesion occurred in onion scales of either variety inoculated with *Phoma* and uninoculated control. Non-infection of *Phoma* in onion scales is expected since it is a root pathogen and unlike *Fusarium* spp, *Rhizoctonia* and *Sclerotium* which shows aggressiveness to onion scales.

Greenhouse

Results of the first trial on the pathogenicity of *Phoma, Fusarium* and their combinations on the incidence of post-emergence damping-off with Yellow Granex as test variety showed high incidence of the disease (29.2%) on onion plants infected with the combination of *Phoma* and *Fusarium* 1. This was followed by *Fusarium* 3 and 1 with 24.4% and 22.9% incidence, respectively. Low incidence was recorded on plants inoculated with the combinations of *Phoma+Fusarium* 2 and *Phoma+Fusarium* 3 with 7.4% and 4.6%, respectively. No incidence of post-emergence damping-off was recorded on plants inoculated with *Phoma* alone and the Uninoculated Control. *Phoma+Fusarium* 1 treated plants still showed the highest percent incidence of the disease (37.5%) on the second trial followed by *Phoma+Fusarium* 2 and *Fusarium* 1 with 16.7% and 12.5%, respectively. *Phoma* alone-inoculated plants showed non-occurrence of the disease.

On pink root and bulb rot incidence, results of the first trial showed high incidence of bulb rot on plants inoculated with *Phoma+Fusarium* 1 (77.8%), followed by *Fusarium* 1 (70.2%), and *Fusarium* 3 (56.2%). Plants inoculated with *Phoma* alone and the Uninoculated Control showed no symptoms of pink root and bulb rot. High temperature prevailing inside the greenhouse, absence of actual field conditions or non-virulence of *Phoma* isolate could be one of the factors for negative results on *Phoma* infection. On the second trial, high incidence of bulb rotting was observed in all of the treatments except in plants inoculated with *Phoma* alone and Uninoculated Control where no pink root was observed. *Phoma+Fusarium* 3 inoculated plants has the highest incidence of bulb rot followed by *Phoma+Fusarium* 2 and *Fusarium* 2 and the combinations of *Fusarium* 1,2,3 with 87.5%, 78.0%, 69.5% and 69.0%, respectively. Similar trend was observed in Tanduyong variety.

2. PCR Assay

PCR on fungal isolates showed DNA amplification on *Phoma* isolates 1,2,3 and 4, Fusarium 1,2 and 3, *Rhizoctonia solani* and *Sclerotium rolfsii* using ITS 4&5 primers at annealing tempt of 56°C at 2% agarose. There was no amplification, however, when Pt primers 1 and 2 were used. Similar results were obtained when annealing temperature was lowered to 52°C at the same concentration of agarose. When all of the DNA's were analyzed using RAPD with OP748 primer, an amplification occurred showing different DNA profiles for *Phoma*, three species of *Fusarium, Rhizoctonia* and *Sclerotium.* DNA profiles of the six *Phoma* isolates were similar except for PT3s with an extra band at 1.3 kb. A constructed dendogram showed that all the *Phoma* isolates were closely related to each other and so with *Rhizoctonia* and *Sclerotium,* and *Fusarium* 1 and 2.

PCR of infected roots from different sampling places using Pt primers at adjusted annealing temperature of 56°C showed negative results. ITS primers yielded positive results, however, it amplifies even the genomic DNA of onion roots.

The negative results could be due to the differences in the DNA sequence of the PT primers (developed based on the

US *Phoma* isolate) and the DNA of the local *Phoma* isolate. Though amplification was observed using ITS primers, still it cannot be used for rapid detection because of its ability to amplify DNA's of other fungal isolates and the genomic DNA of onions.

- Fungal Pathogens and Nematode

All the inoculated plants were positive to *M. graminicola* but not to pink root and bulb rot infections. These results may be due to the microenvironment in the greenhouse not favorable for infection or low virulence of the pathogen due to subsequent transfer or low inoculum density.

Impact

Development of rapid detection method for routine diagnosis of pink root disease of onion.

Networking Activities

"Workshop on Cultural Management Practices and IPM for Vegetables". PhilRice, Muñoz, N.E. July 14-15, 1999.

"Training for Agriculture Technicians and Farmer Leaders on Rice-Vegetables with Emphasis on IPM". PhilRice, Muñoz, N.E. August 2-6, 1999.

S. Miller traveled to PhilRice in October 1998 and February 1999 to evaluate research results and participate in planning for Year 7 experiments.

Training

R. Alberto trained in Dept. of Plant Pathology (PCR Lab), OARDC, OSU, Wooster, OH on the "Principles and Application of Molecular Detection Technologies of *Phoma terrestris*" from August 9 to October 9, 1998, under the supervision of S. Miller.

Publications and Presentations

IPM CRSP. 1999. Pink Root Disease of Bulbs. PhilRice. Maligaya. Muñoz, Nueva Ecija

IPM CRSP. 1999. Training Manual in Rice-Vegetable Production with Emphasis on IPM, PhilRice, Muñoz, Nueva Ecija.

Project Highlight

Development of correct primers for local *Phoma* isolates could be a reliable and rapid diagnostic tool for pink root disease of onion.

Management of Bacterial Wilt Disease in Eggplant Using Genetic Resistance and Cultural Management

Investigators: N.L. Opina[1], R.T. Alberto[2], B.E. Santiago[3], and S.A. Miller[4]

Abstract

The variety of eggplant significantly affected the incidence and Area Under Progress Curve (AUDPC) of bacterial wilt. Jackpot and Dumaguete Long Purple cultivars gave lower incidence and AUDPC of bacterial wilt compared to the Abar cultivar. Cultivated soil without rice straw mulch gave the lowest AUDPC while the soil that has been cultivated and mulched generated the lowest bacterial wilt incidence. The population of the bacterium in the soil markedly decreased 3 months after transplanting from 7 x 10 ^{5} CFU/ml to 0.16 x 10 ^{5} CFU/ml when the soil was cultivated and not mulched with rice straw compared to the treatments with rice straw mulching. The total fruit yields of eggplant cultivars were significantly higher in mulched than in unmulched plots. The Abar cultivar gave the highest yield of 7.58 kg/24 sq. m plots compared to Jackpot and Dumaguete Long Purple with yields of 5.92 and 5.28 kg, respectively. To find additional sources of resistance to bacterial wilt, isolation and classification of the causal bacterium were done and the selected isolates were used for screening for resistance. A total of 96 *R. solanacearum* isolates from eggplant were classified into biovars and of these, 62 belonged to biovar 3 and 34 were biovar 4. Out of 27 eggplant entries screened for resistance to strains of *R. solanacearum*, 6 were resistant and 4 were either resistant or moderately resistant to all strains.

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[2] Central Luzon State University
[3] Philippine Rice Research Institute
[4] Ohio State University

Objectives

1. To determine the effects of resistance on the incidence of bacterial wilt of eggplant.
2. To determine the influence of mulching and tillage on bacterial wilt incidence.

Research Methods

Three eggplant cultivars, namely Abar, Jackpot, and Dumaguete Long Purple (DLP) were grown in farmer's field previously planted to lowland rice and eggplant which was heavily infected with the bacterial wilt pathogen in San Jose, Nueva Ecija. The Abar cultivar, a farmer's variety, was used as check. The seedlings were planted in a 2m x 3 m mulched and unmulched, cultivated and uncultivated plots following a split-plot design with 4 replications. The number of wilted plants were monitored at weekly intervals for a period of 4 months and the effects of mulching, tillage, and eggplant cultivar on bacterial wilt were estimated based on the incidence of the disease at the end of the season and the Area Under Disease Progress Curve (AUDPC). Likewise, the total fruit yields were recorded from each treatment.

The populations of the bacterium in the soil were estimated at the beginning of the growing season and three months after transplanting. The soil samples were collected from each plot and mixed thoroughly. A 10g soil sample was suspended in 90 ml sterile water, shaken for 30 min and serially diluted up to 10^{-5}. A 100µl aliquot of each dilution was spread on a plated SM-1 medium prepared by adding to Kelmans tetrazolium chloride (TZC) medium the following: crystal violet (50µg/ml); polymyxin B sulfate (100µg/ml), tyrothrycin (20µg/ml) and chloromycetin (5µg/ml). The plates were incubated at 30C for 72 h and the typical *R. solanacearum* that grew in each plate were counted and the number of colony forming units was estimated using the formula:

$$\text{CFU/ml} = \frac{\text{average count x dilution factor}}{\text{volume plated}}$$

To search for additional sources of resistance to bacterial wilt, isolation and biovar classification of the causal bacterium collected from major eggplant growing areas were done. The isolates were classified into biovars following Hayward's method (1964) which was based on the utilization of disaccharides (lactose and maltose) and hexose alcohols (mannitol and sorbitol) and the selected isolates were used in screening for resistance.

A total of 6 *R. solanacearum* isolates, which were obtained from Nueva Ecija, Pangasinan, Batangas and Laguna were tested against 27 eggplant entries. The seedlings were grown in plastic cups and 30 ml of standardized bacterial suspension from 24-h old culture were poured onto the base of 4 wk-old seedlings. The seedlings were not watered and the roots were wounded using a knife on the day of inoculation. The inoculated seedlings were kept in the greenhouse and the number of wilted plants were monitored daily for a period of 21 days. The daily temperature in the greenhouse was recorded at 11:00AM. and 2:00 PM throughout the conduct of the experiment. The disease reactions of different entries were based on the developed rating scale as follows: Resistant = 0-29% infection, Moderately resistant =30-59% infection, Moderately Susceptible = 60-79% infection and Susceptible = 80-100% infection.

Results

The effects of host plant resistance and cultural practices on the management of bacterial wilt of eggplant were evaluated on the basis of disease incidence at the end of the season and AUDPC. The variety of eggplant significantly affected the incidence and AUDPC of bacterial wilt (Tables 1 and 2). Jackpot and Dumaguete Long Purple cultivars gave lower incidence and AUDPC of bacterial wilt compared to Abar. The soil that was cultivated and not mulched with rice straw gave the lowest AUDPC value of 11.94 while the soil that was cultivated and mulched generated the lowest bacterial incidence of 16.75 % as compared to uncultivated soil with mulching with an AUDPC and disease incidence of 17.45 and 28.75%, respectively.

Table 1. Incidence of bacterial wilt on different cultural management treatments and eggplant varieties at the end of the season.

Treatment	% Infection			Mean
	Abar	Jackpot	DLP	
ltivated -Mulch	19.25	18.25	12.75	16.75[a]
ltivated - Unmulch	25.00	15.50	12.5	17.67[a]
cultivated - Mulch	46.00	16.75	23.5	28.75[a]
cultivated - Unmulch	30.75	11.00	27.75	23.17[a]
Mean	30.25[a]	15.38[c]	19.13[b]	

CV (a) = 31.5%, CV (b) = 32%; $LSD_{.05}$ = 2.4 %

Table 2. Effect of cultural management and varieties on the Area Under Disease Progress Curve (AUDPC) bacterial wilt on eggplant.

Treatment	AUDPC			Average
	Abar	Jackpot	DLP	
Cultivated -Mulch	23.81	14.33	8.11	15.42[a]
Cultivated - Unmulch	16.44	12.21	7.17	11.94[a]
Uncultivated - Mulch	25.54	13.64	14.08	17.75[a]
Uncultivated Unmulch	17.24	6.74	20.42	14.8[a]
Mean	20.76[a]	11.73[a]	12.45[a]	

CV (a) = 43%, CV (b) = 32%

The populations of the bacterium in the soil were estimated 3 weeks after transplanting the seedlings and 3 months thereafter using a selective medium for *R. solanacearum*. The results showed that there was a marked decrease in the population of the bacterium from 7 x 10^5 CFU/ml to 0.16 x 10^5 CFU/ml when the soil was cultivated and not mulched with rice straw compared to the treatments with rice straw mulching (Table 3). The reduction in the population of the bacterium however, was not enough to significantly reduce the incidence of the disease.

Table 3. Effect of cultural management on population of *Ralstonia solanacearum* in the soil.

Treatment	CFU/ml (x10^5)	
	Feb'99	April '99
Cultivated -Mulch	6.7	7.7
Cultivated – Unmulch	7	0.16
Uncultivated – Mulch	5	4
Uncultivated Unmulch	6	5.3

The total fruit yields of eggplant cultivars grown on mulched, unmulched, cultivated and uncultivated plots were compared. The results showed that the yields of eggplant were significantly higher on mulched than on unmulched plots (Table 4). Abar cultivar significantly gave the highest yield of 7.58 kg /24 sq. m plots compared to Jackpot and Dumaguete Long Purple with yields of 5.92 and 5.28 kg, respectively.

Table 4. Yields of eggplant varieties under different cultural management.

Treatment	Yield (kg)[1]			Average
	Abar	Jackpot	DLP	
Cultivated –Mulch	7.98	6.78	5.18	6.65[ab]
Cultivated – Unmulch	6.05	4.6	4.73	5.13[b]
Uncultivated – Mulch	8.98	7.18	7.6	7.92[a]
Uncultivated Unmulch	7.3	5.13	3.6	5.34[b]
Mean	7.58[a]	5.92[b]	5.28[b]	

CV (a)=28.9%, CV (b) 17%; $LSD_{.05}$ = 1.87; $LSD_{.05}$ = 1.55%

[1]From March 22 - May 17, 1999

To search for additional sources of bacterial wilt resistance in eggplant, isolation and biochemical classification of bacterial wilt pathogen from major eggplant growing areas were made and the selected isolates were tested against 27 entries of eggplant. Of the 96 *R. solanacearum* isolates evaluated 65% belonged to biovar 3 and 36% were biovar 4 (Table 5). Out of 27 eggplant entries screened for resistance to strains of *R. solanacearum*, 6 were resistant to all strains of *R. solanacearum*, 4 were either resistant to some but moderately resistant to other strains and the rest gave a resistant to susceptible reactions to various strains (Table 6).

Table 5. Occurrence of different biovars of *Ralstonia solanacearum* in eggplant

Origin	No. of Isolates in biovar	
	III	LV
Laguna	9	2
Batangas	24	27
Nueva Ecija	14	0
Nueva Viscaya	0	1
Pampanga	1	0
Pangasinan	1	3
Camarines Norte	4	0
Albay	5	1
Sorsogon	2	0
Misamis Oriental	2	0
Total	62	34
Occurrence (%)	64.6	35.4

Table 6. Reaction of different eggplant accessions to the six strains of *R. solanacearum*.

Entries	% Infection (Disease Index)[1]					
	Pangasinan(E154)	Laguna (E174)	Batangas (E129)	Batangas (E104)	Batangas (E106)	Nueva Ecija (E151)
OEG 95-53	56 (MR)	11 (R)	67 (MS)	78 (MS)	100 (S)	44 MR)
Acc 618	78 (MS)	44 (MR)	44 (MR)	56 (MR)	33 (MR)	22 (R)
S90	22 (R)	11 (R)	33 (MR)	56 (MR)	44 (MR)	11 (R)
S69	33 (MR)	44 (MS)	33 (MR)	44 (MR)	78 (MS)	0 (R)
S3	22 (R)	0 (R)	11 (R)	0 (R)	0 (R)	11 (R)
Acc 615	33 (MR)	44 (MR)	11 (R)	56 (MR)	89 (S)	11 (R)
Eg 219	67 (MS)	56 (MR)	100 (S)	100 (S)	100 (S)	100 (S)
Acc 636	67 (MS)	33 (MR)	67 (MS)	56 (MR)	78 (MS)	56 (MR)
Kastanias	89 (S)	44 (MR)	89 (S)	78 (MS)	100 (S)	67 (MS)
OEG 91-049 a	89 (S)	78 (MS)	89 (S)	78 (MS)	78 (MS)	22 (R)
Eg 120	44 (MR)	44 (MR)	56 (MR)	33 (MR)	44 (MR)	11 (R)
Acc 264	11 (R)	0 (R)	22 (R)	22 (R)	67 (MS)	11 (R)
Acc 611	55 (MR)	67 (MS)	100 (S)	89 (S)	67 (MS)	44 (MR)
Eg 192	11 (R)	0 (R)	11 (R)	0 (R)	0 (R)	0 (R)
OEG 89-002	0 (R)	0 (R)	11 (R)	11 (R)	22 (R)	0 (R)
Acc 612	11 (R)	0 (R)	67 (MS)	22 (R)	22 (R)	0 (R)
OEG 95-56	22 (R)	11 (R)	0 (R)	44 (MR)	56 (MR)	33 (MR)
OEG 95-55	55 (MR)	44 (MR)	89 (S)	89 (S)	67 (MS)	33 (MR)
Ac 544	33 (MR)	44 (MR)	44 (MR)	33 (MR)	56 (MR)	22 (R)
EG 195	11 (R)	11 (R)	0 (R)	0 (R)	0 (R)	0 (R)
S 47 a	0 (R)	0 (R)	0 (R)	22 (R)	0 (R)	0 (R)
OEG 91-049 c	33 (MR)	22 (R)	0 (R)	33 (MR)	89 (S)	11 (R)
Acc 616	44 (MR)	0 (R)	44 (MR)	78 (MS)	56 (MR)	11 (R)
EG 203	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Casino	88 (S)	44 (MR)	50 (MR)	88 (S)	88 (S)	22 (R)
Jackpot	11 (R)	0 (R)	11 (R)	56 (MR)	67 (MS)	33 (MR)
DLP	56 (MR)	56 (MR)	89 (S)	78 (MS)	78 (MS)	44 (MR)

[1] R = Resistant (0-29% Infection), MR= Moderately Resistant (30-59% Infection), MS= Moderately Susceptible (60-79% Infection) and S= Susceptible (80 -100% infection)

Impact

Dumaguete Long Purple and Jackpot cultivars can be grown in bacterial wilt infested fields. Bacterial wilt incidence can be reduced when the soil is not mulched with rice straw.

Networking Activities

A. Workshops you have helped plan and/or have participated in

1. Presented a poster entitled " Bacterial Wilt on Eggplant Caused by *Ralstonia solanacearum*" during the presentation of IPM-CRSP Research/Technologies In collaboration with NOGROCOMA Members on July 30, 1999 at PhilRice, Muñoz, Nueva Ecija

2. Participated on the Workshop on Cultural Management Practices and Integrated Pest management (IPM) for Vegetables on July 14-15 1999 at PhilRice, Muñoz, Nueva Ecija

B. Research Information and product Exchange:

1. Impact of CRSP-produced or recommended technology, including crop protection inputs, manuals brochures, etc Assistance you have given to collaborating scientists with research equipment

Networking

S. Miller traveled to PhilRice in October 1998 and February 1999 to evaluate research results and participate in planning for Year 7 experiments.

Publications

Opina, N.L. , Alberto, R.T., Santiago, S.E., Tiongco, E.R. and Miller, S.A. 1999. Bacterial wilt of eggplant caused by *Ralstonia solanacearum*. Poster presented during the presentation of IPM-CRSP Research/Technologies In collaboration with NOGROCOMA Members on July 30, 1999 at PhilRice, Muñoz, Nueva Ecija

Alberto, R.T., Sanchez, L., Amar, G.B., Rillon, J.P., Judal, V.L., Duca, S.V., Santiago, S.E., Padua, L.E., Opina, N.L. and Miller, S.A. 1999. Management of Soil Borne Diseases in Rice-Vegetable Systems. Paper presented during the 30th Anniversary and Annual Scientific Meeting on May 4-6, 1999 held at PhilRice Muñoz, Nueva Ecija

Training Output

Contributor to the IPM-CRSP Training Module on Diseases of Vegetable Crops.

Project Highlights

- Jackpot and Dumaguete Long Purple cultivars gave a lower disease incidence and AUDPC to bacterial wilt compared to Abar cultivar.
- Mulching increased the incidence of bacterial wilt incidence.
- The soils that has been cultivated and not mulched markedly had reduced populations of the bacterium.
- The soil that has been mulched improved the yield of eggplant cultivars.

Economic Impacts of IPM Practices in the Rice-Vegetable System

Investigators: S.R. Francisco[1] and G.W. Norton[2]

Abstract

The results of the different experiments conducted to remedy the pest problem in onion and eggplant showed that majority of the proposed technologies have the comparative advantage over the current farmer's practices. This has a major implication in terms of savings from capital investment and net profits. The proposed technologies have a yield increasing or cost reducing effects or both. Further, these results have clearly showed that the utilization of chemical pesticides in crop production could significantly be lowered with a minimal yield loss. They even have a yield enhancing effect when compared to current farmer's practice. On the welfare of the other members of the society as well as the environment, these results are welcome. The consumers will be safer in terms of smaller possible amount of residue in the vegetables.

Objectives

To evaluate and project impacts of IPM practices tested in the multidisciplinary field experiments on yield, household income, and society.

IPM Constraints

The adoption of IPM practices by farmers will depend on their economic viability. The benefit to society as a whole maybe positive even if they are not beneficial to producers if the use of pesticides that is harmful to human health and environment is reduced. If some practices are beneficial to society as a whole but not to producers, public policies may be required to influence IPM adoption.

Research Methods

Research methods for this activity include partial budgeting and economic surplus analysis. Data on differences in yields, input quantities and associated prices, labor and wages were gathered from each of the multidisciplinary field experiments on onion and eggplant. Partial budgets of each technology were constructed to assess the economic benefits of different alternative pest management strategies to control insects, weeds, and pathogens. The cost structure of production of onion and eggplant were also constructed based on personal interviews of selected onion and eggplant farmers in the study areas.

