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IPM CRSP

INTEGRATED PEST MANAGEMENT

COLLABORATIVE RESEARCH SUPPORT PROGRAM

FIFTH ANNUAL REPORT

1997-1998

Virginia Tech

VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

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IPM CRSP

Integrated Pest Management Collaborative Research Support Program

Fifth Annual Report

1997-1998

(29 September 1997 - 28 September 1998)

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Report Coordinated and Edited by the Management Entity of the IPM CRSP

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Montana State University
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University of Georgia
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Penn State University
USDA Veg Lab
Purdue University
Virginia Tech

Host Country Institutions

Prime Sites

Guatemala - Agri-lab, ALTERTEC, ICTA
Jamaica - CARDI, Ministry of Agriculture
Mali - IER
Philippines - NCPC/UPLB, PhilRice
Uganda - Makerere University
Ecuador - INIAP

Satellite Sites

Honduras - EAP
Eritrea - Minstry of Agriculture

International Centers

AVRDC - Taiwan
CIAT - Columbia
CIP - Peru
ICIPE - Kenya
IRRI - Philippines

Private Sector

The Kroger Company
PICO
Caito Foods

NGOs/PVOs

CLADES
GEXPRONT, Guatemala

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FOREWORD

The Integrated Pest Management Collaborative Research Support (IPM CRSP) has successfully completed the first five years phase of its operation. This Annual Report covers activities completed by the CRSP in the fifth year of its existence, 29 September 1997 to 28 September 1998. The Annual Report is organized by the four major geographical regions the CRSP has operated during the year, Latin America, Caribbean, Africa, and Asia. 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 four 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. The highlights were compiled from site overviews prepared by each prime site chair who served during the fifth year. These 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 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. The series of maps used to mark the beginning of each region were edited from the 1996 NGS Cartographic Division. At the Management Entity, Greg Luther, Stefan Hall, and Jean-Pierre Amirault were instrumental in 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

Introduction

The Integrated Pest Management Collaborative Research Support Program (IPM CRSP) was granted by the USAID Global Bureau on 29 September 1993 with Virginia Tech as the grantee and Management Entity (ME). The IPM CRSP was recently renewed for an additional five years, through September 2003. In Phase I of the CRSP, collaborating institutions included US land-grant universities (University of Georgia, Lincoln University, Ohio State, Penn State, Purdue, Montana State, and Virginia Tech), and USDA, private sector institutions, NGOs, and host country institutions in the Philippines, Guatemala, Honduras, Ecuador, Jamaica, Mali, Uganda and Eritrea.

The site chairs, host country coordinators, and collaborating scientists contributed to this report. The site chairs and host country coordinators during Year 5 were:

Africa: Mark Erbaugh, Sam Kyamanywa (Uganda), John Caldwell, Kadiatou Toure, Amadou Diarra (Mali);
Asia: George Norton, Sally Miller, Victor Gapud;
Latin America: Glenn Sullivan, Guillermo Sanchez (Guatemala), Roger Williams, Carmen Suarez (Ecuador),
Caribbean: Bill Ravlin, Janet Lawrence.

Goals and Objectives of the IPM CRSP

The goals of the IPM 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. Over time, water quality should be improved and the rate of loss of biological diversity reduced.

The objectives of the IPM CRSP are to:

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

IPM CRSP Highlights for Year 5 (1997 - 1998)

Latin American Region

Central American Site in Guatemala

Description of Collaborative Program

The Central American Site operates under a Memorandum of Understanding with Instituto de Ciencia y Tecnologia Agricola (ICTA), the Government of Guatemala's principal agricultural research organization. Dr. G. Sánchez, Head of the Dept. of Agricultural Sciences and Forestry at U. del Valle, currently serves as the Regional Site Coordinator, with site activities administered in collaboration with Ing. L. Calderón at ICTA, and Karina Illescas, an ICTA employee based at U. del Valle to facilitate institutional communications and collaborations with the IPM CRSP

The overall Central American site activities in Year Five were funded primarily through USAID Global Bureau grant monies to the IPM CRSP ($253,815) and Government of Guatemala Matching Funds ($233,848). United States collaborating institutions, U. del Valle, ICTA, AGEXPRONT and APHIS provided nearly $125,500 in additional matching funds in Year 5. IPM CRSP Technical Assistance funding for snow pea and melon research provided an additional $49,861 in funding.

ZAMORANO (Honduras) was the principal regional collaborating research institution outside Guatemala in Year Five. Communications were established with Nicaragua for the purpose of assessing collaboration opportunities in Year Six. APHIS-IS provided strong collaboration in the development of pilot pre-inspection programs for implementation and testing in Years Five and Six. FONAPAZ, a public/private sector development organization based in Guatemala initiated collaboration with the IPM CRSP by establishing research sponsorship for Year Six workplan activities. 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

Research capacity. The 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. Year Five confirmed the progress we have made in resolving this constraint over the last two years. The September '98 IPM CRSP Research Workshop and Seminar clearly exhibited a higher level of scientific approach in our site collaborators' research. Moreover, IPM CRSP research collaborators' Year Five annual reports evidenced greatly improved research capacity. The research is 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 ICTA's reorganization and increased focus on competitive funding support for research, have helped to significantly enhance the scientific rigor of IPM CRSP research in Guatemala.

Interregional cooperation. While the concept of "regionalization" is good in theory, practical implementation is much more difficult to achieve. Interregional competitiveness and national priorities often create difficulties in developing collaborative program initiatives between countries within the region. The IPM CRSP witnessed these constraints in the first four years of program activity. However, Year Five was a "watershed" year for interregional cooperation in IPM CRSP. Research collaborators in Honduras (Zamorano) and Guatemala (U. Del Valle; ICTA) reached a common purpose in their research priorities, and achieved a high level of scientific and program collaboration. This has helped strengthen the capacity and performance of IPM CRSP collaborators in both countries, and sets the stage for future expansion of our regionalization activities. The interregional cooperation fostered through the IPM CRSP clearly has played an important role in resolving this constraint.

Socioeconomic research capacity. Dr. Linda Asturias has been the primary collaborator in socioeconomic research activities, with a small but dedicated staff. In Year Four, however, Dr. Asturias was appointed to a senior level position in the Ministry of Education. While this appointment is a credit to the IPM CRSP, it has become somewhat of a constraint to our productivity in the socioeconomic areas of our research. With the strong and enthusiastic collaboration from Dr. Sarah Hamilton (Virginia Tech), in concert with Dr. Asturias, IPM CRSP socioeconomic research and productivity reached sustainable levels of momentum in Year Five. This is clearly evidenced by the level of research focus that has developed in Year Five. This research is key to future NTAE development and economic sustainability in the rural sectors of Central America.

Technology transfers. The implementation of performance-proven IPM CRSP production and post-harvest handling strategies continues to be a constraint. As Dr. Asturias' socioeconomic research in Year Five indicates, 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 is gradually being overcome as more IPM CRSP approved pest management information is transferred through regional workshops, seminars, and field demonstrations. However, as evidenced in the Year Five research in Xeabaj, this "information transfer" problem is far from being resolved. Nearly 78% of the producers surveyed in Xeabaj indicated that they use programmed pest management pesticide applications, and only 6% verified the EPA status of pesticides before application. IPM CRSP technology transfer initiatives will be increased in Year Six through research funding provided by FONAPAZ for demonstration research activities and field research collaborations at the community level in Guatemala.

Institutional policies. Revision and coordination of policies among the public and private sector institutions significantly influence NTAE development in Central America, and subsequently the implementation of performance-proven IPM practices. The policies of these institutions are slow to change, but we have witnessed significant progress in Guatemala in Year Five. The Government of Guatemala, through the Ministry of Agriculture, has moved aggressively with privatization in the agricultural sector. More importantly, the Government of Guatemala has established national policy priorities in the NTAE sector based upon IPM CRSP research and development activities. For example, the Government has established pre-inspection as a priority issue, and has implemented policies and programs to encourage adoption in the private sector. AGEXPRONT, the private sector NTAE trade association, has made significant progress toward adoption of market oriented policies that will help achieve expanded and more sustainable trade development in the non-traditional crops sector. IPM CRSP has provided leadership in helping create a more market-driven environment among institutional collaborators. This will be critically important as international food safety standards become more demanding and market competition intensifies.

Institutional Building

The 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.

The leadership role that was established for 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.

The Government of Guatemala, through the Ministry of Agriculture, has strongly supported the IPM CRSP's objectives for strengthening research capacity in the NTAE sector. Partially in response to these objectives, the Government initiated a complete reorganization of ICTA in Year Four. The benefits of this reorganization have been witnessed in Year Five of our IPM CRSP activities. This reorganization resulted in a separate division within ICTA devoted solely to NTAE crops research. This division now has six researchers dedicated to NTAE/IPM CRSP research, development, and technology transfer. Clearly this initiative has strengthened the Government's program agenda to further develop Guatemala's NTAE sector in a more socioeconomically and environmentally sustainable manner.

Helda Morales, a native Guatemalan, finished her Ph.D. in 1998, under the direction and support of Dr. Roger Williams, and plans to return to Guatemala to work in the non-traditional crops sector.

Phillip Lamport, a native Guatemalan, initiated his Master's Degree program in the Fall of 1997 under the direction of Dr. Steve Weller at Purdue University. He is focusing his research on genetic improvement the NTAE sector crops, and plans to return to Guatemala upon degree completion.

Jim Julian, a U.S. citizen and graduate student in marketing, is doing his thesis research on NTAE trade. He has traveled to Guatemala twice on research related assignments, and is currently collaborating with Dr. Sánchez at U. del Valle and Dr. Asturias at Estudio 1360.

Key regional collaborators visited the United States in Year Five to strengthen research collaboration and participate in research planning sessions with U.S. scientists; Dr. G. Sánchez, Dr. Linda Asturias, and Ing. Luis Calderón (Guatemala); and Dr. Michael Zeiss and Dr. Allen Hruska (Honduras) all made IPM CRSP visits during this reporting period.

The human resource development strategies in Central America focus on four 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, and (4) continued strengthening of the research capacity of host country collaborators.

Networking

The primary focus of our networking activities in Central America continues to be through IPM workshops and seminars conducted by IPM CRSP research collaborators. Workshops have been developed at the regional, district, and community levels. Again, this activity will be expanded in Year Six with funding from FONAPAZ. The regional workshops have focused on technology transfers to NGOs 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 strategies.

In addition, the Site Committee meets monthly to share new research information and discuss new strategies for networking with key stakeholders in IPM CRSP. New approaches to technology transfer have come largely from these monthly sessions. IPM performance-proven strategies will be introduced at the community level in Year Six as a result of grant funding from FONAPAZ established in Year Five.

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

Selected Research Accomplishments

1. Melons for export to the United States represent a major NTAE crop for the Central American region with a wholesale market value of over $67 million USD annually (Costa Rica $31 million; Guatemala $19 million; Honduras $16 million; El Salvador $1

million). The main pest problem impacting production and trade development was identified as angular leaf spot, caused by *Pseudomonas syringae pr. lachrymans* (PSL). The intensive production practices (2 crops per year) implemented during the rainy season are favorable to disease development. Growers looked to the IPM CRSP for assistance. This was accomplished through an IPM CRSP Technical Assistance grant in Year Five. IPM CRSP researchers first conducted in vitro studies to determine the potential effectiveness of commercial anti-bacterials as an integral part of an IPM-based strategy. It was found that ammonium-based bactericides have excellent inhibitory effects. Iodine-based products also showed some inhibitory potential. These findings will be used to develop IPM strategies for field testing in Year Six. Preliminary research suggests that a performance-proven IPM-based strategy to control PSL can be developed, thereby solving one of Central America's major bacterial disease problems in the region's most important NTAE crop.

2. Snow peas represent a major NTAE crop in Guatemala, impacting nearly 18,500 small independent farmers in the Highlands. Historically, these producers have experienced high economic risk due to dependency on agrochemicals and unstable markets. Great progress was made in Year Five in "breaking the chain" of dependency on agrochemicals and the subsequent market risks associated with product rejection resulting from phytosanitary violations. IPM CRSP made positive forward progress towards integrating new performance-proven IPM strategies into current grower production management regimes. The IPM CRSP/Government of Guatemala program focus on pre-inspection has been an important motivating factor among snow pea growers and exporters. Current year research at twelve IPM CRSP managed plots, comparing performance-proven IPM practices to traditional snow pea production practices, resulted in 25 to 50 percent higher marketable yields with 75 percent fewer pesticide applications from IPM. IPM CRSP research has focused field research efforts to optimize pest control practices through integrated strategies that accommodate production system interaction with the biology of the pest complexes and the environment. Targeted research in snow pea has and is continuing to investigate various aspects of the leafminer problem and potential control strategies. Studies include: the biology of leafminer in regard to cultivar susceptibility; cultural practices and placement of sticky traps and soil surface mulches; appropriate application timing during the day of insecticide sprays for maximum control; identification of leafminer parasitoids and the potential of the biological pesticides *Metarhizium, Beauveria,* and neem for leafminer control.

3. IPM CRSP research has shown the snow pea pod problem "lija" or sandpaper is caused by thrips, not by a fungal pathogen as was previously thought. These findings will lead to decreases in the use of unneeded fungicides, which many growers felt were necessary for "lija" control.

4. Research in broccoli has identified the various species of white grub (Coleoptera:Scarabaeidae) present in growing regions of Guatemala. This work has led to in-depth studies on appropriate control tactics to reduce this pest, including targeted pesticides and alterations in cropping sequences. IPM CRSP research found that control of the most troublesome broccoli pest, *Plutella xylostella* can be improved with integrated use of biological insecticides, such as baculovirus and Bt, and also that trap crops of *B. napus* have potential for reducing infestation levels.

5. 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.

6. This research clearly demonstrates the economic value from IPM CRSP performance-proven management strategies developed over the last few years, and greatly enhances our overall program missions to improve product quality and reduce pesticide use in the NTAE sector. These results provide clear evidence, particularly to small independent snow pea producers, that there is a better way. In Year Six we plan to demonstrate this "better way" at the community level throughout the major snow pea growing districts of Guatemala. This will be accomplished with a research demonstration and technology transfer grant ($150,000 USD over two years) from FONAPAZ.

7. The 1995 leafminer crisis confronted by the snow pea sector in Guatemala, prompted several responses under the leadership of the IPM CRSP. These activities were carried out with the objectives of solving the leaf miner crisis and establishing the basis for a pre-inspection program in Guatemala. Research conducted by IPM CRSP collaborators in Guatemala and the United States, demonstrating that the leafminer species infesting shipments was *Liriomyza huidobrensis* and not an exotic species, was pivotal in reverting USDA PPQ quarantine measures established during the pest's outbreak. Year 5 activities have expanded on this result.

8. In Guatemala 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. It is through this group that a *voluntary pre-inspection pilot program* has been established for implementation in the 1998-1999 growing seasons. After two years of field trials the IPM CRSP and its collaborators demonstrated that high quality snow peas meeting all phytosanitary regulations could be produced with the technology currently available. 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 to be tested in the 1998-99 growing seasons involves the participation of several key collaborators. Seven major NTAE packers/exporters have 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. APHIS-IS has played a significant role in the inspection protocol to be implemented at the packing facilities. Information regarding sample size, pest tolerances and thresholds have also been established by APHIS-IS. The Ministry's Directorate of Plant Health will be issuing a phytosanitary certificate to those shipments that have passed all critical control points from field to post-harvest handling. Through official agreements, the Directorate for Plant Health has resolved to delegate the supervision of snow pea production, handling and export to an impartial organization. ICTA will be the entity providing this support through APHIS-approved field and packing facilities supervisors, hired and trained for this purpose. Twenty-five snow pea plots will be assigned to every field supervisor and two packing plants will be assigned to each supervisor in charge of post-handling inspections. ARF/ AGEXPRONT will be in charge of record-keeping and other managerial aspects of the program, as well as promotion of the pre-inspection program among the snow pea sector.