The highlights of the results of this trials/experiments for the cropping year 1999 are discussed:

A. Onion Production

Complementary weed control strategy

The result of the experiment in Sto Tomas, San Jose City, showed that the use of one spraying of herbicide applied at 2-4 leaf stage of weeds, and one hand weeding with associated tillage (T2) is enough to control weeds. When compared with the farmers' practice of using 2 herbicides+2 hand weedings, and no tillage, (T1), it even gave more yield. The result of partial budget analysis showed that this alternative weed management strategy, if adopted by the farmers will give them a net added benefit of P22,386 per hectare (Table 1). This comes from increase yield. Although the additional cost incurred from doing tillage was higher when compared to the cost incurred by the farmer's practice (T1), this was significantly offset by the increase in revenue. Another promising technology for weed control is a combination of tillage and 2 hand weedings (T4). The partial budget analysis showed that this management strategy, when adopted by farmer, will, on the average give the farmer a net incremental benefit of P40,117 per ha. This comes from the yield increasing effect of the technology.

In the Bongabon site, the farmer's practice (FP) involved 1 herbicide + 3 hand weeding (T4). When compared to proposed alternative management technologies, FP was significantly out yielded by most of the treatments, except T1. Similar as in San Jose experiment, 1 herbicide + 1 hand weeding (T2) gave a higher yield compared to the prevailing farmer's practice. The result of the partial budget analysis showed that farmers will be able to get an additional benefit

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[2] Virginia Tech

of P11,870 per ha if they will adopt this weed control strategy (Table 2). This came from significant cost reducing effect and slightly higher yield obtained from T4.

Table 1. Partial Budgets of Complementary Weed Control Strategies in Onion Production San Jose, 1999

	FP vs. T2	FP vs. T3	FP vs. T4
Added Benefits			
Added return	22,400		40,700
Reduced cost		132	
Total Added Benefits	22,400	132	40,700
Added Cost			
Reduced return		800	
Added cost	14		583
Total Added Cost	14	800	583
Net Incremental Benefits	22,386	-668	40,117

FP= 2HW+2Herb, no tillage; T2= 1HW+1Herb @2-4 leaf stage (w/tillage)
T3= 1HW+1Herb @8-10 leaf stage (w/tillage); T4= 2HW with tillage

Table 2. Partial Budgets of Complementary Weed Control Strategies in Onion Production Bongabon, 1999

	FP vs. T1	FP vs. T2	FP vs. T3	FP vs. T5
Added Benefits				
Added return		3,400	500	14,700
Reduced cost	12,319	8,470	4,306	
Total Added Benefits	12,319	11,870	4,806	14,700
Added Cost				
Reduced return	82,300			
Added cost				1,408
Total Added Cost	82,300			1,408
Net Incremental Benefits	-69,981	11,870	4,806	13,292

T1= 2HW only; T2= 1HW+1Herb; T3= 2HW+1Herb; FP= 1Herb+3HW; T5 = Weed free

Microbials

Results of the trial in San Jose showed that Bt (T1), NPV (T2) and NPV+Bt (T3) are more effective in the control of *Spodoptera* larvae compared to the farmer's practice (FP) of using insecticide. The yields from microbial treatments are slightly higher than FP. The constructed partial budgets of these alternative pest controls are presented in Table 3. Results showed that if farmers will adopt these management strategies for *Spodoptera* larvae control, they would be better off. Adopting T1 alone will give an added benefit of P93,000 per ha. This comes from added yield obtained from this treatment. The associated additional cost of this technology is P7,263 which is the cost of the microbial and the associated application labor. The net added benefit of this technology is P85,738 per ha. Among the proposed microbial control, the most promising in the use of NPV (T2). The result of the analysis showed that once adopted, farmers will realize a net additional benefit of P136,233 per ha.

Table 3. Partial Budgets of Use of Microbials in Onion Production San Jose, 1999

	FP vs. T1	FP vs. T2	FP vs. T3	FP vs. T5
Added Benefits				
Added return	93,000	151,000	76,000	
Reduced cost				1,175
Total Added Benefits	93,000	151,000	76,000	1,175
Added Cost				
Reduced return				24,000
Added cost	7,263	14,768	11,018	
Total Added Cost	7,263	14,768	11,018	24,000
Net Incremental Benefits	85,738	136,233	64,983	-22,826

T1= Bt; T2= NPV; T3= Bt + NPV; T4= Karate; T5= Untreated

The results from the Bongabon experiment showed a similar trend when it comes to yields obtained. The yields in the Bongabon experiment, however, are almost 4X lower than the yields in the San Jose experiment. Results from partial budget analysis (Table 4) showed that on the average, microbial control may not be a viable option for pest control in this area because the marginal yield obtained from the treatments were very low. This implies that the marginal

revenue derived from the use of these technologies were not enough to compensate for the additional cost of these technologies. Unlike in San Jose where the single treatment (Bt alone and NPV alone) gave a higher additional benefit, in Bongabon, the treatment with a little comparative advantage was the combination of Bt and NPV. As shown in Table 4 if farmers will adopt T3, he will have an added benefit of P12,000 per ha against an added cost of P11,108 per hectare will be obtained. This translates to a net additional benefit of P982 per ha.

Rice hull burning

The results from rice hull burning experiment showed that doing rice hull burning in the onion field before land preparation gave a yield of 51.33 ton per hectare against that of 32 tons for the no rice hull burning. The results of the partial budget analysis showed that rice hull burning will give an added benefit of P193,333 per hectare due to the yield enhancing effect of the technology. The corresponding additional cost of using this technology was P6,375 per hectare which was incurred from buying rice hull and the associated labor for scattering and burning management. This gives a net additional benefit of P188,958 per hectare.

Table 4. Partial Budgets of Use of Microbials in Onion Production Bongabon, 1999

	FP vs. T1	FP vs. T2	FP vs. T3	FP vs. T5
Added Benefits				
Added return		14,000	12,000	
Reduced cost				1,175
Total Added Benefits		14,000	12,000	1,175
Added Cost				
Reduced return	3,000			57,000
Added cost	7,263	14,768	11,018	
Total Added Cost	10,263	14,768	11,018	57,000
Net Incremental Benefits	-10,263	-788	982	-55,825

T1= Bt; T2= NPV; T3= Bt + NPV; T4= Karate; T5= Untreated

Table 5. Partial Budgets of Effect of Rice hull Burning in Onion Production Bongabon, 1999

	T2 vs. T1
Added Benefits	
Added return	193,333
Reduced cost	
Total Added Benefits	193,333
Added Cost	
Reduced return	
Added cost	6,375
Total Added Cost	6,375
Net Incremental Benefits	188,958

T1= With rice hull burning
T2= No rice hull burning

B. Eggplant Production

The 1997 data on eggplant experiment identified three alternative promising management strategies for fruit and shoot borer . This includes spraying every three weeks, damaged fruit and shoot removal, and no spraying. Because these technologies were proven to be superior, the project tried one more step to advance the knowledge. Two more treatments were added while the inferior technologies, twice a week, weekly and every two weeks spraying were dropped in 1998 cropping season. These were damaged fruit and shoot removal every two weeks and damaged fruit and shoot removal every three weeks. In that process, the farmer's practice got lost in the experiments in all locations. In the absence of a technology which represents the current farmer's practice, the effectiveness of the technologies proposed will be tested against spraying every three weeks. In San Jose, the yield of every three weeks spraying of insecticides (T1) was lower compared to other treatments, except from untreated (T5). The partial budgets analysis of these technologies is shown in Table 6. The results showed that if these strategies are adopted by the farmers, it will give them net added benefits of P128,157 per hectare for T2; P60,657 for T3; P40,157 for T4; and P2,157 for T5 relative to T1. These additional benefits were realized either as a result of higher returns from increased marketable yield or lower cost of the technology from the treatments.

Table 6. Partial Budgets of Use of Alternative management of Shoot and Fruit Borers in Eggplant Production, San Jose, 1999

	FP vs. T2	FP vs. T3	FP vs. T4	FP vs. T5
Added Benefits				
Added return	166,000	76,000	22,000	
Reduced cost				7,157
Total Added Benefits	166,000	76,000	22,000	7,157
Added Cost				
Reduced return				5,000
Added cost	37,843	15,343	7,843	
Total Added Cost	37,843	15,343	7,843	5,000
Net Incremental Benefits	128,157	60,657	14,157	2,157

FP= Every 3-weeks spray
T2= Weekly removal of damaged fruit and shoot
T3= Every 2-weeks removal
T4= Every 3-weeks removal
T5=Untreated

At the PhilRice Central experiment Station, similar results were obtained, except for T4. The results of partial budget analysis are presented in Table 7. The adoption of T2 will give an net additional benefits of P63,157; P27,657 from T3 and P37,157 for T5 while T4 has no comparative advantage over T1.

It should be emphasized that the reference technology (T1) in this study was found to be one of the promising technologies to manage fruit and shoot borers. Hence the additional benefits mentioned in this report should be added to the financial advantage of T1 over that of the real farmer's practice, which is spraying twice a week.

Table 7. Partial Budgets of Use of Alternative Management of Shoot and Fruit Borers in Eggplant Production, PhilRice, 1999

	FP vs. T2	**FP vs. T3**	**FP vs. T4**	**FP vs. T5**
Added Benefits				
Added return	101,000	43,000		30,000
Reduced cost				7,157
Total Added Benefits	101,000	43,000		37,157
Added Cost				
Reduced return			6,000	
Added cost	37,843	15,343	7,843	
Total Added Cost	37,843	15,343	13,843	
Net Incremental Benefits	63,157	27,657	-13,843	37,157

FP= Every 3-weeks spray
T2= Weekly removal of damaged fruit and shoot
T3= Every 2-weeks removal
T4= Every 3-weeks removal
T5= Untreated

Welfare implications

Any increase/decrease in output or decrease/increase in cost will cause the supply curve to shift downward/upward. This shift in the supply curve will have a corresponding effect the overall welfare of the society. In this section we present a preliminary result of our total economic surplus analyses for two management strategies for onion production (microbials) and eggplant (fruit and shoot borer management). Which party (producer or consumer) has gotten most of the change as a result of the shift in the supply curve will not be dealt in this study. The results are shown in Table 8. In onion production, the technology that would generate more welfare to society, In terms of the net present value (NPV) of stream of benefits and costs and internal rate of return (IRR) is the adoption of NPV with an NPV of P196.4M and IRR of 47% followed by the combination of Bt and NPV (P134.6M, 39%) then by Bt

(P31.5M, 18%). In eggplant production, the best alternative to manage fruit and shoot borers is the weekly removal of damaged fruit and shoot (P777.1M, 82%), followed by every two weeks removal (P179.9M, 44%) then by the untreated (P16.9M, 41%) and lastly the every three weeks removal of damaged fruit and shoot (P76.7M, 29%).

Table 8. NPV and IRR of Total Economic Surplus in Onion and Eggplant Alternative Pest Management

Management Strategy	NPV (P000,000)	IRR (%)
A. Microbial (Onion)		
T1. Bt	31.5	18
T2. NPV	196.4	47
T3. Bt + NPV	134.6	39
T4. Karate (FP)		
B. F&S borer (Eggplant)		
T1. Every 3wks spray		
T2. Weekly removal of damaged F&S	777.1	82
T3. Every 2wks removal	179.9	44
T4. Every 3wks removal	76.7	29
T5. Untreated	161.9	41

Economic and Environmental Impacts of IPM Practices in the Rice-Vegetable System

Investigators: G. Norton[1], L. Cuyno[2], S. Francisco[3], Agnes Rola[4]

Abstract

The economic profitability of the alternative strategies to control insects, weeds, nematodes, and diseases on the IPM CRSP in the Philippines were assessed using partial budgeting techniques. Hazards associated with pesticides being applied to onions in Nueva Ecija were evaluated for various categories of health and the environment. The effects of IPM practices being developed on the IPM CRSP, in terms of projected reductions in pesticide use, were combined with willingness to pay and hazard information to calculate the economic benefits of the environmental and health effects of IPM. This analysis was part of the Ph.D. dissertation of Leah Cuyno, completed in Year 6 of the IPM CRSP.

Objectives

(1) To evaluate and project impacts of IPM practices tested in multidisciplinary field experiments on household income and on society as a whole.

(2) To estimate the economic value of the environmental benefits of IPM practices developed on the IPM CRSP.

IPM Constraints Addressed

(1) Adoption of IPM practices by farmers will depend on their economic viability. Societal benefits may be positive even if they are not beneficial to producers if use of pesticides harmful to health or the environment is reduced. If particular practices are beneficial to society as a whole but not to producers, public policies may be required to influence IPM adoption.

(2) The need to estimate the value of environmental and health benefits in addition to profitability of IPM practices if appropriate policy changes are to be identified that may influence pesticide use and IPM adoption.

Research Methods, Results and Impacts

Research methods for objective 1 of these activities include use of partial budgeting and economic surplus analysis using data from the experiments described elsewhere in this report. Data on differences in yields, input quantities, and prices

[1] Virginia Tech
[2] Graduate student, Virginia Tech
[3] Philippines Rice Research Institute
[4] University of the Philippines at Los Baños

associated with the various treatments for each of the onion and eggplant IPM field experiments were gathered, partial budgets were calculated to assess the relative economic profitability of the alternative practices to control insects, weeds, and pathogens.

Research methods for objective 2 involved 1) classifying the environment into relevant impact categories, 2) identifying risks posed by individual pesticide active ingredients to each category, 3) defining the degree of IPM adoption, 4) assessing the effects of IPM adoption on pesticide use, 5) obtaining willingness to pay information by administering a contingent valuation survey to 176 farmers, and 6) combining risk and willingness to pay information to arrive at an estimate of the economic benefits of the IPM program

Results

Results of the partial budgeting analysis are still being written up in a report. The analysis of the environmental benefits of IPM found economic benefits of 248 to 305 pesos per person per cropping season depending on the environmental category (40 pesos = $1 U.S.). Categories included were human health, beneficial insects, birds, aquatic species, and other animals. The benefits were estimated at more than 6 million pesos for the roughly 4600 inhabitants in the villages where the IPM CRSP program is immediately centered or about $150,000 per cropping season.

Networking Activity

G. Norton traveled to the Philippines in February to discuss research results with Philippine colleagues. Agnes Rola traveled to Virginia Tech to discuss research and participate as committee member at Leah Cuyno's dissertation defense.

Publications

G.W. Norton, E.G. Rajotte, and V. Gapud, "Participatory research in integrated pest Management: Lessons from the IPM CRSP", Agriculture and Human Values, 1999 (in press).

L. Cuyno. An Economic Evaluation of the Health and Environmental Benefits of the IPM CRSP Program in the Philippines", PhD. Thesis, Virginia Tech, May 1999.

Training Output

Ph.D. student Leah Cuyno from the Philippines completed her Ph.D. dissertation on this activity at Virginia Tech

Research Highlight

The environmental benefits of the IPM CRSP were estimated at more than 6 million pesos for the roughly 4600 inhabitants in the villages where the IPM CRSP program is immediately centered or about $150,000 per cropping season.

Follow Up Baseline Survey

Investigators: I.R. Tanzo[1], V.P. Gapud, S.R. Francisco[1], K.L. Heong[2], S. Hamilton[3], G. Norton[3], and E. Rajotte[4]

Abstract

A semi-structured survey was administered to a random sample of 291 male and female heads of farm households in the municipalities of San Jose and Bongabon, Nueva Ecija. Three villages in San Jose (Palestina, Sto. Tomas, and Abar 1st) and one village in Bongabon (San Roque) including the members of the NOGROCOMA cooperative were covered. Data had been encoded and data analysis is currently going on.

Objectives

To conduct a follow-up baseline survey of farmers to elicit information on their current pest management practices and decision-making, their perceptions of their primary pests and

[1] Philippine Rice Research Institute
[2] International Rice Research Institute
[3] Virginia Tech
[4] Penn State University

beneficiaries, their basic socioeconomic characteristics, and determine if there is gender-differentiated pest-related knowledge.

IPM Constraints

To determine if there had been changes in pest management practices, pest and beneficial perceptions, or pest management decision-making since the previous baseline survey in 1994.

Research Methods

A semi-structured survey was administered to a random sample of 291 rice-vegetable farmers in San Jose and Bongabon, Nueva Ecija. The San Jose survey covered a total of 180 respondents; 60 each from the village of Palestina, Abar 1st, and Sto. Tomas. Bongabon respondents were from the San Roque village (57 respondents) and members of the NOGROCOMA cooperative (54 respondents). The Tagalog survey questionnaire used was a modified version of the 1994 survey. The interview was conducted by six trained-enumerators after a pilot test of ten farmers. The interview process took two months.. Data encoding and data analysis were done through SAS that included frequency, ranking, means and measures of dispersion, and testing of significant of differences between the 1994 and 1998 data.

Research Results

The 1998 survey data had been encoded and data analysis is going on. Frequency tables have been produced from the 1998 data through SAS. These data will be compared to the 1994 survey data and tests of significant differences will be made to determine if there had been changes in pest perceptions and management practices. Male and female responses will also be compared to see if there is gender-differentiated knowledge.

Impact

Once the 1994 and 1998 survey data have been compared, results will show if there were changes in the farmer pest management practices, pest and beneficial perceptions, and pest management decision-making.

Networking Activities

Attended the "Workshop on Cultural Management Practices and Integrated Pest Management for Vegetables" on July 14 -15, 1999 at PhilRice, Nueva Ecija.

Presentations

'Women at Work: Gender Issues in Rice-Onion Farming Systems'. Poster presented at the 30th Annual Scientific Meeting of the Pest Management Council of the Philippines, May 4 - 6, 1999 at PhilRice, Muñoz, Nueva Ecija, Philippines.

'Women at Work: Gender Issues in Rice-Onion Farming Systems'. Poster presented at the 15th Annual Scientific Conference of the Federation of Crop Science Societies of the Philippines, May 10 - 15, 1999 at the Family Country Hotel and Convention Centre, General Santos City, South Cotabato, Philippines.

'Gender Issues in Rice-onion Farming Systems'. Report presented at the NOGROCOMA and Bongabon Barangay Captains meeting on July 30, 1999 held at PhilRice, Muñoz, Nueva Ecija

Project Highlight

- Completed the 1998 follow-up baseline survey with 291 respondents. This survey included San Jose and Bongabon, Nueva Ecija as survey sites and included male and female head of households as respondents.

IPM CRSP Overview of Bangladesh Site in Asian Region

Site Coordinator: Rezaul Karim
Site Chair: George Norton

Description of Collaborative Program

IPM activities in the Bangladesh site were concentrated in three program areas during year 6, which was year 1 for Bangladesh. The first of these areas was a baseline survey and crop monitoring. The second was multidisciplinary on-farm pest management experiments. The third was socioeconomic analyses. The work was conducted as a collaborative effort among scientists at the Bangladesh Agricultural Research Institute (BARI), the Bangladesh Rice Research Institute (BRRI), the Asian Vegetable Research and Development Center (AVRDC), the International Rice Research Institute (IRRI), the University of the Philippines-Los Banos, Penn State University, Purdue University, and Virginia Tech. Rezaul Karim served as Site Coordinator and George Norton served as Site Chair.

The Year 6 workplan focused on crops, pests, and constraints identified in the participatory appraisal process. Planning and collaborative research took place through: a) discussions among host country and US/international scientists at planning meetings in Bangladesh and b) preparation of joint host-country/US/international scientist two-page proposals. Planning for Year 7 also involved discussion of the plans jointly with scientists working in the Philippine site during the planning workshop at Purdue in May.

Field research is conducted in farmers' fields in Kashimpur, with BARI/BRRI scientists visiting experiments on a regular basis. Some research is also conducted on station, especially varietal screening for insect, disease, and nematode resistance. Training takes place primarily at U.S. universities and AVRDC. CARE-Bangladesh has participated in the planning but not the research.

IPM Constraints Addressed

The key constraints addressed in Bangladesh in year 6 were the need for IPM solutions to specific pest problems in vegetables and the need for information on socioeconomic factors influencing adoption of IPM. Specific major pests being addressed in the IPM program are fruit and shoot borer (*Leucinodes orbinalis*) and bacterial wilt (*Pseudomones solanacearum*) and other pathogens in eggplant, various weeds in cabbage and eggplant, soil borne pathogens such as root knot nematodes (*Meloidogyne* sp) and *Fusarium* in gourds, and aphids and diamondback moth in cabbage.

Selected Research Accomplishments

Descriptions of research progress and results are provided in the individual institution activity reports, but the following are examples and key results obtained in the Bangladesh site:

1. Baseline surveys conducted in Kashimpur and Konobari districts provided information on existing patterns of vegetable production and pest management practices. Very little IPM was found currently being practiced on vegetables.
2. Monitoring of crop pests and their natural enemies in rice and vegetables identified the most serious insects, diseases, and weeds in the Gazipur district.
3. Of the 23 accessions of eggplant tested for resistance to bacterial wilt, root knot nematode, and fruit and shoot borer, none were found resistant, but a few exhibited tolerance to one or more of the pests and will be tested further.
4. A trap with the synthetic pheromone lure, Cuelure proved effective in trapping fruit flies in cucurbit crops.
5. Results of on-farm experiments in both okra and cabbage found that, instead of the current practice of three or four weedings, farmers can effectively control weeds through deploying two weedings, one early and one mid-growth stage in the crop and generate the highest net returns.
6. The first season's experiments found that incorporation of mustard oil-cake in eggplant fields effectively reduces nematode infestations and increases yield.
7. Plots with poultry manure incorporated produced taller, heavier bunching onions and had less disease and nematode infestation.
8. Sawdust burning and soil incorporation of poultry refuse were effective in reducing deaths of cucumber seedlings, promoted growth of cucumber plants and produced 1.5 times more yield.

Mutuality of Benefits of the Research

The pest problems assessed in these studies are widespread throughout Asia and also occur in other parts of the world. IPM approaches to manage these problems have broad applicability, especially in Asia. The consumption of

vegetables is growing in Bangladesh and the region. The primary feedback in terms of benefits to the United States will be through (a) the effects of economic growth in the region on trade and demand for U.S. products in international markets and (b) improved relations with a major country in a politically sensitive area of the world.

Institution Building

Equipment, vehicles, and other support funds were provided for vehicle repair and rental to facilitate transport to and from research sites. Computers, a copier, and other supplies were provided.

Research Training

One U.S. student, T. Debass, worked on his masters thesis at Virginia Tech (agricultural economics) assessing the economic benefits of the IPM program. One Indian student at Penn State, Joseph Kodamanchaly, began his dissertation research in sociology with a focus on factors influencing IPM adoption in Bangladesh. One Bangladeshi student, Chowdhury Mahmoud, began his MS program in agricultural economics at Purdue.

Scientist Travel

E. Rajotte, G. Luther, C. Sachs, G. Norton, A. Baltazar, and graduate student T.Debass traveled to Bangladesh in February to review research results and help plan additional research. Shively and Kodamanchaly traveled to Bangladesh in June to review socioeconomic research results and help plan additional socioeconomic research. Rajotte and Norton returned in September to further collaborate with host country scientists. S.K. DeDatta traveled to Bangladesh in January to review research progress. J. Wang from AVRDC traveled to Bangladesh in April to review results of experiments involving plant pathology research. R. Karim traveled to the United States and visited Purdue and Virginia Tech to participate in the IPM CRSP annual workshop and planning meeting and to review research at Virginia Tech as well as discuss administrative issues.

Human resource development

A human resource development plan for the next four years was completed that includes both short-term and degree training. The first Bangladesh scientist from the project to enter into degree training will begin studies next August.

Networking Activities

Networking is accomplished through institutional collaboration among BARI, BRRI, UPLB, the Institute of Post Graduate Studies in Bangladesh (IPSA), CARE-Bangladesh, and IRRI-Bangladesh. Both IRRI and AVRDC play key roles in networking with other countries in the region. Scientists involved in the project work throughout the region and can spread research results through visits to other countries and participation in workshops, meetings, and other networking activities. U.S. universities also help with networking in the region. The Bangladeshi student at Purdue was formerly a research assistant at the office of the International Food Policy Research Institute (IFPRI) in Dhaka, and avenues for future collaborative work with IFPRI scientists are being explored. Some of the scientists on the project also work with the Philippines site, including the weed scientist from UPLB working in the Bangladesh site. One US scientist on the project also works with the SANREM CRSP in SE Asia, providing another opportunity for networking within the region and the CRSP system.

Baseline Survey of Existing Patterns of Vegetable Production and Pest Management Practices in Farmers' Fields

Investigators: M.I. Hossain[1]

Collaborating Scientists: G.E. Shively[2] and G. Norton[3]

Abstract

A baseline survey was conducted in four villages, two each in Kashimpur Union and Konabari union to gather information on the existing patterns of vegetable production and pest management practices followed by the farmers. Generally, the farmers were middle-aged small landholders; majority of them had primary to secondary level education but long experience in agriculture. Topography of the study area was mainly highland to medium highland suitable for rice-based vegetable cultivation, vegetables being the dominant crops. Because of training in vegetable production and good marketing facilities the farmers were progressive in producing high-value vegetables almost throughout the year. They were sensitive to crop losses, particularly of vegetable crops, due to the attacks of various pests and they regularly protected the crops through several applications of insecticides. However, their perception and knowledge about the identity of pests and natural enemies, their incidence patterns, and damage potential of the pests and pest suppressing capacity of the natural enemies was poor. As a result, the aptitude of practising IPM among the farmers was lacking. Economic returns of the farmers from farm and non-farm incomes were fairly satisfactory. Probably for this reason, credit use by the farmers was low. Existence of agricultural societies and farmers' involvement with the societies were very poor in the study area. There is ample scope to organise the farmers to develop societies that can help them to improve their knowledge and practice of improved crop production technologies including various socio-economic factors.

IPM Impact

Baseline information is important to know the existing situation of a particular phenomenon in an area. Baseline data are required to understand the suite of socio-economic factors that influence crop production patterns and practices, pest perceptions, pest management practices and potential constraints to IPM adoption. These data can be used to compare practices of different sites, which can be useful for planning and targeting of extension and training efforts. These data can also be used to retrospectively assess the project impacts.

Objectives

To conduct farm survey among a sample of farmers in a representative set of villages; and

To collect data to support statistical analysis of pest perceptions, pest management practices and related socio-economic factors.

Research Methods

Four villages, two under Kashimpur Union and two under Konabari Union belonging to Joydebpur Police Station of Gazipur district were selected for the study. Farmers of Kashimpur area have long been associated with the pilot vegetable production program of the Bangladesh Agricultural Development Corporation (BADC), whereas Konabari area is outside the BADC pilot area. The villages were Enayetpur and Barenda-Noyapara under Kashimpur, and Aahaki and Joyertek under Konabari. The lists of farmers were collected from the respective Union Council offices and also from the respective study villages. A total of 300 farmers, taking 75 from each village, were selected to constitute the sample for male farmers. They were categorized as small, medium, and large farmers based on the BBS (Bangladesh Bureau of Statistics) report. Stratified

[1]BARI [2]Purdue University [3]Virginia Tech

random sampling procedures were followed for farmer selection. Additionally, 100 female respondents were selected from the same villages taking 25 from each village. Female enumerators interviewed them.

Pre-designed and pre-tested interview schedules were used to collect information on as many as twenty major aspects of crop cultivation, pest management, and socio-economic factors. Data from the male farmers were collected from December'98 to February'99 (winter vegetable growing season) and that from the female respondents in March'99. The collected data were summarized, tabulated and analysed through tabular methods taking averages, percentages, or ratios.

Results and Discussion

Background information (age, education, experience and training in agriculture, and involvement in agricultural society)

The respondents were middle-aged averaging 42 years for the males and 36 years for females. The females of Enayetpur village, however, were younger (25 years). Education levels of the sampled farmers were categorized into four groups: illiterate; grade 1-V; grade VI-X; and above X. The males were largely illiterate averaging 42%, the highest being in village Barenda-Noyapara (63%) and the lowest in Enayetpur (32%). Only 5% of the male farmers had education above grade X. Interestingly, none of the females was illiterate and 72% of them had primary, 21% secondary, and 7% higher secondary education. Male farmers had 22 years experience in agriculture compared to 14 years of their counterparts. About 25% of the male farmers received training in rice and vegetable production and most of them belonged to Enayetpur (48%) and Barenda-Noyapara (32%) which were within pilot vegetable project area of BADC. These farmers were also more progressive in vegetable cultivation than those of other areas. Unfortunately, none of the females was exposed to any agricultural training. Only an insignificant number of farmers (7%) were involved in agricultural society of the area, whereas the females were ignorant of its existence.

Land ownership and land type

The total area, including the rented or leased lands, possessed by the sampled farmers was 0.62 ha per farm according to the males and 0.88 ha according to the female respondents; the difference between the male and female response happened as they did not belong to the same farm family. Both the male and female respondents said that 80-85% of the farmlands was high to medium high land suitable for rice-based vegetable cultivation.

Cropping patterns

Cropping patterns represent the spatial arrangement of crops followed in a particular area of land. It varied greatly from area to area. The males named 19 cropping patterns, whereas the females listed as many as 24 patterns. On the average, the major cropping patterns were: Veg-Veg-Veg(23%), Fallow-Fallow-Rice (14%), Veg-Veg-Rice (9%), Veg-Rice-Veg (8%), Fallow-Veg-Veg (7%), Veg-Fallow-Veg (7%), Fallow-Rice-Veg (6%) and Veg-Green manure-Veg (6%). There were many other patterns like Fallow-Maize-Wheat, Fallow-Rice-Mustard, Rice-Rice-Maize, Jute-Veg-Veg, Fallow-Fallow-Pulse, Groundnut-Green manure-Veg, Spices-Veg-Spices, Sesame-Rice-Wheat, etc.

Type of irrigation used

Because of the high land situation, irrigation water plays a determinant role for cultivation of rice and vegetables in the surveyed areas. About 95 percent farmers mentioned that they had facilities to irrigate their crop fields. For rice cultivation, the farmers used deep tube-wells, shallow tube-wells, and low lift pumps and for vegetable cultivation, they used hand tube-wells in addition to these facilities. Almost all farmers used rented irrigation facilities both for rice (99%) and vegetable (92%) cultivation.

Crops cultivated in different seasons

Rice and vegetable crops cultivated by the sampled farmers were categorized under Kharif-I (March-June), Kharif-II (July-October), and Rabi (November-February) seasons. The responses of the male and female members varied little.

In Kharif-I (summer), only 7 percent farmers in all study areas cultivated Aus rice (HYV & LV) and others cultivated different vegetables like lettuce (17%), amaranth (17%), gourd (13%), cucumber (8%), bunching onion (6%), chinese cabbage (6%), okra (7%), red amaranth (4%), celery (4%), etc.

In Kharif-II (monsoon), 28 percent farmers cultivated transplanted Aman rice (HYV & LV). The rest 72 percent farmers cultivated different types of vegetables, like beans (11%), lettuce (10%), chinese cabbage (8%), red amaranth (6%), bunching onion (5%), celery (4%), indian spinach (3%), etc.

Intensive vegetable cultivation was found in the Rabi (winter) season. Farmers cultivated 3 to 4 vegetables in the same piece of land during the season. The common vegetables in the Rabi season were: gourd (14%), beans (10%), radish (9%), tomato (6%), chinese cabbage (5%), red amaranth (5%), cabbage (5%), green pepper (5%)

potato (3%), brinjal (3%), lettuce (3%), bunching onion (3%), etc.

In general, the farmers of Enayetpur and Barenda-Noyapara villages, which are within the BADC project area, were more knowledgeable and progressive in vegetable cultivation than those of the other two study villages which are outside the BADC project area. The farmers had good marketing facilities in these two areas, having direct contact with the buyers of the big hotels of the capital city Dhaka.

Purpose of vegetable cultivation

Farmers produced vegetables for both consumption and sale. About 68% of the male farmers and 78% of the females mentioned that they produced homestead vegetables mainly for home consumption; the excess was sold out. In contrast, 56% of the males and 52% of the females reported that they grew vegetables in bigger fields outside the homestead mainly for sale. This meant that the farm families consumed a lot of vegetables in their daily diet.

Insects and diseases

Rice: Farmers named a number of insects and diseases that attacked their rice fields; the major insects were stem borer, rice hispa, brown planthopper, ear-cutting caterpillar, and rice bug. Among the diseases, stem rot, tungro virus, bacterial leaf blight, and blast were major.

Vegetables: The responses of the male and female interviewees were similar in respect of pest attacks in vegetables. The major insects were caterpillar (defoliators), aphids, ants, fruit fly, and white ants. Different virus diseases including mosaic, leaf blight, stem rot, and leaf spot were among the major diseases.

Opinions on the use of insecticides

Almost all the farmers, both males and females, were in favor of using the insecticides to protect their crops from pest attack; only a few farmers were against using of insecticides because they thought that these were harmful for health.

Preventive measures for insects and diseases

As a preventive measure, farmers adopted unilaterally only chemical control method and used different insecticides to protect their rice and vegetable crops. For rice crops, they applied mainly diazinon, malathion, chlorpyrifos (dursban), dichlorvos (nogos), and phophamidon (dimecron). On an average, they applied insecticides two times on each rice crop starting usually from 20 days after transplanting. The method of insecticide application varied widely among the farmers; some used them in very improper way, which were seemingly hazardous for their health and also ineffective for controlling pests. However, most farmers used spraying machine for insecticide application.

For vegetable cultivation, farmers used mainly chlorpyrifos (dursban), dichlorvos (nogos), diazinon, malathion, and cypermethrin (cymbus). Starting from 15 days to the harvest of the vegetable crops, about 80% of the farmers applied insecticides 2-4 times per crop; some (6%) used 5-8 times. Considerable number of female respondents (46%), however, mentioned of 5-8 times insecticide applications per crop. Most of the farmers (90%) used sprayer machine, and others mixed the insecticides with fertilizers or soil and then applied in the fields. Some farmers used direct hand throwing. Majority of the farmers (57%) applied insecticides a few days after planting, 19% at vegetative stage, and 10% at fruiting stage.

Useful insects/animals

All farmers recognized that the rice and vegetable fields harbored different kinds of arthropods which were useful for the crops. According to them, spiders, frogs, and a number of birds, such as fork-tailed black drongo, owl, magpie robin, myna were the major ones, which were found to prey on different insect pests. However, their knowledge about the efficiency of these animals to suppress the pest populations was poor.

Influence of using insecticides and killing the useful insects/animals

On the average, 94 percent of the rice-farmers and almost all vegetable farmers including the females claimed that the use of insecticides increased their crop yields. The vegetable farmers, in fact, were emphatic in saying that use of insecticides was a must for producing marketable vegetables. Contrarily, all the male farmers and 87% of the females recognised the bad effects of the insecticides upon the useful insects and animals, and they were of the opinion that the insect infestation would increase if useful insects/animals were killed.

Use of insecticides in homestead areas

On an average, 42% of the male farmers 60% of the females said that they used insecticides for homestead vegetables; others did not use since they did not have insect problems. Decision for insecticide use in homestead vegetables came mainly from the male farmers (82%).

Crop loss

No crop loss was noticed in rice by the farmers during the last five years, except in Barenda-Noyapara village of Kashimpur union; 16% farmers reported that the entire rice crop of a plot was damaged by different insects like leafhopper, stem borer, caterpillar and rice hispa. Loss of vegetable crops from insect attack was also high in Barenda-Noyapara village, but the farmer estimates of the quantity of loss appeared to be imprecise when compared with their pest attack reports from all the four villages. On the other hand, 72% of the females reported high pest attacks on the vegetable crops causing about 45% crop loss. The information indicated that the farmers' (both male and female) perception with regard to pest attack patterns and the consequent crop loss was poor.

Selling of rice and vegetables

On an average, 94% of the farmers sold their rice mainly to traders (55%) and wholesalers (26%) in the local markets, which were only a kilometer away; only 16% farmers sold rice to consumers.

About 50% of the farmers of Enayetpur and Barenda-Noyapara villages sold out their vegetables from the fields mainly to traders (76%), whereas those from Aahaki and Joyertek villages sold in local markets. Generally, local markets were the main selling centers for all agricultural produces of the area. The responses of the females were similar to that of the males in this respect.

Visit of extension personnel

The Department of Agricultural Extension (DAE) is mandated to disseminate improved technologies that are crucial for higher agricultural production. The DAE is equipped with extension personnel up to the village level to visit farms and give advice to the farmers. Unfortunately, farmers' reports on the visit of the extension personnel to their villages were discouraging; only 3% farmers reported 1-2 monthly visits of the extension agents in their area. This meant that the farmers of the study area were unaware of the various technologies, including IPM, developed by different research institutes.

Economic returns from agriculture and non-farm incomes

Returns: Returns from agriculture included the incomes from crop cultivation (rice and vegetables), livestock, poultry, and partial labor in agricultural fields; and the non-farm incomes included those from business, jobs, and partial income from labor. The total income per farm family from agriculture and non-agriculture sources was highest in Enayetpur (Tk.1,15,667/year) and lowest in Aahaki (Tk.74,724/year) village. The income in Barenda-Noyapara and Joyertek villages were Tk.1,12,312/year and Tk.1,04,460/year, respectively. Among the different sources of returns, the highest income was from field vegetables in Enayetpur as the farmers of the area had direct contract with the traders who supplied vegetables to big hotels of Dhaka City. In addition, some families of Enayetpur village had their family members working in the Middle-East and earning money amounting to Tk.15,800/year.

Costs: For the production of agricultural crops, the farmers of the study area directly bore mainly the costs of fertilizers, irrigation water, insecticides, and labor. The total costs of inputs per hectare of land varied from Tk.3,832/ha at Joyertek to Tk.7,128/ha at Enayetpur. The cost of insecticides was highest in Enayetpur (Tk.5,537/ha) due to higher frequency of insecticide use.

Use of credit

Credit use in the study area was low. According to the male respondents, only 16% farmers of Barenda-Noyapara village borrowed money from friends (17%), neighbors (15%), moneylenders (17%), and cooperative society (16%). On the other hand, female respondents (32%) of Enayetpur and Barenda-Noyapara villages reported of borrowing money from friends (32%) and neighbors (63%). They utilized the borrowed money for rice and vegetable cultivation.

Conclusions

- Because of receiving more training on vegetables, the farmers of the study area were generally more progressive in vegetable production. They produced high value vegetable crops for supplying to big hotels and elite markets of the capital city, which fetched them good returns. Farmer participatory research in vegetable production program, including IPM, can be established in the area as the farmers have long experience and exposure to training on vegetable production.

- Farmers' group for agricultural development was inadequate in the study areas. Formation of farmers' groups can help the farmers in different ways to strengthen their production activities including gender issues and adoption of improved technologies, credit use, transport and marketing systems of the agricultural produce.

- Although basically rice-based, vegetables are the dominant crops in the study area grown intensively throughout the year. There is ample scope to develop the area as a pilot production area of high valued vegetables that can find export market. Research

programs related to soil improvement and amendments aimed for IPM practices can be undertaken. Success of such programs can create ripples in other progressive areas.

- The farmers of the area, although progressive in rice and vegetable production, and sensitive to pest attack and their control, their perception, knowledge and aptitude to IPM practices was poor. This is an important area where farmer participatory research and training can improve their knowledge for growing healthy and economic crops free from toxic residues of pesticides.

Networking Activities

Participated in the Participatory Appraisal and Planning workshop meetings in August 1998 to prepare the 1998-99 IPM CRSP Workplans for Bangladesh. Attended Review meetings in February 1999 to discuss the progress of the ongoing activities and prepare plans for 1999-2000.

Dr. Gerald E. Shively of Purdue University visited in June 1999 to review the progress of the ongoing activities and discuss the methodologies of the future activities of the socioeconomic studies of IPM CRSP in Bangladesh. Avenues for future collaborative work are being explored with colleagues at the International Food Policy Research Institute (IFPRI) in Dhaka.

Monitoring of Crop Pests and Their Natural Enemies in Rice and Vegetables in Rice – Vegetable Cropping Systems

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Collaborating Scientists: L.Black[3], E. Rajotte[4], A. Baltazar[5], S.K. De Datta[6] and G. Luther[6]

Abstract

Field surveys were done for the incidence of insect pests, diseases and weeds in 1998 Transplant Aman rice (monsoon rice) and 1998-99 winter vegetables in IPM CRSP research site at Kashimpur of Gazipur district, an intensive vegetable growing area. In rice, incidence of leaf folders (RLF), brown planthopper (BPH), green leafhopper (GLH), rice swarming caterpillar, and sheath blight disease was high and apparently caused some yield losses. The common T.Aman rice variety BR11 was more severely infested by insects and diseases than variety Pajam. Use of granular insecticides (carbofuran and diazinon) below recommended doses seemed to increase the populations of BPH and RLF. Problem of diseases and weeds in T. Aman rice was insignificant in the surveyed area.

Tomato was severely infected by leaf curl disease (90%). Other important diseases were late blight and early blight in tomato; mosaic virus in bottle gourd, root-rot in cauliflower and cabbage, leaf-rot in chinese cabbage, bacterial wilt in eggplant, root-knot nematode in country bean and bunching onion, and leaf blight in bunching onion.

Generally, farmers kept their vegetable fields weed free by regular hand weeding and earthing-up practices. The dominant weeds were *Cynodon dactylon* Pers. in cauliflower and bottle gourd, *Cyperus rotundus* L. in eggplant, *Elusine indica* (L). Gaertn. in cabbage, tomato and radish, and *Jussiaea decurrens* (Walt) DC. in amaranth. Tomato and radish fields had the highest weed biomass (156.5 g dry wt/m^2), followed by cauliflower (81.4 g dry wt/m2), eggplant (79 g dry wt/m2), bottle gourd (67.8 g dry wt/m2), amaranth (56.3 g dry wt/m2) and the lowest in cabbage (31.2 g dry wt/m2).

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Objectives

To determine incidence, seasonality, and abundance of pests (insects, diseases, nematodes and weeds) and natural enemies;

To determine pest damage levels; and

To identify species and initiate reference collection of pests and natural enemies.

IPM Constraints

Information on different pest problems and their incidence patterns on the crops, and farmers' attitudes towards them are necessary for the development of appropriate IPM packages.