9. Future development of economically sustainable expansion in Guatemala's NTAE sector will depend significantly upon the industry's capacity to effectively overcome increasingly critical constraints to interregional trade, particularly the more demanding sanitary and phytosanitary standards for food safety in the recipient countries. Holistic IPM strategies, including pre-inspection at the point of origin, represent the most responsible and cost-effective alternative for achieving sustainable expansion in the NTAE sector.

10. Socioeconomic research findings in Year Five provided baseline information needed to strengthen IPM CRSP impact assessment activities at the community level. Over 51 communities in the Districts of Chimaltenango, Sacatapéquez, and Xeabaj are engaged in NTAE crop production, with snow peas and broccoli as the main crops. Leaf miners, thrips, and white grubs are the main insect pests in these production areas; the primary diseases are mildew and aschochyta. Because nearly three-fourths of the small independent farmers in these production areas sell their produce through intermediaries in the wholesale markets, and rely heavily on agrochemical sales agents for pest management information, there is a high dependency on chemical intensive strategies to control pests. Subsequently, NTAE producer households in these communities are at high economic risk due to phytosanitary rejections. Year Five case studies helped to quantify the economic and socioeconomic impacts of traditional pest management strategies in these communities, and provided the documentation needed to achieve a significant level of Year Six funding from FONAPAZ. This funding is targeted for the development of programs that expedite the transfer of IPM CRSP performance-proven pest management strategies to small independent farmers in those communities.

11. Year Five research accomplishments were highlighted in the Third IPM CRSP Seminar held in Guatemala September 30 through October 1, 1998. Thirty-two research reports were presented by IPM CRSP collaborators. The seminar was attended by nearly 200 representatives from public and private sector organizations throughout the region (Guatemala, Honduras, and El Salvador). This year's attendance was nearly double that of the Second Seminar, and clearly confirmed the level of support and acceptance of IPM CRSP activities in the region. The Ministry of Agriculture, through Vice Minister Luis Castañeda, sent a clear message to the seminar attendees that IPM CRSP is the key to future development of the NTAE sector in Guatemala, and IPM CRSP programs have the full support of the Government. This is an important endorsement of the CRSP's accomplishments to date, and for its sustainability in the future.

12. Research publications by the Central American IPM CRSP collaborators increased in both quality and quantity in Year Five. There were five Journal Articles and 32 abstracts given in the "Third Seminar: Integrated Pest Management in Non-Traditional Export

Crops, Guatemala City, September 30- October 1, 1998".

Latin American Site in Ecuador

Description of the Collaborative Program

This is the first year of activity at the Latin American Site in Ecuador. In the seven months since the first IPM CRSP funding reached the researchers several activities have been initiated. 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 IPM CRSP because the crops we work with are primarily located in two locations. Javier Cuesta 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. Carmita 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 plantain. Roger Williams of Ohio State University (OSU) serves as the site chair. Cooperation between the two Site Coordinators (Carmen Suarez and H. Andrade) facilitates institutional communications and collaboration. Each Activity (research, training, or information exchange project) has a leader that is responsible for interactions with their respective coordinators and cooperators.

Activities in Year 5, first year for the Ecuador Site, were funded primarily through USAID IPM CRSP and collaborating institutions: INIAP, PROEXANT, CIP, and FORTIPAPA. Even though research activities at the Ecuador site are just beginning, we are developing collaborative ties with several local organizations which are well established there: CIP (Centro Internacional de la Papa), FORTIPAPA, PROEXANT, and we have Inter-CRSP activities with the SOILS CRSP.

Jointly developed collaborative research plans have allowed us to buy into ongoing research programs and initiate new projects with joint funding. This has been particularly true in Year 5 with the two primary crops on which research was initiated: plantain and potato. Since trained personnel were already on board we were able to take advantage of their skills to cooperate and conduct collaborative investigations. This system will allow us to provide deliverables at a much faster pace.

IPM Constraints Addressed

The Latin American Site in Ecuador is addressing some of the known constraints of key horticultural staples in the area. Late blight of potato is a worldwide limiting factor in potato production. In Ecuador we have the capability to select resistant potato clones with horizontal (durable) resistance. Activities in clonal selection are currently underway, and several lines have been selected for future research. Plantain is a staple 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.

Substantial progress in the use of safer compounds for the control of insect pestshas 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. against the Andean potato weevil. These are both new compounds which represent a major step in pesticide safety to humans and the environment.

The pesticide safety manuals being developed by the Ministry of Agriculture in cooperation with IPM CRSP should enhance awareness of dangers of the toxicity of all pesticides being used in the country/region. Training in the application and handling of pesticides will curtail unnecessary risks. 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.

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 with long term resistance 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 progress is being made.

Institution Building

We have been able to supply INIAP researchers with some of the new biorationals that are expected to be approved by EPA for potatoes within a few months. Two of these have been tested and appear to have promise in the control of the Andean potato weevil.

Several Ecuadorian undergraduate students have worked on the IPM CRSP activities for their Independent Study thesis in Ecuador.

One of the INIAP scientists, Victor Barrera, who works with potatoes in the area of PA and technology transfer

spent three months training at Virginia Tech with George Norton. In addition, Takayoshi Jose Yamagiwa from El Salvador, received his MS in Agricultural Economics at Virginia Tech under George Norton; his thesis topic was, "Analysis of Policies Affecting Pesticide Use in Ecuador". Yamagiwa is a student from El Salvador in Latin America.

Our student training plan is to use as many Ecuadorian students as possible in country in conducting the various activities. In addition, we have plans to bring one person OSU for short term training in biotechnology. Next year we have plans to start a person in a graduate program in some phase of IPM, likely at OSU.

Networking

We had our first one-day Mini-Workshop in Ecuador on October 23, 1998. This mostly covered results of the first year in Ecuador but also the plans for the second year (Sep '1998-99) which began. About 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. We plan for this to be an annual meeting and gradually grow into a larger forum to include students, researchers, extensionists, agricultural buyers and suppliers.

Selected Research Accomplishments

Our program began in March 1998. However, we were able to make some significant accomplishments because we were able to work with researchers that were involved in related work by collaborating with established agencies.

1. One of the first deliverables was the information reported on pesticide policy by Tak Yamagiwa in his MS thesis.
2. Another is the recently completed report on the survey of potato farmers by Victor Barrera, where there is a vast amount of data about many facets of the potato farmer and the potato industry of northern Ecuador.
3. Great strides were made in the control of the Andean potato weevil by finding biorationals that are efficacious to replace hard chemicals.
4. The selection of potato clones which show resistance to late blight and are acceptable to the consumer through taste tests has been a great stride in improving planting material for the future.
5. The survey work in plantain has brought forth information which will aid in the biological control of pests.

Caribbean Region

The research activities of the Caribbean site in Jamaica are reported under four main topic areas: IPM Systems Development, Pesticide Use Residues and Resistance, Socio-economics/Policy and Production Systems, Research Enhancement through Participatory Activities. All research activities presented are contributions from scientists from Caribbean/Jamaican and US Collaborating Institutions including CARDI, MINAG, RADA, Penn State, Virginia Tech, Ohio State, USDA-Vegetable Laboratory, and Lincoln University.

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. 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.

Selected Research Accomplishments

<u>IPM system development for callaloo pests</u>

1. Key components have been identified to form the framework of an IPM model for the management of major pests on callaloo. An identification guide for enhancing diagnostic capabilities of extension agents and farmers was published for distribution and use in education programs. A derived statistical model of lepidoptera populations in the target area and an action threshold of 1 larva/plant per six leaf sample has been used in the development of a sampling plan. From this plan a field chart was designed to guide pest management decisions and reduce the frequency of pesticide application. Validation studies have shown this to be an effective system, with the potential to reduce pesticide inputs by over 40% without significant increase in pest damage.

2. Farmer training has been initiated among 16 farmers within the major callaloo growing parish of St Catherine and farmers were very receptive to information on pest identification and the sampling system.

3. The importance of the need to identify more effective pesticides for controlling major arthropod pests was underscored by crop loss assessments in all studies and initial pesticide evaluation trials showed the biorational emamectin benzoate to give more effective control of defoliating pests resulting in markedly higher salable yields (62.3%) than the grower standard (44%).

4. Initial results from the use of exclusion as an alternative pest management procedure was promising; insect damaged rejects from covered plots being only 14.3% compared to 53.8% in uncovered plots.

IPM Systems Development of Hot Pepper Pests

5. Hot pepper farms in the parishes of St Mary, St Catherine and St Elizabeth were surveyed over four periods between February 1997 and March 1998 to determine the incidence of pests as well as production practices. Virus symptoms were observed on 99% of farms with plants over two months old. Tobacco etch virus was the most frequently detected virus, being present on 72% of farms. Aphid vectors such as *Aphis gossypii* and *Myzus persicae* were the most prevalent arthropod pests and were present on 74% of farms. The population dynamics of these vectors has been monitored, from March 1998, on four farms in South St Catherine using pan traps. *Myzus persicae, Uroleucon ambrosiae* and *A. gossypii* have been the most frequently detected species. Highest populations were recorded at the start of the study in February. *Aphis gossypii* is the only species which has been present throughout the entire study period.

6. A breeding program to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into Habañero pepper was continued; the second backcross was completed and resistant plants were selected from this backcross for use in completing the third backcross. The resistance to the peanut root-knot nematode (*Meloidogyne arenaria* Race 1) exhibited by the *C. chinense* germplasm line PA-353 was found to be conditioned by a single dominant gene; this gene is probably allelic to a gene that conditions the resistance in *C. annuum*.

7. The results of a field test conducted cooperatively with a CARDI investigator in St. Kitts demonstrated that the recently released *C. chinense* germplasm lines PA-353, PA-398, and PA-426 are resistant to indigenous field populations of *Meloidogyne* spp.

8. The results of growth chamber tests indicated that resistance to southern root-knot nematodes (*M. incognita*) in *C. chinense* is compromised at high temperatures. However, the root galling response and nematode reproduction in the resistant Scotch Bonnet germplasm line PA-426 at high temperatures was significantly lower than in susceptible Habañero-type peppers. Root-knot resistant *C. chinense* cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates.

9. An experiment was conducted to compare three levels of soil applied fertilizer, foliar applied soluble fertilizer and a control, on Scotch Bonnet pepper (*Capsicum chinense*). Growth and yield were significantly higher on plots with soil applied nutrients compared to control and foliar applied fertilizer. Aphid and broad mite (*Polyphagotarsonemus latus*) incidence were significantly higher in plots with higher leaf nitrogen.

IPM Systems Development for Sweetpotato Pests

10. Over the past year, the focus of sweetpotato IPM research has been to evaluate the potential of USDA multiple pest resistant sweetpotato breeding lines and selective low toxic compounds for managing the two major pests, the sweetpotato weevil and the newly emergent soil grub. In relation to the USDA breeding lines, significant strides were made in the development of a rating scale to measure levels of resistance. The scale greatly assisted in identifying variation in the levels of insect resistance among USDA lines and local varieties in replicated field studies. Under Jamaican growing conditions, USDA breeding lines produced yields comparable to local lines, exhibited varying levels of resistance to sweetpotato weevil and the soil grub, and met market and consumer criteria. One promising line identified is "Picadito".

11. As a short term strategy, the potential of the low toxic compound Fipronil was evaluated for management of the soil grub. Results indicate that this compound was able to reduce sweetpotato root damage by soil grubs 50% more than the current farmer practice, Ethoprop.

12. In an effort to disseminate the current sweetpotato weevil IPM technology of mass trapping male weevils with high doses of female sweetpotato weevil sex pheromone in combination with cultural practices to farmers/agricultural students and extension in major growing areas, interactive technology transfer sessions were conducted. Over the past seven months over 200 persons have been exposed to the technology.

Pesticide Use, Residues and Resistance

13. The goal of this topic is to assess the extent to which pesticides are used on pepper, callaloo, and sweet potato. 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, efforts were made 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.

14. Samples of callaloo and hot peppers collected in market basket surveys in August 1997 and February 1998 were contaminated with the insecticides diazinon, malathion and profenphos at environmentally unacceptable levels. These insecticides, which were present in seven of twenty-one callaloo samples and six of seventeen hot pepper samples, ranged from 0.48 to 2.2 ppm diazinon, 0.62 to 0.90 ppm of malathion and 0.94 to 1.10 ppm of profenphos. An extensive survey demonstrated that twenty-seven pesticides are in common use and many others are used occasionally. There is good evidence that pesticides are being used too often and too close to harvest.

15. There continues to be dramatic lack of lepidopteran larval control in growers' fields in the presence of 5 to 8 day scheduled applications of pyrethroids, carbamates, organophosphates, microbials (*B. thuringiensis*), and organochlorines applied individually and in tank-mixes. Pesticide resistance is suspected as contributing to this lack of control. The IPM CRSP is developing a Caribbean infrastructural capability to assay for resistance, preparing for a transition to biorational management options within a resistance management program.

Information Systems for Collaborative Research

16. In August 1998, a workshop was held in Kingston, Jamaica with the ultimate goal of enhancing the capability of Jamaican scientists in GIS software and analytical techniques and Global Positioning System (GPS) technologies. Twelve researchers from CARDI, MINAG, RADA and UWI attended the 3 day workshop and overall found the experience most worthwhile and directly relevant to their research experiences. Electronic presentations which were developed for the workshop have been posted on the World Wide Web. The capabilities of Jamaican scientists in GIS software and analytical techniques and Global Positioning System (GPS) technologies were enhanced through an interactive workshop.

Networking

IPM researchers from the wider Caribbean region interacted with each other during the 2nd Meeting of the IPM Network of the Caribbean held in Kingston , February 4-6, 1998. IPM CRSP partners from the US also attended and participated in the review of IPM activities in the various Caribbean countries, prioritizing regional IPM collaborative projects, and organizing a coordinating regional structure that would be responsible for activities in the Network.

During the year the Jamaica based IPM CRSP researchers participated in a collaborative research planning meeting between CARDI and MINAG held at the Bodles Research Station in February. The IPM CRSP Jamaica coordinator, Janet Lawrence, was appointed chairperson to the Collaborative Research Planning committee between CARDI and MINAG.

The IPM CRSP researchers conducted a Farmer Training Workshop on Integrated Pest Management of Callaloo with focus on *Pest Identification, Scouting and Timing of Pesticide Application.* The training was done on April 30 with an attendance of 16 farmers.

During the year several US scientists traveled to the Caribbean to cooperate in the evaluation of field trials.

USDA scientists shipped several USDA-developed, dry-fleshed sweetpotato clones to J. Lawrence to evaluate their potential in Jamaica.

After the GIS training conducted by Virginia Tech scientists for Jamaican collaborators was completed in August, most materials taken by the US scientists to Jamaica for the workshop were left in Jamaica to facilitate the participants' subsequent GIS efforts. CARDI received two Garmin 12 GPS units, one copy of Homesite HTML-editing software, and one copy of SnagIt image-capturing software. The Department of Geography, as compensation for use of its facilities, received one Garmin 12 GPS unit, one copy of Homesite HTML-editing software, one copy of SnagIt image-capturing software, one surge suppresser, one Iomega Zip drive, and two Zip disks. It is expected that CARDI and the Department of Geography, UWI, will use these materials to collaborate in future GIS endeavors.

Institution Building

Graduate student training: Sharon McDonald, a Jamaican PhD student at Virginia Tech, continued conducting research on virus diseases transmission of hot pepper in Jamaica.

For three graduate students in social sciences and economics (Gary Schlosser, Tina Schlosser, and Joseph Ogrodowczyk) methodological training was carried out at Virginia Tech and at CARDI with the participation of CARDI and US scientists.

A farmer training workshop was held for farmers in the old Harbour and Bushy Park communities. The theme of the workshop was "Integrated Pest Management on callaloo- *Pest Identification, Scouting and Timing of Pesticide Application*".