Research Methods

Incidence of insect pests, diseases and weeds in Transplant Aman (T. Aman) rice and some selected winter vegetables were surveyed in IPM CRSP research site at Kashimpur of Gazipur district during 1998-99. Pest incidence in four rice fields was estimated at the reproductive phase from 20 rice hills per field. Arthropods were sampled through 40 to and fro sweeps over the crop canopy by means of a standard sweepnet from one field. In addition, population densities of brown planthopper (BPH), *Nilaparvata lugens* (Stal) and white-backed planthopper (WBPH), *Sogatella furcifera* (Horvath), were estimated in four insecticide treated and four untreated fields. Larvae of more than 40 swarming caterpillars (*Spodoptera* spp.) collected from the field were reared individually on damp sand in test tubes in the laboratory. Diseases and weeds in several rice fields including four selected ones were observed also at the reproductive phase of the crop. Disease severity was graded on a 0-9 scale. Weed infestation was recorded by means of a 50x50 cm quadrat, taking five quadrat samples from each field.

Observations on diseases of different winter vegetables were made at flowering or fruit bearing stage. Average disease incidence was recorded as percent infected plants, while disease severity was graded on a 0-9 scale for all the diseases except for root-knot nematode, where a 0-10 scale was used. Weed abundance in different vegetable fields was estimated by collecting all weeds from a 50x50 cm quadrat from each field. Weeds were separated and biomass was estimated by drying at 60° c for 24 hours.

Results and Discussion

Rice pests

BR11, a modern T. Aman rice variety, was common in the study site. Winter vegetables – summer vegetables – T. Aman rice was the dominant cropping pattern.

In the rice fields, on an average, farmers used 70 kg N, 50 kg P, and 30 kg K per ha which were close to the recommended rates. Some farmers used insecticides, mostly granular (carbofuran or diazinon), about 3-5 weeks after transplanting as a preventive measure. The amount of insecticides applied was approximately half of the recommended rates. Farmers, who used insecticides as a preventive measure, applied less chemical fertilizers than those who did not use insecticides.

BPH, WBPH, rice leaf-folders (RLF) (*Cnaphalocrocis medinalis*, *Marasmia patnalis*, and *M. exigua*) and green leafhoppers (GLH) (*Nephotettix virescens* and *N. nigropictus*) were the dominant rice pests. In two out of four fields RLF damage was moderate to high with 18-26% damaged leaves (Table 1). BPH and WBPH were present (12 /hill) in one and GLH (2/hill) in two out of four fields, but rice tungro virus disease which is transmitted by GLH was not observed. High populations of rice swarming caterpillar, *Spodoptera mauritia* (0.5 pupae/hill) were recorded in higher lands probably due to their migration from low lying fields that remained inundated for a long time during 1998 flood. Insecticide-treated fields had twice as many BPH and WBPH populations (16.5/hill) as the untreated fields (9.6/hill) (Table 2). This might be due to the unnecessary use of insecticides (diazinon/carbofuran) much below the recommended doses that stimulated their fecundity.

Among the natural enemies, spider populations were high (4.5/hill) in one out of four fields (Table 1) which also had high incidence of RLF. Clusters of *Cotesia* sp. were observed on a dead RLF larva. The larvae of rice swarming caterpillar (*S. mauritia)* suffered 5.1% parasitism from a tachinid and an ichnumonid (*Xanthopimpla sp)* parasitoid.

Diseases

At the panicle initiation (PI) stage of the rice crop disease infection was low and sporadic, but increased to moderate levels at crop maturity stage. The prevalent diseases were sheath blight (*Rhizoctonia solani*), bacterial blight (*Xanthmonas oryze pv oryzae*), leaf scald, sheath rot (*Acrocylindrium oryzae*) and brown spot (*Helminthosporium oryzae*); incidence of the last named disease was insignificant. In general, disease severity of sheath blight was high on rice variety BR11 compared to other varieties grown in the area.

Table 1: Incidence of insect pests, damages and natural enemies in rice fields in 1998 T. Aman season, Kashimpur.

Attributes	Field A	Field B	Field C	Field D
Variety	BR11	BR11	Pajam	BR11
Crop stage	Boot	PI	Dough	Dough
Seed quality	Bad Mixture	Not clear	Fairly good	Bad Mixture
Field condition	Wet	Moist	Dry	Dry
Panicle/tiller (No./hill)	9.1	13.2	11.9	12.8
Green leaves (No./tiller)	4.65	3.60	3.57	3.43
Insecticide use	Used	Used	Nil	Nil
Insect Pests				
DH/WH (%)	-	0.21	0.12	0.22
OS (%)	0.36	0.42	-	0.14
GLD (%)	2.76	2.42	1.16	4.92
Folded Leaves (%)	3.27	1.26	26.6	17.73
RLF (No./hill)	-	-	0.15	0.10
BPH & WBPH (No./hill)	12.20	2.35	-	0.50
GLH (No./hill)	1.55	1.75	-	0.10
GH (No./hill)	0.05	0.02	1.30	0.05
Skipper (No./hill)	0.05	-	-	-
Natural Enemies				
Spiders (No./hill)	0.85	0.60	4.50	0.20
LBB (No./hill)	0.40	0.25	-	0.20
Carabid (No./hill)	0.05	-	0.10	0.10
GMB (No./hill)	-	-	-	0.55

Table 2: Cultural operations and BPH & WBPH situations in insecticide treated and untreated rice fields, 1998 T. Aman season, Kashimpur.

Attributes	Insecticide treated	Insecticide untreated
Fields examined (No.)	4	4
Average field size (ha)	0.138	0.135
Variety	BRII	BRII
Crop stage	Milk-dough	Milk-dough
Field condition	Wet	Wet
Fertilizer use (kg/ha)		
Urea	144	154
TSP	108	103
MP	45	51
Insecticide use	Preventive	-
Formulation	Granular	-
No. of application	1 (2 fields) 2 (2 fields)	- -
Time of application	21 & 35 DAT	-
Dose (kg/ha)	7.5 (f)	-
BPH & WBPH	-	-
Stages	II to adult	II to adult
Intensity (No./hill)	16.53	9.61

(f): Formulated insecticide

Weeds

Rice fields were virtually weed free at the reproductive phase. The farmers effectively controlled the weeds by ploughing down the fields thoroughly and keeping the puddled fields inundated for several weeks by trapping rain water before transplanting the rice seedlings. In the surveyed fields, the farmers did not adopt any weed control measure after rice transplanting. However, mixtures of annual and perennial grasses and a few broad leaf weeds were present on the rice bunds. Dominant weeds on rice bunds include : *Cynodon dactylon* (L) Pers., *Elusine indica* (L) Gaertn., *Amoxopus compressus*, *Echinochloa colona* (L) Link, and *Nicotina plumbaginifolia*.

Vegetable diseases

Tomato: Severe incidence of leaf curl disease (90%) was observed on tomato (Table 3). It also suffered moderate damage from late blight (*Phytophthora* sp.) and early blight (*Alternaria* sp.) diseases.

Bottle gourd: Light to moderate infestations of leaf spot (*Cercospora* sp.), mosaic, wilt (*Fusarium* spp.), and root-knot nematode (*Meloidogyne* sp.) were observed (Table 3).

Cauliflower: Cauliflower plants were infected by root-rot (*Rhyzoctonia* sp. and *Fusarium* sp.), black rot (*Xanthomonas campestris*), leaf spot, and mosaic virus (Table 3). Incidence of root rot was moderate; others were minor.

Broccoli: The plants were almost free from diseases, but the leaves were severely damaged by birds.

Cabbage: Moderate infection of root rot (*Rhizoctonia* sp. and *Fusarium* sp.) disease was observed.

Chinese cabbage: Leaf rot disease caused by *Xanthomonas campestris* was the main problem of chinese cabbage and most fields had moderate infection. Minor incidence of leaf spot disease (*Alternaria* sp.) was also observed.

Eggplant: Six diseases infected the eggplants. Among them, bacterial wilt caused by *Pseudomonas solani* and fruit rot caused by *Phomopsis sp* were major causing moderate damage (Table 3).

Country bean: Three diseases were observed on this crop; other than moderate infection of root-knot nematode, these were minor.

Bunching onion: It was infected moderately by leaf blight (*Alternaria* sp., *Cladosporium* sp., and *Colletotrichum* sp.) and root-knot nematode.

Table 3: Disease incidence and their severity on different winter vegetables, 1998-99 winter season, Kashimpur.

Crop	Disease	Average disease incidence & severity		
		Incidence (%)	Severity (1-9) scale	Severity (0-10) scale
Tomato :	Leaf curl	90.0		
	Late blight		6.0	
	Early blight		5.0	
	Root-knot nematode			3.5
Bottle gourd :	Leaf spot (*Cercospora* sp)		3.5	
	Mosaic (Virus)	31.25		
	Wilt (*Fusarium* spp)	7.5		
	Root-knot (*Meloidogyne* sp)		3.33	3.16
Cauliflower :	Root rot (*Rhizoctonia* sp) (*Fusarium* sp)	10.0 33.33		
	Black rot (*Xanthomonas campes*)	16.0		
	Leaf spot (*Alternaria* sp)		1.5	
Brocoli :	Leaf spot (*Alternaria* sp)		2.0	
Cabbage :	Root rot (*Rhizoctonia* sp, *Fusarium* sp)	24.25		
	Leaf spot (*Alternaria* sp)		2.5	
Chinese cabbage :	Leaf rot (*Xanthomonas campestris*)	21.25		
	Leaf spot (*Alternaria* sp)		3.0	

Table 3. *continued*

Crop	Disease	Average disease incidence & severity		
		Incidence (%)	Severity (1-9) scale	Severity (0-10) scale
Eggplant :	Bacterial wilt (*Pseudomonas solani*)	22.40		
	Root rot, Damping off (*Rhizoctonia* sp, *Fusarium* sp, *Selerotium rolfsil*)	8.75		
	Little leaf	6.0	1.75	
	Fruit rot (*Phomopsis* sp)		4.25	
	Black mould (*Capriodium* sp)		3.75	
	Root-knot (*Meloidogyne* sp)			3.0
Country bean :	Leaf spot (*Cercospora* sp)	2.5		
	Root-knot (*Meloidogyne* sp)			5.25
	Anthracnose (*Colletotrichum* sp)	2.0		
Bunching onion :	Leaf blight (*Aspergillus* sp, *Stemphylium, Clead*)	5.5		
	Root-knot nematode			2.25

Weeds in vegetables

In general, the farmers kept their vegetable fields clean by regular hand weeding and mulching the soil. Among several species of weeds in the vegetable fields only a few were predominant: *Cynodon dactylon* in cauliflower (72%) and bottle gourd (50%), *Cyperus rotundus* in eggplant (60%), *Eleusine indica* in cabbage (72%), tomato and radish (60%), and *Jussiaea decurrens* in amaranth (Table 4). Tomato and radish fields had highest weed biomass (156.5 g dry wt/m^2), followed by cauliflower (81.4 g dry wt/m^2), eggplant (79.1 g dry wt/m^2), bottle gourd (67.8 g dry wt/m^2), amaranth (56.3 g dry wt/m^2), and least in cabbage fields (31.2 g dry wt/m^2) (Table 4).

Table 4: Relative abundance of weed species (number basis) and biomass of all weeds in different vegetable fields, Kashimpur.

Crop	Fields examined (no.)	Weed species	Relative abundance (%)	Av. Biomass (g dry wt/m^2)
Cabbage	2	*Eleusine indica* (L.) Gaertn.	72.0	31.22
		Amaranthus viridis L.	6.0	
		Oxalis corniculata L.	20.0	
		Cyperus rotundus L.	2.0	
Cauliflower	3	*Eleusine indica* (L.) Gaertn.	14.1	81.44
		Amaranthus viridis L.	4.2	
		Amaranthus spinosus L.	0.7	
		Oxalis corniculata L.	0.7	
		Cyperus rotundus L.	5.6	
		Cynodon dactylon Pers.	47.9	
		Jussiaea decurrens (Walt.)DC.	12.0	
		Eclipta alba L.Hossk.	14.8	
Eggplant	1	*Cyperus rotundus* L.	60.0	79.04
		Eleusine indica (L.) Gaertn	5.5	
		Cynodon dactylon Pers.	34.5	
Bottle gourd	1	*Cyperus rotundus* L.	10.0	67.80
		Eleusine indica (L.) Gaertn	40.0	
		Cynodon dactylon Pers.	50.0	
Amaranth	2	*Jussiaea decurrens* (Walt.)DC	48.7	56.30
		Cynodon dactylon Pers.	2.7	
		Eleusine indica (L.) Gaertn	8.1	
		Bangchura- local name	40.5	
Tomato + Radish	1	*Eleusine indica* (L.) Gaertn	63.4	156.50
		Cynodon dactylon Pers.	17.1	
		Digitaria sanguinalis (L) Scop	12.2	
		Amaranthus viridis L.	7.3	

Sampling unit = 50 x 50 cm quadrat

Impact

The findings of the survey contributed to understanding of the incidence pattern and status of pests attacking rice and winter vegetables in rice based vegetable cropping systems. The results also helped to identify some appropriate researchable issues in order to develop management technologies.

Networking Activities

Participated in the Participatory Appraisal and Planning workshop in August 1998 for initiating IPM CRSP research activities in Bangladesh and contributed to developing 1998-99 research plan. Dr. Tim Chancellor from IRRI visited IPM CRSP research fields in November 1998 and held meetings with Team Leaders to exchange views. Dr. S. K. De Datta visited in December 1998 and reviewed research progress. In February 1999, Drs. G. Norton, Greg Luther, Ed Rajotte, Carolyn Sachs, and Aurora Baltazar reviewed the progress of all the research activities, exchanged views and held program planning meetings to develop 1999-2000 workplan.

Research Information and Product Exchange

Specimens of different insect pests, including fruit flies, root knot nematodes, and some natural enemies, were given to Drs. Edwin Rajotte and George Norton for confirmation of species and exchange of information.

Project Highlights

Most farmers used mixed rice seeds for which varietal performance for yield and pest reaction varied. Some farmers were misusing insecticides by applying them below recommended doses as a prophylactic measure, which probably induced the proliferation of BPH, WBPH and RLF populations. The survey indicated that leaf curl virus, late and early blight of tomato, root rot of cauliflower and cabbage, leaf rot of chinese cabbage, bacterial wilt and fruit rot of eggplant, root knot nematode of country beans, and leaf blight of bunching onion are causing significant yield losses. Farmers' attitudes towards vegetable pests and management are yet to be determined.

Varietal Screening for Resistance to Bacterial Wilt, Fruit and Shoot Borer, and Root-knot Nematode in Eggplant

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Collaborating Scientists: L. Black[3], J.F. Wang[3], N.S. Talekar[3] and G. Luther[4]

Abstract

Twenty-three accessions of eggplant were tested in the field for their resistance to bacterial wilt (BW), root-knot nematode (RKN), and fruit and shoot borer (FSB). Although none was found resistant, a few entries exihibited tolerant reaction to BW, RKN and leafhopper. Entries that showed variable reactions to BW and tolerance to RKN and FSB were selected for further tests.

Objectives

To confirm the usefulness of the previously reported bacterial wilt (BW) resistant eggplant cultivars and potential focus on *solanum* rootstocks in Bangladesh, and to search for new sources of BW resistance;

To confirm previously reported FSB resistant sources and to find new sources of resistance in eggplant; and

To confirm RKN resistance in four eggplant cultivars previously identified at BARI and evaluate commonly used eggplant cultivars in Bangladesh for their reaction to RKN.

[1]BARI [2]BSMRAU [3]AVRDC [4]Virginia Tech

IPM Constraints

Eggplant, the most popular vegetable in Bangladesh, is cultivated throughout the year. Its production is badly affected by three major pests- bacterial wilt (*Pseudomonas solanacearum*), root-knot nematode (*Meloidogyne* spp.) and fruit and shoot borer (*Leucinodes orbonalis*). Based on previous work done at BARI, AVRDC and elsewhere, natural resistance to BW, RKN and FSB occurs in *Solanum* spp. and their resistance can be introgressed through breeding into the cultivated eggplant cultivars. Use of eggplant varieties resistant to these pests is the most effective and practical way to overcome the yield loss.

Research Methods

All the experiments were carried out at the farm of Bangladesh Agricultural Research Institute (BARI) during 1998-99 winter season (November- February).

Screening for resistance to bacterial wilt (*Pseudomonas solanacearum*)

Twelve 30-day old seedlings of 23 eggplant accessions were transplanted in three replications in a BW sickbed (inoculated with BW) following RCB design. Twelve days after transplanting (transplanted on November 7, 1998), the plants were again inoculated by toothpick method. The reaction of the plants was observed every week and the final record was taken one and a half-month after inoculation.

Screening for resistance to root-knot nematode (*Meloidogyne* spp.)

Ten 30-day old seedlings of 23 eggplant varieties/lines were transplanted in three replications in RCB design in a nematode sickbed, having a population of 3,250 RKN larvae per kg soil. The seedlings were transplanted 15 cm apart in rows having 20 cm space between rows. Sixty days after transplanting, the plants were uprooted, washed in running tap water and their shoot height and weight, and root weight were recorded. The roots of the plants were examined and the severity of galling was graded on a scale of 0 to 10; 0 represented roots without gall and 10 for roots with severe galling. The number of galls and eggmass of RKN per gm of root was also counted. The reactions of the varieties/lines were denoted as highly resistant (HR), resistant (R), moderately resistant (MR), susceptible (S) and highly susceptible (HS). All the data were subjected to ANOVA and Duncan's multiple range tests.

Screening for resistance to fruit and shoot borer (*Leucinodes orbonalis*)

Twenty 35-day old seedlings of 18 eggplant varieties were transplanted at 75 cm plant spacing in rows, one meter apart, in three replications following RCB design. Standard rates of manures and fertilizers were applied and necessary cultural operations were done. No pest control measure was adopted. Weekly observations were made to record infestation of different insect pests.

Results and Discussion

Eggplant resistance to bacterial wilt

All the eggplant varieties showed susceptible reaction to BW. However, a few plants of varieties BL083, BL099, B009, ISD006 and Black Long M survived, suggesting that these genotypes were heterogeneous for their resistance to BW. Seeds of the surviving plants were collected to confirm their reactions next year.

Eggplant resistance to RKN

The results showed that higher gall number, eggmass number and gall index was associated with reduced shoot height, shoot weight and root weight (Table 1). The shoot height (cm) and shoot weight (g) ranged from 21.3 to 42.9 and 10.8 to 42.5, respectively. The plant growth decreased with increasing disease incidence. The shoot weight Ysw and gall index Xgi were inversely correlated (r=0.425). Considering the gall index value, six varieties (Islampuri, A. Keshar, BLS18, BL118, ISD001 and Mixture) were considered tolerant to root knot nematode. These varieties were selected for retest.

Table 1: Reaction of eggplant varieties to root-knot nematode (*Meloidogyne* sp.)

Treatment	Shoot height (cm)	Shoot eight (gm)	Root Weight (gm)	Gall no./ gm root	Eggmass/ gm root	Gall index (0-10 scale)	Disease reaction
BL009	30.7 b-d	25.5 a-d	6.1 a	53.3 a-d	48.3 d-g	4.0 f-h	MR
BL114	31.4 b-d	24.2 b-d	2.4 cd	43.0 b-e	54.7 c-g	3.4 gh	MR
BLS5	34.2 a-c	19.2 d	5.3 a-c	53.3 a-d	61.3 b-f	6.7 ab	S
BL099	27.1 b-d	15.8 d	2.7 b-d	58.7 a-c	99.0 b-d	3.8 f-h	MR
ISD011	26.7 cd	13.4 d	3.2 a-d	64.3 ab	186.0 a	6.6 a-c	S
BL072	25.8 cd	13.3 d	2.9b-d	60.7 a-c	86.3 b-e	5.1 c-g	S
BLS2	32.4 a-c	19.9 cd	4.1a-d	34.3 c-g	52.3 d-g	4.2 f-h	MR

Table 1. *continued*

Treatment	Shoot height (cm)	Shoot eight (gm)	Root Weight (gm)	Gall no./ gm root	Eggmass/ gm root	Gall index (0-10 scale)	Disease reaction
Islampuri	33.4 a-c	20.3 cd	3.5 a-d	28.7 d-g	30.7 fg	3.7 f-h	MR
A.Keshar	31.5 b-d	27.9 a-d	3.4 a-d	7.7 g	16.7 fg	3.1 h	MR
BL039	28.8 b-d	21.5 cd	3.3 a-d	46.7 b-d	91.7 b-e	5.2 b-f	S
Uttara	33.8 a-c	28.5 a-d	3.6 a-d	62.7 a-c	108.0 bc	5.0 d-g	S
BL056	27.7 b-d	11.6 d	2.9 b-d	56.7 a-d	88.3 b-e	7.2 a	S
BL081	29.8 b-d	18.6 d	3.9 a-d	81.0 a	57.0 c-g	6.9 a	S
BLS18	36.7 a-c	39.6 ab	5.5 ab	12.7 fg	5.7 g	3.2 h	MR
BL034	21.4 d	11.6 d	3.1 b-d	66.3 ab	113.3 b	5.8 a-e	S
ISD006	34.0 a-c	42.5 a	3.7 a-d	45.7 b-e	101.7 b-d	3.7 f-h	MR
BL045	27.9 b-d	12.5 d	3.5 a-d	67.0 ab	114.7 b	6.4 a-d	S
BL083(1)	31.6 b-d	18.4 d	2.1 d	33.0 c-g	47.7 d-g	4.6 e-h	S
BL083(2)	42.9 a	37.8 a-c	3.9 a-d	39.7 b-f	53.3 d-g	4.2 f-h	MR
BL118	38.0 ab	27.6 a-d	3.8 a-d	8.0 g	14.0 fg	3.2 h	MR
ISD001	33.4 a-c	22.9 b-d	2.7 b-d	14.3 e-g	17.3 fg	4.2 f-h	MR
Mixture	27.1 b-d	16.8 d	2.3d	6.0 g	6.7 fg	3.1 h	MR
BLS4	32.6 a-c	37.5 a-c	4.5 a-d	33.3 c-g	38.3e-g	3.7 f-h	MR

Values, in a column, having a common letter are not significantly different by modified DMRT

Eggplant resistance to FSB

None of the test varieties was resistant. Fruit infestation was more severe compared to shoot infestation. Fruit infestation ranged from 22.5 – 56.2%, the lowest being in genotype BLS5 (22.5%). High infestation of jassid (leafhopper) was observed on all the varieties, except mild infestation in ISD006, ISD011 and BLS2 (Table 2).