Two educational and implementation tools for IPM in callaloo were developed: the *Identification Guide: Major Pests of Callaloo* (D. Clarke-Harris, S. Fleischer, and A. Fender, 1998) based on field collection and taxonomic collaborative research, and a sampling plan, based on field research and statistical collaborative research. Both are formatted for use in educational programs with extension specialists and farmers and have already been used in training workshops.

A district in St Mary has been selected for the transfer of IPM technology. Four training sessions were held in the district. Topics covered have included common pests of hot pepper and their control, IPM, and common questions which arise at the start of hot pepper production. Officers from the local extension service (RADA) have been in attendance at all the training days and have provided valuable input. The training days are now being held in farmers' fields where hot pepper crops have been monitored since the seedling stage.

During August 18-20, Virginia Tech based IPM CRSP scientists conducted a workshop training Jamaican participants to use GIS software and analytical techniques and Global Positioning System (GPS) technologies for IPM. Twelve researchers/technicians from CARDI, MINAG, and UWI were trained.

Africa Region

In the Africa Region, Mali and Uganda were the focal countries for fifth year IPM CRSP research, training, and information exchange activities. These activities were concentrated in four topical areas:

a) Pre-harvest pest management, monitoring and on-farm and coordinated on-station field experimentation;
b) Post-harvest pest management with selected crops;
c) Socioeconomic and participatory assessments of IPM technologies;
d) Degree training and dissemination activities.

All work plan activities were conducted as a collaborative effort among scientists from host country research institutions and USA based institutions. Research activities in Mali are coordinated by the Institut d'Economie Rurale (IER), with research cooperation from the Operation Haute Vallee du Niger (OHVN), Groupe de Recherche et d'Application Technique (GRAT) and the University of Mali. Research activities in Uganda are coordinated by Makerere University Faculty of Agriculture and Forestry and the National Agricultural Research Organization (NARO), with additional support from the Ministry of Agriculture's Extension Service and four independent farmer associations. Scientists at host country research institutions are linked with research scientists at The Ohio State University, Purdue University, Montana State University and Virginia Tech.

Research efforts at both sites are planned through a series of steps. Priority crops, pests and constraints were initially identified through a participatory appraisal process, a baseline survey and on-going activities that monitor pests and disease incidence. Farmer participation in the research process is a critical component of the overall research strategy in the Africa Region and contributes to the redesign of current activities and to the design of new activities. Actual Workplan development began with planning sessions held in-country at both sites with the Site Chair and Vice Chair. They continued with in-country visitations from other co-principal investigators and resulted in the development of pre-proposals. Pre-proposals were then discussed, prioritized and integrated into a workplan at the Annual Meeting of the IPM CRSP held in Blacksburg, Virginia, at which five of the host country co-principal investigators and all USA based co-principal investigators were present. Finally, suggestions and revisions of the workplan were made by the Technical Committee, the ME and USAID.

This broad based planning process includes participation and financial inputs from several other sources. In Uganda, the International Center for Insect Physiology and Ecology (ICIPE) and the Rockefeller Foundation are collaborating with the IPM CRSP in funding three graduate students. ICIPE scientists also have provided parasitoids for release, evaluated research proposals and assisted in the advising of graduate students. The Rockefeller Foundation through the Makerere University Legume Improvement Program provides multiple venues for the presentation and discussion of research results with professionals on their staff. Three International Centers, IITA, CIMMYT /Harare and CIAT are also contributing germplasm, facilities and advice to IPM CRSP activities in Uganda. In Mali, IER has supported companion research at the Cinzana station on IPM for cowpea grown commercially, thereby achieving the expansion into that zone envisioned in the Phase I plan developed by the initial February 1994 stakeholders' meeting. This companion research has drawn on technologies and methods developed both by the IPM CRSP-Mali research in the original OHVN zone, and in one case of cross-site application, from IPM CRSP research in Guatemala.

Finally, collaboration between the Africa Region sites has mainly taken the form of idea sharing and researcher discussions at the Annual Meetings. Since IPM CRSP activities were initiated in Mali much of the information sharing has been from Mali to Uganda. Ideas such as integrated *Striga* management and the participatory technology development model were borrowed from the Mali Site and adapted to Ugandan conditions.

The following have been identified as key constraints on IPM in the Africa Region:

1) A lack of farm-level knowledge and data on incidence and severity of pest problems;
2) A lack of proven IPM alternatives that have been adapted to local conditions;
3) Incomplete understanding of socioeconomic and gender factors that influence perception of pests, diseases and pest management strategies and that both constrain and contribute to adoption of IPM;
4) Weak farmer participation in pest management research;
5) Lack of continuity and institutional fragmentation of IPM research.

In addition to these, important constraints on key pests were addressed by research activities as detailed in the Year 5 workplan. Selected research accomplishments and highlights are described below

African Site in Mali

Selected Research Accomplishments

1. Monitoring of the population dynamics of the blister beetles *Psalydolytta* spp. and *Mylabris* spp. in two zones in north central Mali confirmed that the peak period of blister beetle appearance is relatively stable even though populations may fluctuate nearly seven-fold from one year to another, as was observed in 1997 compared to 1996. In both drier and wetter zones, the respective peaks for each zone were the same in 1996 and 1997. This finding provides farmers with the knowledge of the period when they should plan for blister beetle control.

2. Across both zones and all villages, *Bacillus thuringiensis* and locally-pressed neem oil decreased the number of blister beetles in 24 and 48 hours after application. Neem reduced beetles by about 75%, compared to about 55% with *B.t.* As a result of an increase in undamaged ears, total yield in plots with *B.t.* (711 kg $\cdot$ ha^{-1}) was increased 56%, and total millet yield in plots with neem (846 kg $\cdot$ ha^{-1}) was increased by 86%, over the control (455 kg $\cdot$ ha^{-1}). The size of the effects was greater in the semi-arid Mourdiah zone than the semi-humid Sirakorola zone, reflecting differences in insect pressure and base yield levels.

3. The results of Phase I research over 4 years show the importance of multiple year assessment of monitoring and control measures. Populations of blister beetles are highly variable from year to year, and over four years, the effectiveness of the use of neem has depended on the level of infestation. In 1995 and 1996, at levels of 4 beetles or less per head, reductions of beetle numbers were small and yields were affected less. At the higher levels of infestation, 7 beetles / head or more, observed in 1997 and 1994, effects on yield were more substantial. Monitoring of beetle levels is needed to make a decision about the use of neem. These results suggest that neem application may be justified in about half of the years.

4. Other control measures also had positive results on insect pressure and yield. Millet / sorghum association increased yield by 114% (321 kg $\cdot$ ha^{-1}) in the Sirakorola zone, due to reduced blister beetle numbers on millet. Millet varieties with tolerance to blister beetles were identified for each zone: 'GRP1' in Mourdiah, with highest yields in both 1996 and 1997, despite having the highest percentage of damaged heads; 'M2D2' in Sirakorola, with highest yields in both years. Light traps reduced numbers of blister beetles at heading, with 3.4 times as many beetles with no trap and 1.9-2.3 times as many at 50 m from the trap, compared to 5 m from the trap. Yields showed a significant linear effect, decreasing with distance from the trap, and lowest in the field without traps in both villages. The percentage of stems with holes bored by the stem borer *A. ignefusalis* increased at all three stages (tillering, heading, and maturation) as a function of distance from pheromone traps.

5. In companion research in the Cinzana zone, recommended by the 1994 stakeholders' meeting for expansion in the latter part of Phase I, four experiments identified promising alternatives to scheduled insecticide application on cowpea grown as a cash crop. In an example of cross-site application of IPM technology, yellow Vaseline traps (observed in the Guatemala IPM CRSP program) decreased thrips infestation and increased yield (430 kg $\cdot$ ha^{-1}) relative to the control (240 kg $\cdot$ ha^{-1}). Neem extract, soap, and potassium reduced thrips by 31-53% and increased yields by 58-74%, but neem flour was not effective in increasing yields. Insecticide application was reduced from 4 to 2 with no negative effect on yields. Screening of 14 cowpea varieties identified three varieties ('IT93KD-692-1'; 'IT90KD-372-1-2'; 'IT89KD-245') with tolerance to rates of aphid infestation equal or greater than the average rate of infestation in the experiment, and consequent higher yields.