Table 2: Reactions of eggplant varieties to fruit and shoot borer.

Germplasms	% Shoot infestation	% Fruit infestation	Healthy fruit yield (t/ha)	Infested fruit yield (t/ha)	Jassid infestation
Islampuri BADC	3.3	42.6	8.7	3.8	Moderate
BL099	5.0	35.4	8.1	5.3	Moderate
BL14	2.7	38.3	9.2	3.0	Moderate
ISD006	5.0	49.7	11.0	7.1	Mild
BL045	2.7	57.5	12.8	7.7	Severe
ISD011	2.5	42.9	12.6	8.3	Mild
BL039	1.6	44.3	6.0	5.0	Moderate
BLS18	2.5	44.0	7.0	2.9	Moderate
Islampuri Inbrid	2.5	33.7	15.4	7.2	Moderate
BL118	4.2	43.4	14.6	5.2	Moderate
BLS5	2.1	22.5	7.5	2.4	Moderate
BL083	1.7	35.3	5.7	2.0	Moderate
BL034	4.1	38.4	7.0	2.0	Severe
BLS4	2.5	34.6	6.6	3.0	Severe
Uttara	3.4	56.2	10.5	1.5	Moderate
BLS2	2.3	37.9	7.3	2.3	Mild
BL009	2.8	46.8	5.4	5.8	Moderate
BL056	2.6	46.5	8.3	3.6	Moderate

Impact

The overall results indicate that the test eggplant varieties have genetic variability for their resistance /tolerance to bacterial wilt, root-knot nematode and fruit and shoot borer. Test of traditional and exotic varieties against these pests may lead to the identification of resistant sources, which may be used for developing agronomically acceptable resistant varieties.

Networking Activities

Participated in the Participatory Appraisal and Planning Workshop in August 1998 to develop Annual Workplan of IPM CRSP in Bangladesh. Dr. S. K. De Datta visited in December 1998 to supervise the progress of the experiments. In February 1999, a team of 5 scientists from USA and the Philippines visited Bangladesh and reviewed with them the progress of the on-going activities and prepared the future workplan.

Received nematode separation sieves through Dr. Edwin Rajotte of Penn State University.

Project Highlights

Results indicate the possibility of getting resistant/ tolerant sources of eggplants by evaluating local and exotic germplasm that can then be developed into commercial varieties.

Cultural Control of Aphid and Diamondback Moth in Cabbage

Investigators: S.M. Monowar Hossain[1], S.R. Mallik[1], M. Nazimuddin[1], M.I. Ali[1] and A. Mannan[1]

Collaborating Scientists: N.S. Talekar[2], E. Rajotte[3] and G. Luther[4]

Abstract

Mustard was grown as a trap crop to attract and control diamondback moth and aphid of cabbage. In place of the above pests, the leaf-eating caterpillar, *Spodoptera litura*, invaded the experimental cabbage field and caused considerable damage. Mustard failed as a trap crop to attract *Spodoptera* caterpillar.

IPM Constraints

Diamondback moth (*Plutella xylostella* L.) and aphids [*Lipaphis erysimi* (Kalt)] are the two major insect pests of cabbage in Bangladesh. To control the pests, frequent use of pesticides by the farmers on cabbage causes residual effect in the food chain. Cultivation of mustard as a trap crop can be used as an alternative to keep away the pests and produce a pesticide free cabbage crop.

Research Methods

The experiment, laid out in RCB design with four replications, was conducted in farmer field at Kashimpur of Gazipur district from November 1998 to February 1999 with the following two treatments: Cabbage + mustard (T_1) and Cabbage only (T_2). Thirtyfive-day old seedlings of cabbage (variety – Atlas 70) were transplanted on 30 October, 1998 in each plot (10 m X 6 m) at a spacing of 50 X 50 cm. Each plot contained eight rows of cabbage and after four rows of cabbage there were two rows of mustard (variety – Rai). First sowing of mustard as trap crop was made on 14 October, 1998 and second was made on 25 October, 1998. Manures (cowdung) and fertilizers (N, P, K, S, Zn, and Bo) were applied at recommended rates.

Insect infestation records were taken weekly starting from early planting to head formation stage and cutworm larvae (*Spodoptera litura*) were counted from all plants. At the maturity stage, the head size, head weight and number of culled heads were recorded. Returns from the treatments were also calculated.

Results and Discussion

Infestation of cabbage plants by cutworm in cabbage+mustard (28.6%) and sole cabbage (26.6%) plots was comparable. Culled heads were lower in cabbage+mustard plot (16.1%) than in sole cabbage (22.2%), but the single head weight did not differ between the treatments. The yield of cabbage in sole cabbage plots

[1]BARI [2]AVRDC [3]Penn State [4]Virginia Tech

was, however, much higher than that of the other treatment and so was the gross return (Table 1).

The results of the trial showed that, in absence of diamondback moth and aphids, intercropping mustard with cabbage did not produce any advantage to control the cutworm (*Spodoptera litura).*

Table 1: Effect of cutwom (*Spodoptera litura)* infestation in cabbage in cabbage+mustard intercrop.

Treatments	Mean Infestation[1] (%)	Culled head (%)	Single head weight (g)	Yield (ton)		Return[2] (Tk.)		Gross return (Tk.)
				Cabbage	Mustard	Cabbage	Mustard	
Cabbage+Mustard (T_1)	28.6	16.1	1210	25.0	1.12	125,000	16,800	141,800
Sole Cabbage (T_2)	26.7	22.2	1195	31.02	-	155,100	-	155,100

[1]Average of four observations; [2]Farmgate price of cabbage Tk.5,000/t and mustard Tk.15,000/t

Impact

Pest control treatments in an area must be based on the identification of actual pests and their patterns of incidence.

Networking Activities

Participated in the Participatory Appraisal and Planning workshop in August 1998 and developed workplan for IPM CRSP in Bangladesh. Dr. S. K. De Datta visited the experiments in December 1998 and reviewed the progress. Attended the Review meetings in February 1999 with the visiting IPM CRSP scientists to discuss progress of the ongoing experiments and prepare future workplan.

Comparison of Lures and Effectiveness of Mass Trapping for Cucurbit Fruit Flies *Bactrocera cucurbitae* (Coquillett)

Investigators: M. Nasiruddin[1], M.F. Zaman[1], M.N. Islam[2], H.S. Jasmine[3] and D.K. Das[3]

Collaborating Scientist: E. Rajotte[4], G.Luther[5], N.S. Talekar[6] and T. Chancellor[7]

Abstract

Two synthetic pheromones, Cuelure and Methyl eugenol, and one indigenous material, mashed sweet gourd, impregnated with insecticide were tested in farmer fields at Kashimpur and at BARI farm, Gazipur to determine their efficacy for trapping adult fruit flies, *Bactrocera cucurbitae*, infesting bitter gourd and cucumber crops. The lure traps were placed in the fields in two designs: one by placing the traps only in the center of the field, and the other both in the center and periphery of the field. Irrespective of the trap placing design, Cuelure proved to be the best capturing 57% and 86% of the total fruit fly catch in design 1 and design 2, respectively.

[1]BARI [2]BSMRAU [3]IPM CRSP [4]Penn State [5]Virginia Tech [6]AVRDC [7]IRRI

Objectives

To compare the effectiveness of cuelure, methyl eugenol and mashed sweet gourd in bait traps; and

To compare the effectiveness of mashed sweet gourd peripheral traps as a mass trapping technique.

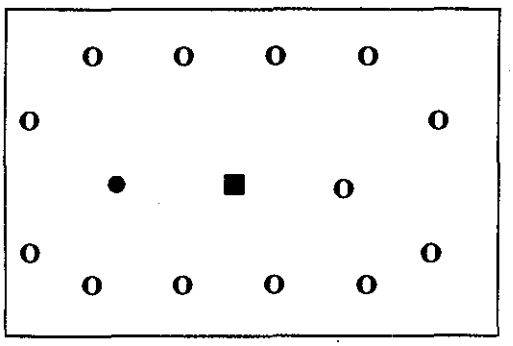
IPM Constraints

Fruit fly, *Bactrocera cucurbitae*, is the predominant damaging pest of a number of cucurbit crops in Bangladesh. To protect the crops, farmers use heavy doses of insecticides, which are hazardous to health and environment. In preliminary tests lure traps have been found to be useful to control fruit flies. Usefulness of this technique needs to be tested in farmer fields and if found effective, it will reduce pesticide residues in the food source and promote production of healthy cucurbit crops.

Research Methods

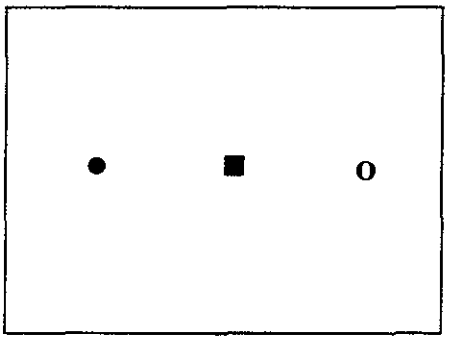
The experiments were conducted during the summer season from March to July 1999 at BARI farm and in two villages of Kashimpur, an intensive vegetable growing area in Gazipur district. Two fields of bitter gourd, *Momordica carantia* and two fields of cucumber, *Cucumis sativus* in each village were selected; each field was situated 800 to 1000 meters away from each other. Bitter gourd and cucumber fields were planted in the third week of March, and the final harvest was done in the third week of July for bitter gourd and third week of June for cucumber. Bitter gourd and cucumber plants were grown in pits, about 1.6m apart. Traps were placed in two designs:

a. Design 1: Placing 12 mashed sweet gourd traps on the periphery and 3 traps each of cuelure, methyl eugenol and mashed sweet gourd 10 meters apart in a row in the middle of the field; and



Design 1. Peripheral trapping

Design 2: Placing only 3 traps each of cuelure, methyl eugenol and mashed sweet gourd 5 meters apart in a row in the middle of the field.



Design 2. Central trapping

● Cuelure ■ Methyl Eugenol O Mashed Sweet Gourd

The traps were placed at about 60cm height on a bamboo mount. Mashed sweet gourd traps were prepared with 100g mashed sweet gourd, 0.5 ml dichlorovos (Nogos 100EC) and 100ml water and were placed in 12cm dia earthen saucer. An inverted saucer (25 cm dia.) was placed about 20cm over the trap pan to protect it from rainwater and sunlight. The pheromone lures, cuelure and methyl eugenol, were placed in a (12 cm dia and 20 cm height) transparent, round plastic container; a round 12cm dia sticky board was placed at the bottom of the plastic container and the lure (4ml) soaked in a cotton wick was suspended from the top (mouth) of the container about 5cm above the sticky board. Two inverted 'v'- shaped openings were cut on the opposite lateral sides of the plastic container to provide access for the fruit flies to the trap. The traps were set in the crop fields at the beginning of flowering (2nd to 3rd week of May) and continued until the harvest of the crop (3rd week of June to 3rd week of July). Trapped fruit flies were recorded everyday. Materials of mashed sweet gourd bait were changed twice a week; while pheromone lures were changed every month.

Results and Discussion

At Kashimpur site, fruit fly catch was about 2 to 5 times higher in the bitter gourd and cucumber plots when the lure traps were placed both at the periphery and in the center of the fields (design-1) than when placed only in the center (design-2, Table 1). At BARI farm, however, the difference in the total fruit fly catches between the trap setting designs was small, probably because of the fact that the fruit flies were also attracted to the mashed sweet gourd traps set in many adjacent gourd fields to control the fruit flies. Among the three lure traps placed in the center of the fields, cuelure traps captured the highest number of fruit flies followed by mashed sweet gourd traps, irrespective of the

kind of crops or design of the trap placing system. Totally, cuelure traps captured 3830 fruit flies (56.9%) in design-1 and 2997 fruit flies (86.3%) in design-2 as compared to 182 and 276 fruit flies, respectively, in mashed sweet gourd traps. This showed that cuelure was a better fruit fly lure than methyl eugenol and mashed sweet gourd. It was important, however, that mashed sweet gourd traps placed in the periphery of bitter gourd and cucumber fields captured 35-39% of the total fruit flies, which included both male and female fruit flies in the proportion of 1:2. No female fruit flies were trapped in cuelure or methyl eugenol pheromone traps. This means that capturing fruit flies by mashed sweet gourd traps may create a negative impact gradually on the proliferation of the fruit flies.

Capture of fruit flies in the traps, irrespective of the trap setting pattern (design-1 or 2), were usually higher from the beginning of fruiting to peak harvest time; it gradually tapered towards the end of harvest (Tables 3-8). Higher fruit fly catch in design-1, however, is not reflected in fruit fly damage in bitter gourd or cucumber crops. Greater percentage of bitter gourd or cucumber fruits were damaged in design-1 fields, where higher number of fruit flies were captured (Table 2). The results of the trapped fields could not, however, be compared with a no-trap field. Farmers, on the other hand, were highly interested in the results as they reported at least 50% loss of marketed fruits in unprotected fields.

Table 1: Total number of fruit flies captured by different bait materials at farmer fields at Kashimpur and BARI.

Locations	Trap-ping period	Design 1.					Design 2			
		Cuelure Center %	Methyl eugenol Center %	Mashed sweet gourd (center) %	Mashed sweet gourd (peri-pheral) %	Total (%)	Cuelure (center) %	Methyl eugenol Center %	Mashed sweet gourd (center) %	Total (%)
Kashimpur (Bitter gourd)	70 days	1754 (56.18)	99 (3.17)	83 (2.65)	1186 (37.98)	3122 (100)	504 (72.51)	81 (11.65)	110 (15.82)	695 (100)
Kashimpur (Cucumber)	35 days	1715 (57.30)	21 (0.70)	78 (2.60)	1179 (39.39)	2993 (100)	1689 (93.83)	78 (4.33)	33 (1.83)	1800 (100)
BARI (Bitter gourd)	56 days	361 (58.03)	22 (3.53)	21 (3.37)	218 (35.04)	622 (100)	804 (82.37)	39 (3.99)	133 (13.62)	976 (100)
Total		3830	142	182	2583	6737	2997	198	276	3471
Avg. (%)		(56.9)	(2.1)	(2.7)	(38.3)		(86.3)	(5.7)	(8.0)	

Table 2: Fruit fly damage rates in bitter gourd and cucumber crops as effected by lure traps.

Locations	Field size (Sq.m)	Trap setting patt-ern	Heal-thy fruits/ plot (No.)	Fully dam-aged/ plot (No.)	Parti-ally dam-aged /plot (No.)	Marke-table fruits/ plot (No.)	Total fruits/ plot (No.)	wt. of heal-thy fruits/ plot (kg)	wt.of parti-ally dam-aged (mark-etable) fruits / plot (kg)	Total wt. of mark-etable fruits/ plot (kg)	Value of mark-eted fruits/ plot (Taka)
Kashimpur (Bitter gourd)	600 (25x24m)	Design1	3760 (48.1%)	2843 (36.4%)	1210 (15.5%)	4970 (63.6%)	7813	301.0	64.5	365.5	3705.0
	165 (15x11m)	Design2	1640 (57.1%)	95 (32.2%)	309 (10.7%)	1949 (67.8%)	2874	105.0	16.0	121.0	1440.0
Kashimpur (Cucumber)	560 (28x20m)	Design1	361 (74.7%)	71 (14.7%)	51 (10.6%)	412 (85.3%)	483	73.0	13.0	86.0	765.0
	1150 (50x23m)	Design2	1643 (84.8%)	90 (4.6)	206 (10.5%)	1847 (95.3%)	1937	333.0	39.0	372.0	2900.0

1 US dollar = 50 Taka

Table 3 Fruit fly capture in sex pheromone and mashed sweet gourd traps in design 1 in bitter gourd at Kashimpur.

Days after trapping	Number of fruit fly captured in			
	Cuelure (Center) M	Methyl eugenol (Center) M	Mashed sweet gourd (Center) M+F =Total	Mashed sweet gourd (periphe-ral) M+F =Total
07 DAT	193	22	6+5 = 11	52+60 = 112
14 DAT	205	4	3+5 = 8	29+37 = 66
21 DAT	244	7	7+1 = 8	61+87 = 148
28 DAT	203	7	5+8 = 13	54+114 = 168
35 DAT	255	11	2+8 = 10	55+149 = 204
42 DAT	153	3	2+11 = 13	49+157 = 206
49 DAT	199	8	4+9 = 13	20+94 = 114
56 DAT	112	17	1+2 = 3	16+35 = 51
63 DAT	108	11	1+3 = 4	34+76 = 109
70 DAT	80	10	0+0 = 0	2+5 = 7
Total	1754	99	31+52 = 83	372+814 = 1186

M = Male, F = Female

Table 4: Fruit fly capture in sex pheromone and mashed sweet gourd traps in design 2 in bitter gourd at Kashimpur.

Days after trapping	Number of fruit fly captured in		
	Cuelure M	Methyl eugenol M	Mashed sweet gourd (Center) M+F=Total
07 DAT	81	10	0+1 = 1
14 DAT	73	4	1+7 = 8
21 DAT	61	5	2+6 = 8
28 DAT	64	4	7+17 = 24
35 DAT	38	7	11+27 = 38
42 DAT	36	17	4+14 = 18
49 DAT	42	16	8+18 = 26
56 DAT	15	9	2+5 = 7
63 DAT	65	6	0+3 = 3
70 DAT	29	3	1+3 = 4
Total	504	81	36+74 = 110

M = Male, F = Female

Table 5: Fruit fly capture in sex pheromone and mashed sweet gourd traps in design 1 in cucumber at Kashimpur.

Days after trapping	Number of fruit fly captured in			
	Cuelure (Center) M	Methyl eugenol (Center) M	Mashed sweet gourd (Center) M+F =Total	Mashed sweet gourd (periphe-ral) M+F =Total
07 DAT	290	13	9+13 = 22	118+299 = 417
14 DAT	387	3	5+3 = 8	84+162 = 246
21 DAT	555	3	7+28 = 35	76+195 = 271
28 DAT	320	2	2+6 = 8	42+73 = 115
35 DAT	163	0	1+4 = 5	50+80 = 130
Total	1715	21	24+54 = 78	370+809 = 1179

M = Male, F = Female

Table 6: Fruit fly capture in sex pheromone and mashed sweet gourd traps in design 2 in cucumber at Kashimpur.

Days after trapping	Number of fruit fly captured in		
	Cuelure (Center) M	Methyl eugenol (Center) M	Mashed sweet gourd (Center) M+F=Total
07 DAT	245	16	3+3 = 6
14 DAT	343	2	0+0 = 0
21 DAT	434	17	0+2 = 2
28 DAT	394	35	3+12 = 15
35 DAT	273	8	1+9 = 10
Total	1689	78	7+26 = 33

M = Male, F = Female

Table 7: Fruit fly capture in sex pheromone and mashed sweet gourd traps in design 1 in bitter gourd at BARI.

Days after trapping	Number of fruit fly captured			
	Cuelure (Center) M	Methyl eugenol (Center) M	Mashed sweet gourd (Center) M+F =Total	Mashed sweet gourd (periphe-ral) M+F =Total
07 DAT	65	1	0+0 = 0	7+24 = 31
14 DAT	99	4	2+7 = 9	15+43 = 58
21 DAT	57	0	1+1 = 2	9+28 = 37
28 DAT	33	0	1+4 = 5	14+39 = 53
35 DAT	59	2	0+2 = 2	9+14 = 23
42 DAT	35	4	1+1 = 2	1+10 = 11
49 DAT	5	4	1+0 = 1	2+2 = 4
56 DAT	8	7	0+0 = 0	0+1 = 1
Total	361	22	6+15 = 21	57+161 = 218

M = Male, F = Female

Table 8: Fruit fly capture in sex pheromone and mashed sweet gourd traps in design 2 in bitter gourd field at BARI.

Days after trapping	Number of fruit fly captured		
	Cuelure (Center) M	Methyl eugenol (Center) M	Mashed sweet gourd (Center) M+F=Total
07 DAT	274	7	4+7 = 11
14 DAT	230	5	3+26 = 29
21 DAT	128	4	7+23 = 30
28 DAT	57	0	8+19 = 27
35 DAT	64	3	7+16 = 23
42 DAT	33	5	3+4 = 7
49 DAT	13	5	2+4 = 6
56 DAT	5	10	0+0 = 0
Total	804	39	34+99 = 133

M = Male, F = Female

Impact

Results so far obtained suggest that the lure traps can capture considerable number of cucurbit fruit flies and thereby reduce the natural populations of fruit flies. Using this technique the use of chemical pesticides can be greatly minimized, which will ultimately contribute to production of healthy, pesticide free cucurbits.

Networking Activities

Attended the review meetings in February 1999 with the visiting IPM CRSP overseas scientists to discuss setting up the experiments and preparing future plans.

Dr. Edwin Rajotte of Penn State University supplied the pheromone lures, and Dr. N.S. Talekar of AVRDC also supplied insecticide impregnated pheromone lures, which are yet to be tested.

Project Highlights

Cuelure, a pheromone lure for fruitflies, appeared to be a potential material which can capture cucurbit fruitflies and reduce the natural populations of the pest. Intensive experimentation is, however, needed to find out a satisfactory design of trap setting based on fruitfly population dynamics.

Efficacy of Weed Control Methods in Cabbage

Investigators: M.A. Rahman[1], M.S. Hasan[1], D.K. Das[2]

Collaborating Scientists: S.K. De Datta[3], A. Baltazar[4]

Abstract

Eight weed species were recorded from the cabbage experimental fields. Two hand weeding at 15 DAT and 45 DAT and 3 hand weeding in farmer practice had fewer number of weed species and lesser weed biomass (by fresh wt.) compared to no weeding or one hand weeding. Two hand weeding and the farmer practice produced twice as much yields of edible cabbage and higher economic return as that of no weeding.

Objectives

To determine the minimum number of weeding operations required for effective weed control that can bring about higher yield and economic return.

IPM Constraints

Cabbage is one of the most popular winter vegetables in Bangladesh. Weed infestation, particularly during head formation, is responsible for high yield reduction for which farmers' cost for weed control is very high. Determination of minimum number of weeding required for maximum

[1]BARI [2]IPM CRSP [3]Virginia Tech [4]UPLB-NCPC

weed control can ensure higher yields offering higher economic returns to the farmers.

Research Methods

Two experiments were conducted during the winter season 1998-99 (November to January) in two farmer fields at Kashimpur of Gazipur district to evaluate five weeding treatments in four replications laid out in RCB design. The treatments were: a) One hand weeding (HW) at 15 days after transplanting (DAT); b) Two HW at 15 and 45 DAT; c) Farmer practice; d) Weeding by BARI weeder at 15 and 45 DAT; and e) No weeding (control). Each plot (15.6 m^2) contained 7 rows, 60 cm apart, with 6 plants/row at 45 cm spacing.

Data were recorded on weed composition and weed number, weed weight, plant height, height and breadth of cabbage head, and edible yield. Economic returns from each treatment were also calculated.

Results and Discussion

As many as eight weeds species were recorded from the cabbage plots (Table 1). The number of weeds and weed fresh weight/m^2 in the control plot (no weeding) were 2 and 17 times higher, respectively, when compared with those in farmer practice treatment, where the farmers kept the plots almost weed free. In other treatments also the weed number and weed weight were, respectively, about 1.5 and 3 times lower than that of the control (Table 2). The results showed that higher weed biomass lowered the cabbage head size (head height and breadth) (Table 3) and reduced the yield (Table 4).

Table 1: Composition of weeds in cabbage experimental fields at Kashimpur.

English name	Scientific name	1 HW	2 HW	FP	BW	NW
Bermuda grass	*Cyperus rotundus*	+	+	+	+	+
	Cynodon dactylon	+	+	–	+	+
Barnyard grass	*Echinochloa colonum*	+	+	+	+	+
Goose grass	*Eleusine indica*	+	+	+	+	+
	Alternathera sessilis	–	+	–	+	–
Green amaranth	*Amaranthus viridis*	+	+	+	+	+
	Pasplam commersonni	+	+	–	+	+
Spiny amaranth	*Amaranthus spinisus*	+	+	–	+	+

HW = Hand weeding; FP = Farmer practice; BW = BARI weeder; NW = No weeding

Table 2: Weed infestation in cabbage 45 days after transplanting as affected by weed control method.

Treatment	No. of weed species/m^2			Fresh weight g/m^2		
	F_1	F_2	Mean	F_1	F_2	Mean
One HW at 15 DAT	5.2	4.2	4.7	372	225	298
Two HW at 15 & 45 DAT	5.7	3.2	4.4	334	120	229
Farmer Practice 3-4 HW	2.7	3.2	2.9	58	45	51
BARI Weeder at 15 & 45 DAT	3.7	4.2	3.9	333	220	276
No Weeding	6.2	6.4	6.3	961	800	880

All figures are averages of four replications; F = Farmer

Table 3: Plant characteristics of cabbage under variable weed control method.

Treatment	Plant characteristics								
	Plant height (cm)			Head height (cm)			Breadth (cm)		
	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean
One HW at 15 DAT	18.9	17.6	18.3	11.9	11.8	11.9	17.2	19.1	18.2
Two HW at 15 & 45 DAT	19.0	17.0	18.0	12.0	11.2	11.6	19.5	20.4	20.0
Farmer Practice 3-4 HW	19.3	16.4	17.9	11.7	11.4	11.6	18.3	19.5	18.9
BARI Weeder at 15 & 45 DAT	19.0	17.9	18.5	12.0	10.9	11.5	19.5	19.5	19.5
No Weeding	19.9	18.0	19.0	11.4	11.1	11.3	16.7	18.8	17.8

All figures are averages of four replications; F = Farmer

Two hand weeding at 15 and 45 DAT, farmer practice, and weeding by BARI weeder produced similar yields. The highest mean yield (44.9 t/ha) from two farmer fields was obtained from two hand weeding, followed by farmer practice (44.3 t/ha) and the lowest (30.9 t/ha) in no weeding treatment. Two hand weeding at 15 and 45 DAT cut down the weeding operations and weeding cost by about 50% without reducing the cabbage yield (Table 4).

Table 4: Cabbage yield (t/ha) as affected by weed control method.

Treatments	Edible yield (t/ha)			Weeding cost/ha (Tk)			Mean savings by 2 HW	
	F_1	F_2	Mean	F_2	F_2	Mean	Taka	%
One HW at 15 DAT	28.0a	40.6	34.3	1602	2160	1881	4244	69
Two HW at 15 & 45 DAT	44.0a	45.8	44.9	2884	3086	2985	3144	50
Farmers' Practice	45.2a	43.4	44.3	5769	6481	6125	–	–
BARI Weeder at 15 & 45 DAT	41.2a	37.8	39.5	3205	4320	3762	2363	39
No Weeding	24.9b	36.9	30.9	0	0	0	–	–

All figures are averages of four replications; F = Farmer

Impact

Results of two on-farm experiments showed that, instead of three to four weeding, farmers can effectively control the weeds in their cabbage field through deploying only two weeding operations during the early and mid growth stages of the crop and his practice will minimize the cost of cultivation bringing about higher yield and economic returns.

Networking Activities

Participated in the initial Participatory Appraisal and Planning meetings in August 1998 to develop workplan for IPM CRSP in Bangladesh. Dr. S. K. De Datta visited the experimental fields in December 1998 and reviewed the progress. In a review meeting in February 1999, discussed the results of the experiments with the visiting overseas scientists and prepared the future workplan.

Project Highlights

Two weeding operations during the active growth stage of cabbage can effectively control the predominant weeds, reduce the weeding operations and weeding cost by 50% and bring about higher yield.

Efficacy of Weed Management Practices in Okra

Investigators: M. Nazrul Islam[1], D.K. Das[2] and Anwar Karim[1]

Collaborating scientists: A. Baltazar[3] and S.K. De Datta[4]

Abstract

Three on-farm experiments conducted in two villages at Kashimpur site during the summer season from April to July 1999 showed that the weed species, their infestation intensities and predominance varied in different fields. The results revealed that the farmers can reduce their weed control practices in okra field by about 50% by adopting only two hand weeding operations at 15 and 35 days after okra seeding instead of 3-5 weeding operations as practised

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by them. Two hand weeding effectively controlled the weeds and produced higher yield which fetched better economic returns through saving the production cost significantly.

Objectives

To determine the number of weeding required in okra field for effective weed control, higher yield and satisfactory economic return.

IPM Constraints

Weed infestation in okra field is a major cause of yield loss. Farmers expend a considerable amount of money for weed control which greatly inflate the cost of okra cultivation. There is a need to determine appropriate weed control measures at the critical period of crop growth that can effectively control weeds, reduce yield loss and cost of cultivation, and bring about higher economic benefits to the farmers.

Research Methods

Three experiments were conducted separately during 1999 summer season (April to July) in three farmer fields in two villages (Nayapara and Barenda) of Kashimpur site using the following treatments: T_1- One handweeding (HW) at 15 days after seeding (DAS) of okra; T_2- Two HW at 15 and 35 DAS; T_3- Farmer practice; T_4- Mechanical weeding by BARI weeder at 15 DAS and one HW at 35 DAS; T_5- No weeding (control); and T_6- Weed free throughout the crop period. In each of the farmer fields, the treatments were laid out in RCB design with four replications in unit plots of 5m X 4.5m. Seeds of Okra (variety BARI Dherosh-1) were planted 45 cm apart in rows keeping 50cm space between rows. Fertilizers (N, P, K, Zn) were applied at recommended rates and usual cultural practices were followed. Two sprays of phosmamidon (dimecron 100) were done in all the experiments to control leafhopper infestation. Data were recorded on plants/m^2, plant height, weed composition, weed number/m^2, weed biomass, yield attributes, and yield. All the data were subjected to ANOVA and the differences of means were based on LSD. Economics of returns from the treatments were also calculated.

Results and Discussion

Field 1 (Nayapara village)

Nine weed species were recorded from this experimental field; *Echinochloa crusgalli* being the major (35%), followed by *Cyperus rotundus* (25%), *Eleusine indica* (10%), and *Portulaca oleraceae* (9.3%). Highest weed biomass (1164 g/m^2 by dry wt.) was recorded in T_5 (no weeding), followed by T_4 (BARI weeder + one HW). Weed biomass in T_1 (one HW), T_2 (two HW), T_3 (farmer practice-5 HW) and T_6 (weed free) was comparable ranging from 209 g to 280 g/m^2. Negative effects of weed infestation were observed on plant height, fruit bearing and yield; the higher the weed biomass, the lesser was the plant height, fruit number and yield. Two HW (T_2) at 15 and 35 DAS was better giving higher economic returns, although it produced yield comparable to that obtained by five weeding in farmer practice (T_3) or weed free (T_6) plots (Table 1).

Field 2 (Barenda village)

Seven species were recorded from this field, *Cyperus esculentus* being the most dominant weed (79%), followed by *Echinochloa crusgalli* (17%). Results were similar to those of field 1. Control plots (no weeding) had the highest weed biomass (455 g/m^2 by dry wt.), about twice as much as in other treatments, which affected the plant growth, fruit bearing and yield. Weed biomass in other treatments, excepting for T_1 (one HW), was comparable (193g to 217g/m^2) and the plant growth, fruit bearing per plant and yields did not vary. One HW was unsatisfactory for weed control and higher yield (Table 2). Instead of three HW as practised in farmer practice (T_3) and weed free (T_6) plots, two HW (T_2) appeared to be better in controlling the weeds and producing economically better yields.

Field 3 (Nayapara village)

Eight weed species were recorded from this experimental field; the major ones were *Cyperus esculentus* (33%), *Portulaca oleraceae* (25%), *Cynodon dactylon* (12%), and *Echinichloa crusgalli* (9%). A number of unidentified weeds (14%) were also recorded in this field. However, weed infestation in the control plots (no weeding) of this field was very low; the weed biomass was only 129g/m^2 compared to 455g and 1164g/m^2 in other two fields. This happened probably because of okra cultivation just after wheat in the dry winter season. Weed infestation was lowest (42g/m^2 by dry wt.), followed by 48.5g in one HW (T_1), 63g in farmer practice (T_3), 64g in BARI weeder (T_4), and 80g in weed free (T_6) plots. Because of low weed infestation, there was no difference in plant growth and fruit bearing among the weeded plots, but two HW at 15 and 35 DAS gave the highest yield as the weeding operations were apparently done during the critical growth stage of the crop (Table 3).

The overall results of the experiments showed that the number weed species and their predominance varied considerably in different fields. As a result, the farmers weeded their fields at different frequencies without considering the crop growth stage critical for weeding and

the cost of weeding. Two HW at 15 and 35 DAS, on the other hand, coincided with the critical crop growth stage when weeding was practically needed to cease yield loss from weed infestation. Weeding after 15 and 35 DAS was economical as taller growth and denser canopy of the plants afterwards suppressed weed emergence. Two HW at 15 and 35 DAS, therefore, saved weeding cost by an average of Tk. 3523/ha (22%) (Table 4).

Table 1: Effects of weed management on weed infestation, plant growth, yield attributes and yields of okra. (Field 1)

Treat-ment	Weed dry biomass g/m^2)	Plant height (cm)	Fruit/plant (No.)	weight/fruit (g)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)	BCR	MBCR
T_1	279.8	144.9	12.4	12.3	13.5	1.2	9.4	2.19	12.47
T_2	219.1	146.5	12.6	12.3	13.8	1.2	10.2	2.24	8.42
T_3	209.4	153.2	13.4	13.4	13.1	1.3	11.8	2.23	5.87
T_4	405.1	126.1	10.3	12.2	13.3	1.2	8.8	1.97	7.47
T_5	1164.0	79.35	4.5	10.7	11.4	1.1	1.8	0.49	–
T_6	220.2	151.5	12.9	12.8	13.2	1.3	11.6	2.08	4.95
LSD at <0.05	31.62	12.92	1.42	1.24	0.63	NS	0.82	–	–
CV (%)	5.05	6.41	8.56	6.71	3.19	7.30	6.12	–	–

All figures are averages of four replications.
T_1 = One HW at 15 DAS; T_2 = Two HW at 15 DAS & 35 DAS; T_3 = Farmer practice-5 HW; T_4 = Weeding by BARI weeder at 15 DAS & one HW at 35 DAS; T_5 = No weeding; T_6 = Weed free- 5 HW

Table 2: Effects of weed management on weed infestation, plant growth, yield attributes and yields of okra. (Field 2)

Treat-ment	Weed dry biomass g/m^2)	Plant height (cm)	Fruit/plant (No.)	weight/fruit (g)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)	BCR	MBCR
T_1	231.2	174.5	13.4	15.0	13.5	1.3	10.4	1.73	7.21
T_2	217.5	186.9	15.2	15.0	13.1	1.4	11.5	1.70	4.33
T_3	193.4	189.1	17.2	16.8	14.7	1.2	12.7	1.80	4.29
T_4	208.4	175.2	16.3	16.2	14.6	1.9	12.4	1.84	5.04
T_5	455.0	154.6	10.8	14.3	12.7	1.4	5.4	1.01	–
T_6	200.8	187.4	15.5	16.7	14.6	1.5	12.5	1.78	4.23
LSD at <0.05	27.58	13.77	0.81	1.33	1.09	0.18	1.1	–	–
CV (%)	7.29	5.14	3.68	5.62	5.20	8.04	6.70	–	–

All figures are averages of four replications.
T_1 = One HW at 15 DAS; T_2 = Two HW at 15 DAS & 35 DAS; T_3 = Farmer practice- 3 HW; T_4 = Weeding by BARI weeder at 15 DAS & one HW at 35 DAS; T_5 = No weeding; T_6 = Weed free- 3HW

Table 3: Effects of weed management on weed infestation, plant growth, yield attributes and yields of okra. (Field 3)

Treat-ment	Weed dry biomass g/m^2)	Plant height (cm)	Fruit/plant (No.)	weight/fruit (g)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)	BCR	MBCR
T_1	48.5	190.8	16.5	16.3	11.0	1.2	16.9	3.06	10.82
T_2	42.3	185.7	17.0	17.3	12.0	1.3	17.6	3.06	8.67
T_3	62.9	190.8	16.8	17.1	11.5	1.3	16.1	2.77	5.87
T_4	64.2	198.8	16.8	16.5	11.4	1.2	16.1	2.77	8.17
T_5	129.0	185.0	15.0	15.5	10.8	1.1	14.2	2.72	–
T_6	79.6	173.0	16.5	15.8	11.2	1.1	14.6	2.47	4.95
LSD at <0.05	7.60	NS	0.74	1.12	NS	0.09	0.97	–	–
CV (%)	7.09	6.4	3.01	4.54	7.0	4.90	4.08	–	–

All figures are averages of four replications.
T_1 = One HW at 15 DAS; T_2 = Two HW at 15 DAE & 35 DAS; T_3 = Farmer practice-2 HW; T_4 = Weeding by BARI weeder at 15 DAS & one HW at 35 DAS; T_5 = No weeding; T_6 = Weed free-2 HW
MBCR = Marginal return/Variable cost
Marginal return = Treatment return – Control return

Table 4: Cost saving from two hand weeding compared to farmer practice (1 US $= Tk. 48.32)

Field Number	Yield (t/ha)		Weeding cost (Tk)		Cost saving by 2 HW		MBCR
	T_2	T_3	T_2	T_3	Taka	Percent	
Field 1	10.2	11.8	9787	17131	7344	43	8.4
Field 2	11.5	12.7	14137	17013	2876	17	4.3
Field 3	17.6	16.1	5180	5530	350	6	6.5
Average	13.1	13.5	9701	13225	3523	22	6.4

T_2 = Two HW at 15 & 35 DAS; T_3 = Farmer practice

Impact

Results showed that farmers adopted weed control measures to keep their okra fields free of weeds without considering the crop growth stage when weeding was most critical to minimise yield loss. As a result, frequent weeding operations increased the cost of cultivation. On the other hand, two hand weeding at 15 and 35 DAS, which coincided with the critical active growth stage of the crop effectively controlled the weeds, minimised weeding cost and produced satisfactory yield that brought about better economic returns.

Networking Activities

Attended the review meetings in February 1999 to discuss with the visiting overseas scientists the progress of the experiments and prepare future workplan.

Project Highlights

Farmers' weed control practices can be reduced by about 50% by adopting only two hand weeding at 15 and 35 days after okra seeding that can effectively control the weeds and cut down the production cost without reducing the okra yield.

Integrated Management of Soil-borne Pathogens in Eggplant

Investigators: M.H. Rahman[1], M.S. Nahar[1] and H.S. Jasmine[2]

Collaborating Scientists: L. Black[3]

Abstract

Application of various soil amendment treatments in seedbed nursery and main field of eggplant showed that sawdust burning in seedbed nursery and mustard-oil cake incorporation in the main eggplant field gave the best results. Sawdust burning in seedbed nursery gave highest seed germination, and produced taller and healthier seedlings with minimum disease and root-knot nematode infestation. In the eggplant main field, plots incorporated with mustard oil-cake had lowest mortalities of plants from bacterial wilt and fungus infections, lowest infestation of root-knot nematode, and produced highest yield.

Objectives

To determine the effectiveness of different soil amendment treatments to control soil-borne diseases in seedbed nursery and main planting field of eggplant.

IPM Constraints

A number of soil and seed-borne diseases, such as bacterial wilt (*Ralonstonia solanacearum*), fruit rot and wilt (*Fusarium* spp), damping-off, root rot and seedling blight (*Rhizoctonia solani*, *Pythium* spp), root-knot nematode (*Meloidogyne incognita*), fruit and stem rot, and blight (*Phomopsis vexans*), and little leaf (*Mycoplasma*) cause high mortality of eggplant both in seedbed nursery and main planting field. In absence of any effective control measures, farmers face serious difficulty to raise eggplant

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seedlings in seedbed as well as maintain satisfactory plant population in the field.

Research Methods

The experiments were conducted in farmer fields at Nayapara village of Kashimpur site during the winter season (October '98 to April '99).

Seedbed nursery

The experiment was laid out in RCB design in four replications with the following five treatments in $3m^2$ (3x1 m) plots: T_1– Soil solarization with polythene mulch; T_2– Sawdust burning; T_3– Soil treated with formaldehyde @ 5%; T_4– Seed treatment with vitavax 200 @ 0.25%; and T_5– untreated control.

The field was first prepared by incorporating alluvium soil and well decomposed cowdung and then 3x1m seedbed were raised. Soil solarization was done for one month by covering the seedbeds with transparent polythene. Soil temperatures of solarized and non-solarized seedbeds were recorded daily; average temperature was 52^0 C in solarized plot and 35^0 C in non-solarized plot. Sawdust burning was done by burning 6cm thick sawdust over the seedbed. Eggplant (variety Uttara) seeds were sown @ 7.0 g/seedbed (approximately 2,200 seeds/bed). Prior to sowing, seed health was tested by blotter method to determine seed germination and observe seed-borne microflora following ISTA rules. Soil samples were collected from the field and assayed for soil-borne microflora following dilution plate method. Bearman tray technique was used to determine nematode population. Seedling emergence in seedbed was recorded 20 days after seed sowing. Plant population, fresh and dry weight of seedlings, and number of diseased plants were recorded from half sqm area of each seedbed. Length of seedlings was recorded from 20 seedlings 30 days after sowing. All data were subjected to ANOVA and the means were separated by LSD.