6. *Striga* infestation in 1997 in the IPM CRSP experiments was low, <2.5 plants / m^2, compared with 12 plants/ m^2 in 1996 and 58 plants / m^2 in 1995. *Striga* counts were reduced with both alternate row (inter-row) and alternate hills (intra-row) arrangements using the *Striga* resistant cowpea cv. IT 89KD 245 in

one of two villages in each zone, but yields were increased in only one of the four villages. These results over a three year period suggest that response to improved intercropping arrangements depends on the level of *Striga* infestation.

7. The tolerance of sorghum cv. Séguétana to *Striga* spp. was reconfirmed in 1997. Infestation was 1.8-2.2 higher in plots with cv. Séguétana than in plots with other varieties, but yields of 'Séguétana' were equivalent to other varieties with less *Striga* infestation.

8. A bio-economic model of millet production in the presence of the parasitic weed *Striga* was developed for two zones in Mali. Preliminary results indicate that low rates of nitrogen application are not profitable as they facilitate *Striga* development. As the application rate increases, nitrogen becomes profitable. The exact rate above which nitrogen impedes *Striga* development and increases net returns is dependent on the density of *Striga* seeds in the soil and millet planting density. For example, at a millet density of 3.5 plants/m^2 and *Striga* seed density of 40,000/m^2 (average for Mourdiah), nitrogen does not become a profitable input until application rates exceed 130 kg/ha. At a millet planting density of 0.5 plants/m^2 and 40,000 *Striga* seeds/m^2 nitrogen application rates above 114 kg/ha are profitable.

9. Powder from the fruit of the local plant *Nguo* (*Canavalia ensiformis*) or from roots of the local plant *Diro* (*Securidaca longipedonculata*), used as a seed coating, reduced the incidence and severity of *Sclerospora graminicola* of millet relative to the farmer control of no seed treatment

10. Interviews with Mali-based non-governmental organizations (NGOs) and research site villagers indicated value-added products such as peanut oil, sesame oil, oil of poughere could be sold as a source of cooking oil, light and energy to run small engines, and as the active ingredient in antimicrobial soap. A plan was developed for a loan-credit-replacement process in which village groups would collaborate with a Malian NGO, Groupe de Recherches et d'Applications Techniques (GRAT), and a Malian (Bamako) branch of a Washington, D.C. based NGO, Appropriate Technologies, Inc. (ATI).

11. Laboratory studies on Mali neem kernel extract (NKE) confirmed the improved homogeneity of ultra-low volume (ULV) application. HPLC demonstrated a linear relationship between NKE volume and azadirachtin A content, indicating homogeneity of azadirachtin A in the NKE samples. Adding surfactants (Malian village-prepared soap or a commercial product X-77) failed to improve the miscibility of NKE in water. Use of undiluted 100% NKE in ultra-low-volume application provided a homogenous application.

African Site in Uganda

Selected Research Accomplishments

1. The average proportion of maize stand exhibiting foliar stalk borer injury was 15% over five growing seasons in Iganga District. This level of foliar infestation resulted in 10% stalk injury and 5% ear injury. Such levels of infestation provide an indication of the proportion of stand that may be treated if growers apply insecticide treatments limited to plants exhibiting foliar injury.

2. The average proportion of maize impacted by termites was 18% over five growing seasons. Thus, the impact of termites on maize in Iganga District is likely greater than that of the stalk borer complex.

3. Six diseases of maize were observed to be predominant during the second season of 1997 and first season of 1998: maize streak virus, MSV, gray leaf spot GLS (*Cercospora zeae maydis*), northern leaf blight, NLB (*Exserohilum turcicum*), diplodia leaf streak DPS (*Diplodia macrospora*), common rust PS (*Puccinia sorghi*) and tropical rust PP (*Puccinia polysora*). Gray leaf spot was the most predominant disease in all fields with incidence as high as 75%. It was followed by northern leaf blight and maize streak virus. The least were the rusts. Maize streak virus severity was significantly (P=0.01) higher in the local variety than in Longe 1, whether under mono or intercrop. There were no significant differences among varieties in disease reaction to GLS, NLB, DPS, PS and PP. In all cases the improved variety outyielded the local variety. Higher yields of maize were obtained from a monocrop than in the intercrop.

4. Survey results demonstrated the prevalence of gray leaf spot (GLS) throughout important maize producing regions of Uganda despite its fairly recent arrival. Resistant germplasm has been identified from GLS resistant tropical breeding lines from the OSU/Uganda program. Polymorphic simple sequence repeat (SSR) molecular markers have been identified and are being used to ascertain quantitative trait loci associated with resistance to *Cercospora zeae-maydis*.

5. The dominant stem borer found on maize and sorghum at both research sites in Iganga and Kumi was *Chilo partellus* followed by *Busseola fusca*. Monitoring surveys also established that of the larval parasitoids, *Cotesia sesamiae* Cameron (Hymenoptera: Braconidae), was the most common and attacked both

Chilo partellus and *Busseola fusca*, however, parasitism was generally low (7.7%). The exotic parasitoid *Cotesia flavipes* was recovered prior to the initiation of the release program. Following the release, larval parasitism has increased with a higher rate of parasitism occurring in Kumi District (30.3%). This is an early indication that *Cotesia flavipes* is becoming established in the study area.

6. Farmer monitoring of pest activity on beans clearly demonstrates that bean fly is the major constraint of bean production with stand infestation averaging 54% over five growing seasons. Significant stand and yield losses are associated with such levels of bean fly infestation.

7. The effects of seed dressing and earthing-up on bean fly incidence and damage indicated that seed dressing and earthing-up significantly reduced bean fly damage and bean root rot. There was an increase in bean grain yield of between 72% and 213% associated with seed dressing. Earthing-up and seed dressing, however, did not significantly influence incidences of bean aphid and bean striped weevils.

8. All treatments in the bean fly management trial produced a higher net income than the controls. Seed dressing with Endosulfan produced the highest net income with a 213 percent increase 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.

9. Post-harvest treatment of beans using solar heat and tobacco demonstrated comparable efficacy to application of Actellic for prevention of bruchid damage in stored beans. Since solar heat treatment has a negative effect on bean germination, this treatment should be limited to beans used for food consumption. Since tobacco treatment does not have a negative effect on bean germination, this treatment may be a useful treatment for seed beans.

10. The baseline survey and case study analysis of cowpea producers indicates that commercial growers are likely to commence spray programs earlier and to apply sprays more frequently, sometimes up to 8-10 applications per season. Aphids are consistently ranked by farmers as the most important insect pest of cowpea, however, chemical control of aphids at the vegetative stage alone had no significant impact on grain yield and a low marginal return. A single spray at flower initiation, flowering and podding reduced thrips, *Maruca* and pod sucking bugs and had the highest marginal returns.

11. Preliminary results of the occurrence and management of cowpea diseases show that viral, scab and pink rust were the major diseases observed on field cowpea. Plant population densities significantly ($P<0.05$) affected cowpea disease incidence. Late planting significantly increased disease incidence and severity. The use of benomyl (Benlate) and Dithane-M45 in a tank mixture also significantly reduced disease development on cowpea.

12. Farmer evaluation confirmed the importance of IPM priorities and indicated a high propensity for adoption of Igola 1 groundnut variety and bean seed treatment.

13. IPM CRSP Open Days held at research sites in Eastern Uganda exposed 140 new farmers to IPM and IPM CRSP field trials. Farmers are generally unaware of most plant diseases except maize streak, sorghum smut, and groundnut rosette disease. The resistant groundnut variety Igola 1, demonstrated by the IPM CRSP, is being adopted by farmers near research sites in Kumi District.

14. Using a variety of *Striga*-resistant sorghum lines and low doses of environmentally friendly herbicides, e.g. sulfonylureas, either as seed dressings or as timely foliar sprays provided effective *Striga* control under greenhouse conditions in Blacksburg, VA. These treatments will now be further investigated under representative field conditions at research sites in Uganda.