Main planting field

Eight soil amendment treatments were laid out in RCB design with 4 replications in unit plots of 7.5 m^2 (3x2.5m). The treatments were : T_1– Deep ploughing; T_2– Incorporation of poultry refuse @ 20 t/ha; T_3– Incorporation of neem leaf @ 2.5 t/ha; T_4– Saw dust burning (6 cm thickness); T_5– Appli- cation of Rugby 10G @ 30 kg/ha; T_6– Application of bleaching powder [Ca (OCl) Cl] @ 15 kg/ha; T_7– Incorporation of mustard oil-cake @ 6 t/ha; and T_8– untreated control. Deep ploughing was done by deep spading and turning down the surface soil. Poultry refuse, ground neem leaf, bleaching powder and mustard oil-cake were incorporated 15 days before planting of eggplant seedlings. Eggplant seedlings (variety Sabuj Pata) were transplanted at 50 spacing in rows having 75 cm distance. Disease incidence was recorded weekly. All data were subjected to ANOVA and the means were separated by Duncun's multiple range tests.

Results and Discussion

Management of soil-borne pathogens of eggplant in seedbed nursery

In seed health tests (in-vitro) the eggplant seeds were found to harbor several fungi, such as *Aspergillus niger* (5%), *Aspergillus spp* (4%), *Fusarium spp* (1%), and *Myrothecium sp* (2%), but the seed germination was satisfactory (82%). Similarly, examination of seedbed soils, before adding any soil amending treatments, showed that the soils contained nine fungal species: *Aspergillus flavus*, *Aspergillus niger*, *Aspergillus sp*, *Fusarium oxysporum*, *Fusarium solani*, *Phomopsis sp*, *Rhizoctonia sp*, *Trichoderma sp*, and an unidentified non-sporulating fungi. The average number of fungal colony per gram of soil was 23.25 at 1,000 dilution and the average number of nematode was 2.14 per gram of soil.

Highly significant effects of all the soil amendment treatments were observed when compared with the untreated control. Plots treated with sawdust burning showed the best results giving highest seedling emergence (72%), tallest seedlings (25.5 cm), heavier seedlings having 3.8g fresh weight and 0.46g dry weight, and minimum diseased (0.5%) and nematode infested plants (Table 1). Seedlings of other treatments were also much better compared to those of the control plots. *Rhizoctonia solani*, and *Fusarium spp*. were the major fungal pathogens associated with the diseased seedlings.

Table 1: Effects of soil and seed treatments on seedling emergence and growth, and disease incidence in eggplant seedbed nursery.

Treatment	Seedling emergence per half sqm.	Plant height (cm)	Seedling weight		Diseased plant (%)	Gall index (0-10 scale)
			Fresh (g)	Dry (g)		
T_1 = Soil solarization	228.4*	20.4**	2.3**	0.30	2.6	2.25**
T_2 = Sawdust burning	263.7	25.5	3.8	0.46	0.5	0.75
T_3 = Soil treated with formalin	221.6	16.2	2.1	0.32	1.6	1.00
T_4 = Seed treatment with vitavax	219.2	17.0	2.2	0.30	4.6	1.75
T_5 = Untreated control	203.7	10.2	0.9	0.18	5.2	2.50
CV %	9.40	13.47	21.17	20.47	13.19	28.75
LSD	46.17	5.19	1.03	0.126	0.8309	1.025

All data are averages of four replications; *significant at 5% ; and **significant at 1% level

Disease management in eggplant field

Considerable number of eggplants died in plots of different treatments due to the infection of bacterial wilt (*Ralonstonia solanacearum*), root-rot/blight (*Rhizoctonia solani*), and stem blight and fruit rot (*Phomopsis vexans* and *Fusarium* spp.). But, the plots incorporated with mustard oil-cake showed the best results giving lowest plant mortalities (1.8 – 4.2%) from disease infection and minimum root-knot infestation and also produced the highest yield (26,267 Kg/ha). This was followed by plots incorporated with neem leaf which had lower plant mortalities (2.2- 4.2%) from disease infection and lower nematode infestation and produced better yields (22,883 Kg/ha). Nematode infestation and plant mortalities from disease infection were, however, highest (5.6- 10.5%) in the control plots producing much lower yields (18,767 Kg/ha (Table 2). The overall results indicate that, without resorting to chemical control of diseases, farmers can get higher yields by applying mustard oil-cake in eggplant fields which will significantly minimise plant mortalities due to the infection of various diseases. Soil incorporation of mustard oil-cake, which contains a number of plant nutrients, can enrich the soil over time and can cut down the application of chemical fertilizers appreciably.

Table 2: Effects of soil amendment treatments on disease incidence and yield of eggplant.

Treatment	Plant mortality (%)due to			Root-knot severity (0-10) scale	Yield (kg/ha)
	Bacterial wilt	Rhizoctonia Root-rot & blight	Stem blight & Fruit rot		
T_1 = Deep ploughing	9.0bc**	3.1ab	4.5ab	2.5ab	19,267b
T_2 = Poultry refuse	10.6ab	3.2ab	4.5ab	1.6bc	19,233b
T_3 = Ground neem leaf	4.2d	2.2b	3.5b	1.6bc	22,883ab
T_4 = Sawdust burning	6.9cd	2.8b	4.2ab	2.0ab	19,533b
T_5 = Rugby 10 G	13.2a	4.0ab	5.5ab	1.2bc	17,967b
T_6 = Bleaching powder	4.5d	4.1ab	6.5a	2.4ab	20,433b
T_7 = Mustard oil-cake	4.2d	1.7b	3.1b	0.5c	26,267a
T_8 = Untreated control	10.5ab	5.6a	5.7ab	3.0a	18,767b
CV %	21.01	36.68	25.27	31.28	16.47

All data are averages of four replications; Values, in a column, having common letters are not significantly different at 1% level by DMRT.

Impacts

The first season experimental results showed that, among the various soil amendment treatments and chemical control, soil incorporation of mustard oil-cake in eggplant field can effectively minimise nematode infestation and plant mortalities due to the infection of various soil-borne diseases, and can produce higher yield. This will also help to reduce the residues of chemical fungicides in the food chain.

Networking Activities

Attended the initial Participatory Appraisal and Planning meetings in August 1998 and contributed to the development of a workplan of IPM CRSP activities in Bangladesh. Dr. S. K. De Datta visited the experiments in December 1998 and reviewed the progress. In February 1999, discussed the experimental results with the visiting IPM CRSP scientists and developed the future program.

Project Highlights

Incorporation of mustard oil-cake in eggplant field was highly promising with respect to soil nematode control, reduce plant mortality from the infection of various soil-borne diseases and higher yield. This management technique also reduces the chances of chemical fungicide applications in eggplant.

Production of Healthy Bunching Onion (*Allium fisturosum*) through Integrated Disease Management

Investigators : M.H. Rahman[1], M.S. Nahar[1], and H.S. Jasmine[2]

Collaborating Scientists: L. Black[3]

Abstract

An on-farm experiment was conducted during the summer season at Kashimpur to determine the effects of soil amendment treatments and applications of nematicide and fungicide for producing healthy bunching onion (*Allium fisturosum*), a high value spices crop used by the elite society of the Dhaka city. The results showed that the plots incorporated with poultry refuse produced taller, heavier and healthier bunching onion plants with minimum disease infection and nematode infestation compared with those of the farmer practice and control plots. Poultry refuse treated plots also produced about twice as much yield as that of the plots managed by the farmer. Poultry refuse probably contains factors that inhibit the growth of fungi and nematodes.

IPM Constraints

Bunching onion is a high value spices crop cultivated throughout the year in the pre-urban areas around the capital city of Dhaka due to high demand from elite hotels and restaurants. Farmers face difficulties to grow a healthy crop due to the attack of diseases and nematodes and apply different kinds of pesticides without understanding the causes. There is a need to develop non-chemical control measures and use of judicious of pesticides in controlling the diseases and root-knot nematode in bunching onion.

Objectives

To determine the effects of organic and inorganic soil amendments and efficacy of fungicide and nematicide applications to control diseases and root-knot nematode infestation in order to produce healthy bunching onion crop.

[1]BARI [2]IPM CRSP [3]AVRDC

Research Methods

Ten treatments, comprising of soil amendment treatments and fungicide/nematicide applications, were laid out in RCB design with four replications in a farmer field of Nayapara village (Kashimpur site) during the summer season (April-July 1999). The treatments were: T_1= Soil incorporation of mustard oil-cake @ 5 t/ha; T_2=soil incorporation of carbofuran (Furadan 5G) as nematicide @ 60 kg/ha + Rovral fungicide (0.2%) spray; T_3= Soil incorporation of poultry refuse @ 15 t/ha; T_4=soil incorporation of carbofuran (Furadan 5G) @ 60 kg/ha; T_5= Rovral fungicide (0.2%) spray; T_6=Soil incorporation of poultry refuse + Rovral (0.2%) spray; T_7= Score fungicide (0.05%) spray; T_8= Untreated control; T_9= Farmer practice + Poultry refuse @ 15 t/ha + Rovral spray; and T_{10}= Farmer practice.

In all the treatments, except in farmer practice, manures and fertilizers were applied at recommended rates: cowdung @ 10 t/ha, N @ 60 kg/ha, P @ 30 kg/ha, K @ 100 kg/ha, S @ 20 kg/ha, Zn @5 kg/ha and Boric acid 5 @ kg/ha.. In farmer practice, the farmer applied the manures and fertlizers at double of the recommended rates: cowdung @ 20 t/ha, N @ 100 kg/ha, P @ 250 kg/ha, and K @ 180 kg/ha. Mustard oil-cake and poultry refuse were incorporated with the soil 25 days before transplanting. The nematicide, carbofuran (Furadan 5G), was incorporated with the soil during final preparation of the plots. The fungicides, Rovral and Score were sprayed thrice at 15-days interval starting from the initiation of disease symptoms.

Forty five-day old seedlings of bunching onion (Korean variety) were transplanted at 15 cm spacing in 2.5 meter rows having a row distance was of 30 cm.The crop was harvested about 2 months after transplanting. Disease incidence of leaf blight/ purple blotch was graded on a 0-5 scale, while severity of root- knot nematode infestation on 0-10 scale. The number of nematode galls, eggs and nematode larvae per gram of root, shoot and root length of bunching onion, number of plants per hill, fresh and dry weight of plants and yields were also recorded. The data were subjected to ANOVA and Duncun's multiple range test.

Research Results

The results showed that, compared with the control plots of farmer practice and standard fertilizer use, all the treatments having poultry refuse as one of the soil amendment inputs had lower leaf blight infection, lower gall index, and fewer number of nematodes per plant (Table 1). As a result, poultry refuse treated plots had higher number of taller and heavier plants and produced much higher yields (Table 2). Plots treated with nematicide (carbofuran) or fungicide (Rovral and Score) alone had 2-4 times more nematode population and slightly lower leaf blight infection when compared with the control plots, but these treatments had about 4 times more nematode population and higher disease infections than those treated with poultry refuse. Similar trend was also observed in respect of plant number per hill, plant height and weight, and yields. The results suggest that poultry refuse contains factors that enriches the soil health and hinders the growth of root-knot nematode and leaf blight pathogens. The economic benefit from the use of poultry refuse could not be obtained as the farmer did not agree to sell his crop separately for each treatment and mixed up the yields of all the treatments to get better price.

Table 1: Effects of soil amendments and application of nematicide and fungicides on disease and nematode incidence in bunching onion

Treatments	Leaf blight	Gall index	Egg / g root	Nematode/plant		
				Larvae	Adult	Total
T_1 = Mustard oil cake	1.5	1.2 cd	93	29	2	31
T_2 = Furadan + Rovral	1.5 a	1.9 bcd	763	73	30	103
T_3 = Poultry refuse	1.4 a	1.1 cd	170	22	3	25
T_4 = Furadan	1.6 a	2.0 bc	658	87	14	101
T_5 = Rovral	1.4 a	2.4 ab	1134	135	11	146
T_6 = Poultry refuse + Rovral	1.0 ab	1.0 cd	175	30	3	33
T_7 = Score	1.6 b	3.0 ab	1169	138	11	149
T_8 = Control	1.7 a	3.2 a	2781	501	33	534
T_9 = Farmer's practices + Poultry refuse + Rovral	1.3 ab	0.9 d	41	32	1	33
T_{10} = Farmer practice	1.6 a	2.7 ab	1854	240	23	263
CV (%)	17.45	25.06	–	–	–	–

All the figures are averages of four replications. Values, in a column, followed by a common letter are not significant at 5% level by DMRT.

Table 2: Effects of soil amendments and application of nematicide and fungicide on the growth and yield of bunching onion

Treatments	Shoot height	Root length	Plant weight / hill (g)		Plant number / hill	Yield (t / ha.)
			Fresh	Dry		
T_1 = Mustard oil cake	55.9 ab	13.0	92.8 bc	74.3 ab	7.3 bc	17.1 bc
T_2 = Furadan + Rovral	54.6 ab	11.4	81.2 cd	61.4 bcd	7.7 abc	14.3 cd
T_3 = Poultry refuse	58.5 a	12.7	119.3 a	88.4 a	10.0 ab	22.8 a
T_4 = Furadan	55.7 ab	12.1	85.2 bcd	62.3 bc	8.7 abc	14.8 cd
T_5 = Rovral	53.6 b	11.5	64.6 d	39.3 e	6.5 c	10.9 d
T_6 = Poultry refuse + Rovral	58.3 a	12.4	119.7 a	89.0 a	10.5 a	23.1 a
T_7 = Score	53.7 b	11.8	65.0 d	42.8 cde	6.6 c	11.8 d
T_8 = Control	52.7 b	11.0	67.4 cd	40.8 de	6.9 c	12.5 cd
T_9 = Farmer's practices + Poultry refuse + Rovral	56.8 ab	12.3	107.1 ab	80.3 ab	9.5 abc	19.8 ab
T_{10} = Farmer practice	53.1 b	12.0	67.7 cd	41.8 cde	6.9 c	11.5 d
CV (%)	15.74	10.24	13.95	15.74	16.55	14.38

All figures are averages of four replications; Values, in a column, are not significantly different at 5% level by DMRT.

Impact

Soil incorporation of poultry refuse alone or in combination with fungicide and nematicide appli-cations can effectively minimise leaf blight and nematode infestation and can promote the growth of bunching onion producing significantly higher yield. Since poultry refuse is abundant and much cheaper, farmers can use it to obtain more profits from the cultivation of bunching onion.

Networking Activities

Participated in the initial Participatory Appraisal and Planning meetings in August 1998 to develop IPM CRSP workplans in Bangladesh. Dr. S. K. De Datta visited in December 1998 to review progress of the ongoing experiments. In February 1999, discussed the results of the experiments with the visiting IPM CRSP scientists and the future research program.

Project Highlights

Poultry refuse, which is abundant and cheaper, can be used by the farmers to produce almost two-fold higher yields of healthy bunching onion. This may be practiced in other areas where bunching onion is intensively cultivated.

Disease Management in Cucumber

Investigators: M.H. Rahman[1], M.S. Nahar[1], and H.S. Jasmine[2]

Collaborating scientists: L. Black[3]

Abstract

An on-farm study at Kashimpur during the summer season showed that soil amendment by sawdust burning or soil incorporation of poultry refuse + sawdust burning in cucumber planting beds can effectively reduce pre-and post-emergence deaths of cucumber plants, and produce healthier plants and about 1.5 times more higher yields. These treatments were better than applying fungicide and nematicide in cucumber with respect to palnt mortality, plant growth and yield.

[1]BARI [2]IPM CRSP [3]AVRDC

Objectives

To determine the effects of organic soil amendments and applications of fungicide and nematicide to control wilt and leaf blight diseases in cucumber.

IPM Constraints

Farmers face great difficulties to establish cucumber crop due to high mortality of plants and infection of wilt and leaf blight diseases. They use various pesticides at high rates without understanding the causes. There is a need to develop non-chemical disease management practice(s) for growing healthy cucumber crop with higher yields.

Research Methods

The experiment was carried out in a farmer field at Kashimpur with eight treatments laid out in a RCB design with four replications. The treatments were: T_1= Soil incorporation of poultry refuse @10 t/h; T_2 = Soil incorporation of neem oil-cake @ 5 t/h; T_3= Soil incorporation of carbofuran (Furadan 5G) as nematicide @ 60 kg/h; T_4= Sawdust burning (6 cm thickness); T_5 = Soil drenching with Bavistin fungicide @ 0.2%; T_6= Poultry refuse + sawdust burning; T_7= Soil incorporation of mustard oil-cake @ of 6 t/h; and T_8= Untreated control.

Poultry refuse, neem oil-cake, and mustard oil-cake were incorporated with seedbed soil 25 days before sowing of cucumber seeds.Thirty seeds of a local cucumber variety were sown in 3x1m beds, each bed representing a replication. Data on seed germination, pre- and post-emergence death of seedlings, fresh and dry weight of 30 day-old seedlings, shoot and root length, and incidence of diseases were recorded. After taking the initial data on plant characteristics, 6 plants were retained in each bed up to harvest of the crop and the excess plants were removed. The data were subjected to ANOVA and the means were analysed by Duncun's multiple range test.

Results and Discussion

All the treatments showed better results with regard to seed germination, plant growth, and yield when compared with those of the control plot (Table 1). Significantly better seed germination (68-72%), lesser pre- and post-emergence plant mortality (27-32%), heavier shoot and root weight, and higher yields (14.3-14.6 t/ha) were obtained in plots having sawdust burning alone, or poultry refuse + sawdust burning; reduction in blight, wilt and virus infection was, however, insignificant (Table 2). The plots having sawdust burning or poultry refuse + sawdust burning treatments produced about 1.5 times more yields than the control plots (9.9 t/ha). It is presumed that sawdust burning killed the soil inhabiting pathogens and poultry refuse inhibited their growth. Since sawdust and poultry refuse are easily available and much cheaper, the farmers can use these materials in cucumber fields for better stand, healthier crop and better yields. This practice will also minimise pesticide use and its bad effects in the food source.

Table 1: Effect of soil amendments and applications of fungicide and nematicide on plant growth and yield of cucumber

Treatments	Germi-nation (%)	Shoot height (cm)	Fresh shoot weight (g)	Fresh root weight (g)	Dry shoot weight (g)	Yield t/ ha.
T_1 = Poultry refuse	48.3 c	26.8 abc	39.5 b	2.4 ab	3.9 ab	12.7 ab
T_2 = Neem oil cake	35.0 c	26.1 bc	24.1 cd	2.1 abc	4.0 ab	11.2 ab
T_3 = Furadan 5G	47.5 c	24.9 bc	35.4 bc	1.3 c	2.7 b	11.7 ab
T_4 = Sawdust burning	68.3 ab	34.9 a	58.8 a	2.7 a	5.0 a	14.6 a
T_5 = Bavistin	51.7 bc	26.9 abc	21.6 d	1.7 bc	2.8 b	11.2 ab
T_6 = Poultry refuse+Sawdust burning	72.5 a	32.7 ab	39.7 b	2.1 abc	3.4 ab	14.3 a
T_7 = Mustard oil cake	43.3 c	24.1 bc	30.8bcd	1.7 bc	3.1 b	12.7 ab
T_8 = Control	37.4 c	21.4 c	17.9 d	1.3 c	2.7 b	9.9 b
CV(%)	17.71	14.37	18.37	31.03	22.42	12.87

All data are averages of four replications; Values, in a column, having a common letter are different at 1% level by DMRT.

Table 2: Effects soil amendment and applications of fungicide and nematicide on disease incidence in cucumber.

Treatment	Pre & post emergence death (%)	Leaf blight (0-5 scale)	Wilt (%)	Virus (%)
T_1 = Poultry refuse	51.7 a	2.7	38.6	9.2 bc
T_2 = Neem oil cake	65.0 a	3.1	34.2	8.7 bc
T_3 = Furadan 5G	52.5 a	2.9	20.3	5.5 c
T_4 = Sawdust burning	31.7 bc	3.5	33.9	22.5 a
T_5 = Bavistin	48.3 ab	3.6	23.3	8.0 bc
T_6 = Poultry refuse+Sawdust burning	27.5 c	3.1	22.5	18.7 ab
T_7 = Mustard oil cake	56.7 a	3.2	55.7	15.0 abc
T_8 = Control	62.5 a	4.0	63.1	23.2 a
CV (%)	18.09	20.93	56.53	42.99

All the figures are averages of four replications; Values, in column, having a common letter are not significantly different at 1% level by DMRT.

Impact

Sawdust burning and soil incorporation of poultry refuse + sawdust burning in cucumber planting beds were highly effective in reducing pre- and post-emergence deaths of cucumber seedlings, promoted the growth of cucumber plants and produced 1.5 times more yield. This practice can reduce pesticide use minimizing its residues in the food chain.

Networking Activities

Participated in the Participatory Appraisal and Planning workshop in August 1998 and contributed to the development of 1998-99 workplan of IPM CRSP in Bangladesh. Dr. S. K. De Datta visited in December 1998 and reviewed the progress of the experiments. Participated in the IPM CRSP discussion meeting along with the visiting IPM CRSP scientists in February 1999 to review the research results and prepare the future program.

Project Highlights

Soil incorporation of poultry refuse + sawdust burning, or sawdust burning in cucumber planting beds can effectively reduce pre- and post- emergence deaths of cucumber seedlings, promote better plant growth and produce higher yield.