15. The use of inorganic fertilizer combined with interplanting with *Striga* chaser (*Celosia argentea*) appears to reduce the effect of *Striga* on sorghum crop growth. An integrated strategy based on application of inorganic fertilizer in combination with interplanting with *Striga* chaser and two hand weeding appears to be effective in *Striga* management.

Institution Building

The IPM CRSP has promoted the institutionalization of IPM in both countries in the Africa Region through collaborative partnerships with host country institutions. From the onset, in Mali and Uganda, the IPM CRSP has sought to merge the collective interests of National Agricultural Research Systems, Universities, Extension Organizations and Farmer Associations around the central concept of IPM. This is a particular need in the Africa Region in order to surmount the previously identified

constraint of institutional fragmentation and lack of continuity of IPM research.

Human resource development (HRD) plays a particularly important role in the Africa Region. From the beginning our HRD strategy focused on building the research capacity of farmers through implementation of a participatory agricultural research process. Farmers at both research sites have demonstrated an independent capacity to conduct their own research, a vital objective of the participatory approach. Farmers in Mali demonstrated their own post-harvest trials; in Uganda farmers have implemented agronomic treatments on cowpea that were recommended for groundnuts.

Degree training programs are also now underway in both countries. The IPM CRSP in the Africa Region is collaborating with host-country universities to provide degree training programs, while focusing graduate student research on topics relevant to IPM. There are currently five Masters level degree programs being supported in-country by the IPM CRSP. In each case, a U.S. co-principal investigator serves on the advisory committee of the IPM CRSP supported student. This method promotes collaborative links between the host country and the IPM CRSP, directly strengthens institutional IPM capacity, and contributes directly to IPM CRSP research output. In addition to host country degree provision there is one Malian student pursuing a Masters Degree at OSU, and one U.S. Ph.D. student working on *Striga* IPM in Mali who is about to complete his program. The dissertation by this latter student is focused on one of the major constraints on cereal production in the Sahel, *Striga*. The Malian student's program at OSU is proceeding on schedule and he will complete his program and return to Mali in June, 1999.

During the course of Year 5 of the IPM CRSP, five host country scientists visited collaborating scientists in the USA. These individuals participated in writing and analyzing their research results, presenting their research at the Third IPM CRSP Symposium, and planning research activities for the next cropping season while in the USA. There were a total of 11 trips by U.S. scientists to Africa Region sites: 5 to Mali and 6 to Uganda. In each case, host-country scientists demonstrated collegiality and collaboration by making available scarce transportation resources and traveling with U.S. scientists to research sites.

Networking

Networking at both sites has been greatly improved over the course of the project through access to the Internet. The Africa IPM-Link is to be commended for greatly improving communication by providing resources and expertise to link host country institutions with this invaluable tool. In-country networking has been improved through annual research planning meetings. These meetings have been held in both countries for the last two years with U.S. scientists contributing catalytic support. Scientists and farmer training and farmer open days have also been outlets for improving and providing an outlet for research results. Additionally, most of our host country collaborators participate with other projects and donors. In Uganda, the Makerere University Legume Improvement Program, funded by the Rockefeller Foundation has jointly supported graduate students and their research with the IPM CRSP. This project has also provided venues for the presentation of research results. In this regard, ICIPE has also supported and provided an avenue for enhanced regional networking.

IPM Electronic Communication in Africa

The Africa IPM Link initiative is the primary activity that addresses the issue of IPM Electronic Communication in Africa for the IPM CRSP. Activities of the Africa IPM Link were supported through funding from USAID AFR/SD office.

Principal Accomplishments

1. The IPM Communications Workshop: Eastern/Southern Africa (ICWESA) was held at the International Center for Insect Physiology and Ecology (ICIPE) in Nairobi from March 1 to March 6, 1998 in Nairobi, Kenya. The Africa IPM Link / IPM CRSP was one of the main organizers and implementers of the workshop.

2. The Africa IPM Link web site http://www.cals.vt.edu/ail/index.html which is both in English and French is well established and is being regularly updated. Based on extensive search of the WWW, new links are being added on a regular basis. Average successful requests (hits) per day on the Africa IPM Link web site have increased to an average of 180 per day since the Nairobi workshop. Africa IPM Link has been accessed from several African countries such as Kenya, South Africa, Ethiopia, Namibia, Zambia, Botswana, Uganda, Côte d'Ivoire, Egypt, Sénégal, Ghana, Malawi, Mozambique, and Tanzania.

3. An Email-based discussion list, Afrik-IPM, has been implemented. The discussion list will be instrumental for fulfilling the major objective of Africa IPM Link, developing IPM networking initiatives within sub-Saharan Africa. The purpose of the list is to promote the exchange of information and ideas among ICWESA participants and to post IPM-related news and information for sub-Saharan Africa. The first message on the Afrik-IPM listserv was posted on April 28, 1998. While initially intended for the ICWESA participants, the list currently counts sixty one subscribers representing a wide range of organizations and geographical areas. Discussions on various IPM topics

related to Africa are actively going on. It is an excellent and inexpensive medium to stimulate the exchange of ideas and information across the continent. Efforts will continue into promoting the existence of the list throughout sub-Saharan Africa and particularly in the French speaking countries.

4. Partnership and ongoing communication with other organizations with an interest in IPM and electronic communications in sub-Saharan Africa is actively pursued. These include, but are not limited to CICP, IITA, FAO, and ICIPE. Communication channels have been opened with ORSTOM, ENDA-TM and other Francophone organizations present in West Africa in order to initiate a partnership for a proposed IPM Communications Workshop for West and Central Africa.

5. Future efforts of the Africa IPM Link initiative will strengthen ongoing activities such as increasing English and French informational content on the Africa IPM Link Web Site, assisting directly or indirectly in providing Internet/Email connectivity in sub-Saharan Africa, and enhancing existing linkages and forging new linkages with regional and international organizations.

Asian Region

Asian Site in Philippines

IPM activities in the Philippine site were concentrated in three program areas during Year 5:

1. Multi-disciplinary on-farm pest management experiments,
2. Multi-disciplinary laboratory, greenhouse and microplot experiments, and
3. Socioeconomic analysis and training.

Three special projects were also carried out in Year 5: (1) Eggplant resistance to leafhoppers and eggplant borer, (2) Adoption profiles: Intrahousehold decision processes, community socioeconomic networks and IPM, and (3) 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), Penn State University, Ohio State University, and Virginia Tech. George Norton at Virginia Tech served as Site Chair while Victor Gapud at PhilRice served as Site Coordinator.

The Year 5 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. and Philippines scientists at planning meetings in the Philippines, (b) joint host-country/U.S. scientist two page proposals, (c) a workshop among U.S. and Philippines scientists to integrate the two page proposals into the overall plan and budget, and (d) revisions to the plan following review by the scientists, the ME and USAID.

Field research is conducted in six villages in San Jose, Nueva Ecija and in Bongabon, Nueva Ecija. The host country Site Coordinator oversees the field research activities. U.S., UPLB, 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 (student and scientist) take place at Virginia Tech, Penn State, Ohio State, UPLB, and AVRDC.

IPM Constraints Studied

The key constraints of IPM in the Philippines that were addressed during Year 5 were:

1. Absence of economical IPM solutions for specific pest problems,
2. Lack of basic understanding of the biology of specific pests, and
3. 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 litura),* and various weeds, particularly *Cyperus rotundus*, in onions. Eggplant shoot and fruit borers *(Leucinodes orbinalis),* leafhoppers *(Amrasca biguttula)* and bacterial wilt *(Pseudomonas solanacearum),* as well as *Maruca testulalis* and *Spodoptera litura* in string bean were also addressed.

Selected Research Accomplishments

Descriptions of research progress and results are provided in the individual institution/activity reports found in the IPM CRSP Annual Report. The following are examples of progress and key results obtained in the Philippines site.