IPM-CRSP Social Science Research Activities in Bangladesh

1. Measure Economic Impacts of Bangladesh IPM-CRSP Research Activities

Investigators: I. Hossain, G. Norton, T. Debass (graduate student), G. Shively

Abstract

The aggregate economic impacts of selected IPM technologies being developed on the IPM CRSP are being assessed using partial budgeting and economic surplus analysis methods. Preliminary results indicate that all experiments give higher net return than the farmers' practice.

Objectives

1) evaluate and forecast economic impacts of pest management strategies developed by the IPM CRSP in Bangladesh

2) estimate potential country-wide impacts of pest management strategies developed on the IPM CRSP

3) assess potential transferability of the strategies to farms outside of Bangladesh and likely economic impacts

IPM Constraints

Examination of economic constraints to IPM adoption must be fully considered in evaluating an IPM program.

Research Methods

Partial budgeting and ex-ante economic surplus analysis is employed to assess the aggregate benefits of IPM CRSP strategies in Bangladesh. Also, a Geographic Information System (GIS) is used to project the transferability of IPM-CRSP strategies beyond the primary sites using agro-ecological and socio-economic information in determining adoption rate patterns. Data on production, consumption, prices, price elasticities for demand and supply, and experiment costs are gathered and assessed to project aggregate benefits to the respective countries. Expert questionnaires were developed to determine adoption rates. Agro-ecological and socio-economic data were collected to facilitate the spatial framework to examine adoption rate patterns.

Networking Activity

G. Norton traveled to Bangladesh in February and September to discuss research results with Bangladeshi colleagues. T. Debass spent two weeks in Bangladesh collecting information for his thesis in February.

Training Output

Thomas Debass is working on his M.S. thesis on this activity at Virginia Tech.

2. Pest Management Practice Adoption Study and the Price and Marketing Context of Pest Management Decisions in Vegetables

Investigators: I. Hossain, G. Shively, C. Mahmoud (graduate student), G. Norton

Abstract

The likely adoption and on-farm impact of selected IPM technologies being developed on the IPM CRSP are being assessed using farm-level mathematical programming models. The model being developed takes specific account of production and marketing risks faced by low- to moderate-income farmers.

Objectives

1) assess the likely patterns of IPM adoption in Bangladesh,
2) measure the on-farm impacts of pest management strategies developed on the IPM CRSP
3) assess the role of commercial marketing of vegetable crops on the likelihood of IPM adoption.

IPM Constraints

Examination of economic constraints to IPM adoption must be fully considered in evaluating an IPM program.

Research Methods

A farm-level mathematical programming model is being used to study the impact of socioeconomic and biophysical factors on returns to various pest management strategies, including IPMCRSP strategies. The model accounts for production uncertainty and the impact of IPM practices on production risk. Baseline survey data on production outcomes, resource availability and constraints, and prices are used to formulate representative farms for simulating the impacts of policy changes or new technologies. Optimal cropping patterns and technology choices for representative farms are characterized. This work is ongoing. Model parameters are being derived from baseline survey data and on-going socioeconomic surveys, including price monitoring and market surveys.

Networking Activity

G. Shively traveled to Bangladesh in June to discuss research results with Bangladeshi colleagues and to explore avenues for collaborative research with colleagues at the office of the International Food Research Institute in Dhaka.

Training Output

Chodhury Mahmoud is working on his M.S. thesis on this activity at Purdue.

Eastern European Site in ALBANIA

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IPM CRSP Site Overview for Albania

Charles Pitts[1], Douglas Pfeiffer[2], Josef Tedeskini[3]

The Collaborative Program

A. Albanian scientists are distributed across disciplines (Entomology, Plant Pathology, Crop Protection, Agricultural Economics, and in three institutions: Agricultural University of Tirana, Plant Protection Research Institute (Durress) and Fruit Tree Research Institute (Vlore).

B. The entire budget for the Albanian IPM CRSP project originates from the USAID mission in Tirana. This will support all objectives in the plan of work.

C. We will investigate potential collaboration with Volunteers in Overseas Cooperative Assistance (VOCA).

D. Albanian and American scientists met in Tirana after the farm visits during the PA to develop proposal, and to sign up individual faculty with projects of interest.

IPM Constraints

A. **Overview of IPM constraints in the country/region.** By 1990 the cumulative effects of Albania's central planning system had led to an economic crisis. The transition from a centralized system to a market economy brought about radical changes concerning the nature of basic elements of Albanian agriculture (the production process, farmers, the farm and farm business) as well as the functioning of essential support services. Currently pesticides are seldom available to growers. The result has been uncontrolled populations of some key pests, but establishment of natural enemies for other pests. A challenge is to develop control for the key pests that are nondisruptive to existing beneficial populations.

B. **Examples of research progress.** The research in only now getting underway. The Baseline Survey was completed, providing a detailed evaluation of the nature of the Albanian olive industry and pest management problems.

C. **Mutuality of Benefits.** Benefits to Albania relate to development of IPM practices that are not disruptive to ecological systems or human welfare, and will allow Albanian olive products to be competitive in an international market. Benefits to U.S. relates to observation of IPM systems in perennial cropping systems under a regime of low pesticide availability. American commodities are facing loss of key pesticide groups, and specialists will benefit from working in the Albanian system.

Research Accomplishments

Projects are now being reorganized after the Kosovar-Serbian conflict. The main accomplishment has been the execution of the baseline survey of olive pest management, being prepared as an IPM CRSP Working Paper.

[1] Penn State University
[2] Virginia Tech
[3] Plant Protection Research Institute, Durress

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Albania Baseline Survey

Fadil Thomaj[1], Myzejen Hasani[1], Rexhep Uka[1], Magdalena Bregasi[1], Enver Isufi[2], Brunilda Stamo[2], Harallamb Pace[2], Josef Tedeskini[2], Dhimiter Panajoti[3], Hajri Ismaili[3], Mendim Baci[3], Zaim Veshi[3], Charles W. Pitts[4], Doug Pfeiffer[5], Lefter Daku[5], Beth Teviotdale[6], Louise Ferguson[6], Milt McGiffen[6]

Abstract

On October 29, 1998, a meeting was held at OIRD between Albanian mission officers and Virginia and Penn State participants, to discuss the Participatory Appraisal. A PowerPoint presentation was made on the interaction between olive IPM and Albanian history and politics. The Baseline Survey was executed in Albania in January 1999. In that survey, 200 farmers were surveyed. The results of this survey (i) provide an understanding of the group of socioeconomic factors that influence pest perceptions, pest management practices and potential constraints to IPM adoption, (ii) serve as a basis for quantitative comparison of pest management practices between olive growers over time and the retrospective assessment of project net benefits, and (iii) help design and prioritize the research, extension, and training efforts. The men's and women's role in pest management decision making was discussed and the respective knowledge gaps regarding olive pest management practices were identified.

This survey is an integrated activity that describes the socioeconomic context of pest management in olive production in Albania. It provides background and context for the experimental studies to be carried out by IPM CRSP/Albania. The main purpose of the Baseline Survey is to identify the farmers' stock of knowledge and their perceptions regarding olive pests, natural enemies, and pest management practices, as well as to specify their knowledge gaps with respect to olive pest control.

Objectives

A. The first objective (I. Baseline Survey and Crop/Pest Monitoring) was addressed, namely performance of the Baseline Survey.

B. The overall objective of the Baseline Survey was to identify farmers' knowledge and attitudes towards pesticide use and pest management practices in olives in Vlora district, Albania. The specific objectives were to:

1. conduct a farm baseline survey among a sample of farmers in a representative set of villages in Vlora district, Albania;
2. collect data to support statistical analysis of pest perceptions, pest management practices and related socioeconomic factors; and
3. provide baseline data to retrospectively assess project impacts.

Research Methods

The survey was implemented in January 1999 by a team of Albanian researchers from Agricultural University of Tirana (AUT), Plant Protection Research Institute (PPRI) Durres, and Fruit Tree Research Institute (FTRI) Vlore in close collaboration with Dr. Charles Pitts (IPM CRSP/Albania Site Chair, Penn. State), Dr. Greg Luther

[1] AUT
[2] PPRI
[3] FTRI
[4] Penn State
[5] Virginia Tech
[6] University of California

(Assistant Program Director, IPM CRSP, Virginia Tech), Dr. George Norton, Dr. Daniel Taylor and Lefter Daku (Department of Agric. & Applied Economics, Virginia Tech). Lefter Daku (Virginia Tech) and Josef Tedeskini (PPRI) coordinated the fieldwork. The team was made up of 14 research scientists: 4 from AUT, 3 from PPRI, 6 from FTRI, and one from Virginia Tech, USA. Initially, the team was divided into five combined groups with specialists from each institution. The mixture of the team was changed everyday to avoid some kind of "enumerator or group biases" during the interviews.

The questionnaire instrument was developed based on a previous version that had been used to study the pest management practices in rice and vegetables in the Philippine IPM CRSP research site in 1995. Most of the questions from this previous version were modified to fit the specific features of the olive production system in Albania. Additional questions concerning the marketing, credit, institutional, and informational constraints faced by the olive growers in the study area were added.

The survey questionnaire was divided into eight sections. The questionnaire was translated into Albanian and was pre-tested on ten farmers to ensure that each question fits to the reality and is understandable for farmers. After the pre-testing, the study team discussed the questions that needed to be dropped, added, or modified in order to come up with the final version of the questionnaire. Next, the final version of the questionnaire was coded by assigning a given number to each possible response. For the open-ended questions, the possible responses were grouped into broad categories.

The first section requested background information on olive production systems. The second section asked for the pest management decision making within the household regarding the purchase of pesticides, pest control, and marketing of agricultural products.

The third section dealt with factors affecting pesticide use. The farmers were asked to give information about the level of olive production, olive yields, the olive oil marketable surplus, olive processing technologies, transport and processing expenditures, marketing of olive oil and the constraints they face. Questions also were included about the amount spent for purchasing pesticides, the importance of various factors affecting their choice of pesticides for different crops, borrowing and credit opportunities as well as constraints they face for getting credit.

Section four requested farmers' opinions and perceptions about the effects of pesticides on human health and the environment. Section five dealt with farmers' knowledge about olive pests and their natural enemies. Farmers were asked about the olive pests they know, the nature of the damage they cause on olive trees and fruits, the natural enemies of olive pests and their respective role, and their opinion on effects of pesticides on this natural enemies. Section six asked for information about the olive pest management practices including the olive pests encountered during the last season, methods applied for controlling those pests, use of pesticides, timing of pesticide application, the effects of pesticides on those pests, and the spraying equipment. Farmers also were asked to list the reasons for not applying pesticides on olive trees.

Section seven dealt with sources of information used by farmers in making decision with respect to olive pest control. Farmers were asked to identify the most important sources of pest control advice, as well as about their participation in training courses.

Questions were also included about the adequacy of information they receive, the innovative cultural, production and pest control practices that they have introduced into the olive production system. The seventh section asked about the farmer's socioeconomic characteristics including level of education, years of experience working with olives, tenure status, age, household size, membership in farm organization, and major income sources.

Farmers' interviews were conducted from Sunday, January 24 through Sunday, January 31, 1999. The team was made up of 14 research scientists: 4 from AUT, 3 from PPRI, 6 from FTRI, and one from Virginia Tech, USA.

The survey was conducted by personal interviews with a sample of 200 farmers in 5 villages. Out of 200 farm households, in a target group survey of 50 households both male and female household heads were interviewed to obtain gender-differentiated data and determine their respective role in pest management decision making. Overall, 250 questionnaires were completed.

Completed questionnaires were reviewed by the interview team to ensure completeness and response consistency. After this review and error checking, completed questionnaires were entered into the computer. The frequency tables and some simple statistical computations were done using Excel Spreadsheet Program. The descriptive statistics were generated using the statistical procedures available in the Statistical Analysis System (SAS).

Results

The most important findings relate to the level of grower education, and the inadequacy of a viable extension

system.

1. A valuable descriptive cross section of the Albanian olive industry was created. This included size of crop, marketing outlets, main pest problems, etc.
2. Significant gaps in grower educated were revealed. Farmers gave diverse responses regarding the nature of damage caused by olive pests. They generally could give a description of the damages caused by pests on olives, but in some cases they failed distinguish between certain pests. In many cases their description of pest damages did not match those of respective pests. Farmers' knowledge about the natural enemies of olive pests was very limited. Even those farmers, who responded, seemed a little bit surprised about this question because they had never thought about it. Farmers revealed little awareness with respect to the potential harmful effects of pesticides on human health and the environment. The majority of farmers either did not agree or expressed no opinion that pesticides can harm water quality.
3. There are significant obstacles to farmers obtaining agricultural credit. Only 38% of respondents consider it possible to borrow. The rest stated they have not tried to get credit because there are so many constraints and the interest rates are too high.
4. Farmers mentioned various reasons for the credibility of sources of pest advice in olives (Table 64). Most of respondents indicated that extension specialists are more credible as a source of advice because they are more knowledgeable, have more experience, have university education, tell what and how to do things. However, no farmer interviewed quoted extension specialists as being accessible. A small number of respondents also considered research specialists as a credible source of information for being knowledgeable and experienced, but not accessible in most of the cases. Only two percent of farmers reported to have participated in a training course related to pest control in olives. However, the overwhelming majority (82.5%) said they are willing to participate in such courses in the future.

Impact

The baseline survey draft was only recently distributed to Albanian institutions, and the impact is yet to be determined.

Networking Activities

A. A meeting was held on October 29, 1998 at Virginia Tech between USAID personnel from Albania, Washington, and selected CRSP personnel, for the purpose of discussing the Participatory Appraisal, and planning for the period during Year 6 in which US co-Pis were not allowed into Albania.

Publications

Participatory Appraisal of Olive Pest Management in Albania to Initiate IPM CRSP Activities in Eastern Europe (Gregory C. Luther, Keith M. Moore, Charles Pitts, Lefter Daku, Josef Tedeskini, Enver Isufi, Fadil Thomaj, Rexhep Uka, Hajri Ismaili, Beth Teviotdale, Doug Pfeiffer, Magdalena Bregasi, Harallamb Bace, Mendim Baci, Milt McGiffen, Louise Ferguson, Myzejen Hasani, Dhimitraq Toti, Brunilda Stamo, Zaim Veshi and Uran Abazi). Working Paper 99-2, published on CRSP web site July 1999. (http://www.cals.vt.edu/ipmcrsp/papers/Alb_wp0299.pdf)

LIST OF ACRONYMS

ADI	acceptable daily intake
AG	Anastomosis group
AGEXPRONT	Non-Traditional Products Exporters Association of Guatemala
AGRILAB	Agriculture Laboratory
AI	Active Ingredient
ALCOSA	Alimentos Congelados S.A.
ALTERTEC	Technología Alternativa
AMC	Agricultural Marketing Cooperation
ANOVA	Analysis of Variance
APHIS	Animal and Plant Health Inspection Service
APHIS-IS	Animal and Plant Health Inspection Service - International Service
APHIS-PPQ	Animal and Plant Health Inspection Service – Plant Protection Quarantine
ARF	Agricultural Research Fund
ATI	Appropriate Technologies, Inc.
AUDPC	area under disease process curve
AVRDC	Asian Vegetable Research and Development Center
BCA	bio-control agent
BFT	Bearmann funnel technique
BIFA	Bulamagi Integrated Farmers Association
BPH	brown planthopper
BUWOSA	Bukedia Women Strugglist Association
BW	bacterial wilt
CARDI	Caribbean Agricultural Research and Development Institute
CATIE	Centro Agronomico Tropical de Investigacion y Enseñanza
CDC	Center for Disease Control
CES	Central Experiment Station
CIAT	Centro Internacional de Agricultura Tropical
CIP	Centro Internacional de la Papa
CRSP	Collaborative Research Support Program
CSC	Central St. Catherine
CSREES	Cooperative State Research, Education, and Extension Service
CUNSURORI	Centro Universitario de Oriente
CV	Coefficient of Variation
DA	Department of Agriculture
DAI	days after inoculation
DAP	days after planting
DAS	days after seeding
DAT	days after transplanting
DBH	days before harvest
DBP	days before planting
DIBA	dot blot immunobinding assay
DIGESA	General Directorate of Agricultural Services
DPS	diplodia leaf streak
DRSPR	Departement Recherche sur les Systèmes de Production Rurale
DT	days after transplanting
DTSV	Dirección Tecnica de Sanidad Vegetal
EEP	External Evaluation Panel
ELISA	enzyme-linked immunosorbent assay
EPA	Environmental Protection Agency
EUCARPIA	European Association of Plant Breeders
FAME	fatty acid methyl ester
FDA	Food and Drug Administration
FFG	functional feeding groups
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FPA	Fertilizer Pesticide Authority
FSB	fruit and shoot borer
GEXPRONT	Gremial de Exportadores de Productos No Tradicionales
GIL	ground infected leaves
GIS	Geographic Information Systems
GLH	green leafhopper
GLM	General Linear Models
GOG	Government of Guatemala

GPS	Global Positioning System
GRAT	Group for Research and Technical Application
HACCP	Hazard Analysis and Critical Control Point
HBI	Hilsenhoff Biotic Index
HPLC	high performance liquid chromatography
HRD	human resource development
IARC	International Agricultural Research Center
ICIPE	International Center for Insect Physiology and Ecology
ICM	Integrated Crop Management
ICN	IPM Consultative Network
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICTA	Instituto de Ciencia y Tecnología Agricolas
IER	Institut d'Economie Rurale
IGSS	Instituto Guatemalteco de Securidad Social
IICA	Inter-American Institute for Cooperation in Agriculture
IITA	International Institute of Tropical Agriculture
INIAP	Instituto Nacional de Ciencias Agropecuarias
IOBC	International Organization for Biological Control
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
IS	Information Systems
ITS	internal transcribed spacer
IWM	Integrated Weed Management
LSD	Least significance difference
MAAIF	Ministry of Agriculture, Animal Industries, and Fisheries
Mab	monoclonal antibody
ME	Management Entity
MEA	malt extract agar
MINAG	Ministry of Agriculture
MinAM	Jamaican Ministry of Agriculture and Mining
MOU	Memorandum of Understanding
MRR	Marginal rate of return
MST	mobile sticky trap
MSU	Montana State University
MSV	maize streak virus
NAARI	Namulonge Agricultural and Animal Research Institute
NARC	National Agricultural Research Council
NARO	National Agricultural Research Organization
NCPC	National Crop Protection Center
NGO	Non-Governmental Organization
NKE	neem kernel extract
NLB	northern leaf blight
NOGROCOMA	National Onion Growers Cooperative and Marketing Association
NPR	nominal rates of protection
NPV	Nuclear Polyhedrosis Virus
NSC	North St. Catherine
NSE	North St. Elizabeth
NSM	North St. Mary
NTAE	Non-Traditional Agricultural Exports
NTE	Non-Traditional Exports
OARDC	Ohio Agricultural Research and Development Center
OHVN	Operation Haute Vallée du Niger
OIRD	Office of International Research and Development
OM	organic matter
OSP	Oregon Sugar Pod
OSU	Ohio State University
PA	Participatory Appraisal
PAM	Pesticide Analytical Manual
PCCMCA	Central American Cooperative Project for the Improvement of Food Crops
PCR	polymerase chain reaction
PDA	potato dextrose agar
PhilRice	Philippine Rice Research Institute
PLAA	percent leaf area affected
PMB	pink mealybug
PNRT	National Program for Roots and Tubers-Potato
PPMP	Pest and Pesticide Management Project
PSL	Pseuodomonas *syringae pv lachrymans*

PSU	Pennsylvania State University
PVY	potato virus Y
Q	quetzal
RADA	Rural Agricultural Development Authority
RCBD	Randomized Complete Block Design
RKN	root-knot nematode
RLF	rice leaf folder
RVD	Rosette Virus Disease
SARI	Serere Agricultural Research Institute
SC	South Carolina
SDR	summed dominance ratio
SEL	Systematic Entomology Laboratory
SEM	Standard Error of the Mean
SESM	Southeast St. Mary
SNPV	Service National de Protection de Végétaux
SPE	solid phase extraction
SPLB	Sweetpotato Leaf Beetle
SPW	sweet potato weevil
SSC	South St. Catherine
SSE	South St. Elizabeth
SSR	simple sequence repeat
SWSM	Southwest St. Mary
TC	Technical Committee
TEV	tobacco etch virus
TMV	tobacco mosaic virus
ULV	Ultra Low Volume
UNFA	Uganda National Farmers' Association
UP	University of the Philippines
UPLB	University of the Philippines Los Baños
US or U.S.	United States
USA	United States of America
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USDA-IS	USDA-International Services
USDA/ARS	USDA/Agriculture Research Service
USDA/FAS	USDA/Foreign Agricultural Service
USVL	US Vegetable Laboratory
UVG	Universidad del Valle de Guatemala
UVTT	Validation and Transfer of Technology Unit
UWI	University of West Indies
VA	Virginia
VOCA	Volunteers in Overseas Cooperative Assistance
VPI&SU	Virginia Polytechnic Institute & State University
WAT	weeks after transplanting
WDS	Wireworm-Diabrotica-Systena
WID	Women in International Development
WS	weeks after seeding
WT	weeks after transplanting
WWW	World-Wide Web