1. In spite of inherent differences in dominant weeds and prevailing weed control practices between farms, the use of a single herbicide and one hand weeding provided weed control and onion yield comparable to

those obtained using the farmers' practice of two herbicides and two hand weedings.

2. The microbial insecticides NPV (Nuclear Polyhedrosis Virus) and Bt *(Bacillus thuringiensis)* alone and in combination were more effective than the standard insecticide Karate in reducing larval counts of *Spodoptera litura,* but yield effects are not entirely clear. A wettable powder formulation of NPV has been developed to replace the crude extract and enhance grower adoption of this practice.

3. Rice hull burning improved yields and reduced pink root, nematodes and *Cyperus rotundus* in onions. The use of compost had little or no effect on these organisms, but continued use may provide a substrate for growth of soil microbes and improve soil structure. The practice of rice hull burning killed nematodes to a soil depth of at least 20 cm.

4. Pink root was dramatically reduced in onions planted in a rotation scheme after pepper-rice-cucumber, compared with the common rotation of onion-fallow-rice- onion. Effects of crop rotation schemes on buildup of the root knot nematode are not clear-cut and need to be investigated further.

5. None of five commercially available biofertilizers/soil inoculants suppressed root knot nematode populations in onions. However, the plants *Tagetes* spp., *Crotolaria incana* and C. *mucronata* were effective in reducing root galls and nematode populations in roots and soil.

6. Castor plants surrounding onion plantings effectively attracted *Spodoptera litura* and *Helicoverpa armigera,* but have not been shown conclusively to prevent the pests of S. *exigua,* which had not been detected previously. It is believed that the abundance of this pest was related to the unusually hot, dry conditions resulting from the El Niño phenomenon.

7. Weekly removal of eggplant fruit damaged by the shoot and fruit borer *(Leucinodes orbonales)* resulted in highest yields, followed by triweekly insecticide applications. Combining damaged fruit removal with harvest of healthy fruit would reduce labor costs for this alternative.

8. Habitats adjacent to the rice-onion cropping system serve as habitats for generalist predators of insect pests. The movement of predators between these habitats and onion fields is being evaluated.

9. Parasitism of *Leucinodes orbonalis* by the ichneumonid parasitoid *Trathala flavoorbitalis* is highest in eggplants in March, which is approximately two-thirds of the way through the eggplant growing season (October - May). The parasitoid may be present as early as mid-January. Levels of parasitism reached 20-25% in most farmers' fields. This parasitoid may be a candidate for mass-rearing and subsequent release into eggplant fields.

10. Five species of the fungus *Trichoderma* and three *Bacillus* species showed activity against fungal pathogens of onion in vitro assays. Greenhouse/microplot studies will determine which species should be carried into field evaluations.

11. Upland and lowland ecotypes of *Cyperus rotundus* are being evaluated to determine the adaptation of the weed to different environments. Molecular genetic analysis will also be done to assess genotypic variation among and within ecotypes. This basic information will be necessary to understand the biology and adaptability of this weed pest in the rice-onion system.

12. Participatory appraisal and household survey results for San Jose and Bongabon, Nueva Ecija suggest that women are involved in decision domains that directly affect pest management practices. One-third of 32 female household heads interviewed reported participating in "farm-related decisions." Most of these farm decision-makers participated in decisions relating to amount of money to spend for pesticides, who should buy the pesticides, and selection of brands of pesticides to be used.

13. 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. Each of the experiments had at least one treatment with a higher yield, lower pesticide use, and higher net return than the farmers' practice.

14. A survey questionnaire to obtain information from Philippine households on their willingness to pay for reduced health and environmental hazards due to pesticides was administered to 206 households in Nueva Ecija. The hazards associated with the various pesticides being applied in the region are also being assessed 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, are being combined with the willingness to pay and hazard information to calculate the economic benefits of the environmental and health effects.

15. The eggplant variety SRO2 was least preferred by nymph and adult leafhoppers, whereas the variety IPB GS1 yielded the most healthy fruit and showed

tolerance to leafhopper damage, of the six eggplant varieties tested. The variety Dingras Long Purple was least preferred by the fruit and shoot borer, and may be a source of tolerance in development of improved eggplant varieties.

16. Preliminary results of case studies of seven female farmers in Nueva Ecija supported the previous observation that women are indeed involved in pest management, regardless of socio-economic standing. Selection of pest management strategy to use was generally jointly decided by male and female heads of the household. Women were also knowledgeable of the pests in the field and generally were the pesticide buyer. The use of insecticide was perceived as necessary to control onion pests for lack of alternatives.

17. *Phoma terrestris,* the pink root pathogen of onion, and *Meloidogyne graminicola,* causal agent of onion root knot, were widely distributed in onion-growing regions throughout the Philippines. Bulb rot, caused by *Fusarium* spp., was also a serious problem in many fields. Methods for identification of *P. terrestris* in culture were established, and used to characterize isolates from onion fields. A rapid molecular method for detection of *P. terrestris,* utilizing the polymerase chain reaction assay (PCR) was also developed. PCR primers specific for *P. terrestris* were developed, and DNA extraction techniques for fungal mycelium and onion roots were adapted. This technique will allow rapid detection of *P. terrestris* in onion and differentiation of the pathogen from other fungi common in roots.

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. For example, herbicide application could be drastically reduced or eliminated in onion production. In eggplant production, removal of damaged eggplant fruit may be an effective means of managing the eggplant shoot and fruit borer. Other cultural methods, including mulching and crop rotation, also show promise for management of pests and diseases, allowing reduced pesticide input, or providing a control strategy where none was previously available. Economic analyses will pinpoint the practicality of these pest management strategies, and assess the willingness of farmers to adopt these strategies.

V. Gapud, A. Baltazar, R. Alberto, I. Tanzo, L. Padua and K. L. Heong traveled to Virginia Tech in May 1998 to participate in the IPM CRSP symposium and planning meeting. Gergon, Baltazar and L. Cuyno presented results of their research. Norton, Rajotte, Hamilton and Miller also participated.

Institution Building

Equipment, vehicles and other support

Funds were provided for long-term rental of a vehicle for travel to and from research sites. Under the special project "Phoma", a thermal cycler for PCR and other lab equipment (pipets, sieves, etc.) and supplies were provided. Numerous research articles were sent from U. S. collaborators, and bibliographies were prepared at Penn State and provided to IPM CRSP scientists. More than 50 of the total Philippines site budget was provided to PhilRice and other collaborative institutions in the Philippines.

Research Training

R. Alberto undertook training for two months in 1998 in the laboratory of S. Miller at Ohio State University , in the areas of molecular detection technology (PCR) for fungi and biocontrol. Alberto had responsibility in Year 5 for all IPM CRSP pathology-related laboratory, greenhouse and field experiments at PhilRice.

E. Gergon visited the laboratory of S. Miller at Ohio State for three weeks in 1998 to obtain training in the use of PCR to detect the root knot nematode, *Meloidogyne graminicola.* She also visited the laboratory of J. Eisenback, nematologist at Virginia Tech. She was responsible at PhilRice for IPM CRSP experiments related to root knot nematode, and began Ph.D. dissertation studies at UPLB in 1998.

Clarinda Pile completed five months of training in Year 5 with N. S. Talekar at the AVRDC, focusing on mass-rearing of *Maruca* and *Leucinodes* and host plant resistance to several insects.

Scientist travel

E. Rajotte, S. Hamilton and S. Miller traveled to the Philippines in November 1997 to help lay out experiments with the host country collaborators for the upcoming crop production season. In February, 1998, E. Rajotte, G. Norton, and S. Miller traveled to the Philippines to review field results and help plan additional experiments. S. K. DeDatta also traveled to the Philippines during this time to assess research progress.

Several Philippines scientists undertook training activities outside the Philippines; R. Alberto completed a two-month training in molecular detection technology at Ohio State, while C. Pile trained with N. Talekar at AVRDC in insect mass-rearing studies and evaluation of host plant resistance to various insects. while C. Pile trained with N. Talekar at AVRDC in insect mass-rearing studies and evaluation of host plant resistance to various insects.

Human resource development

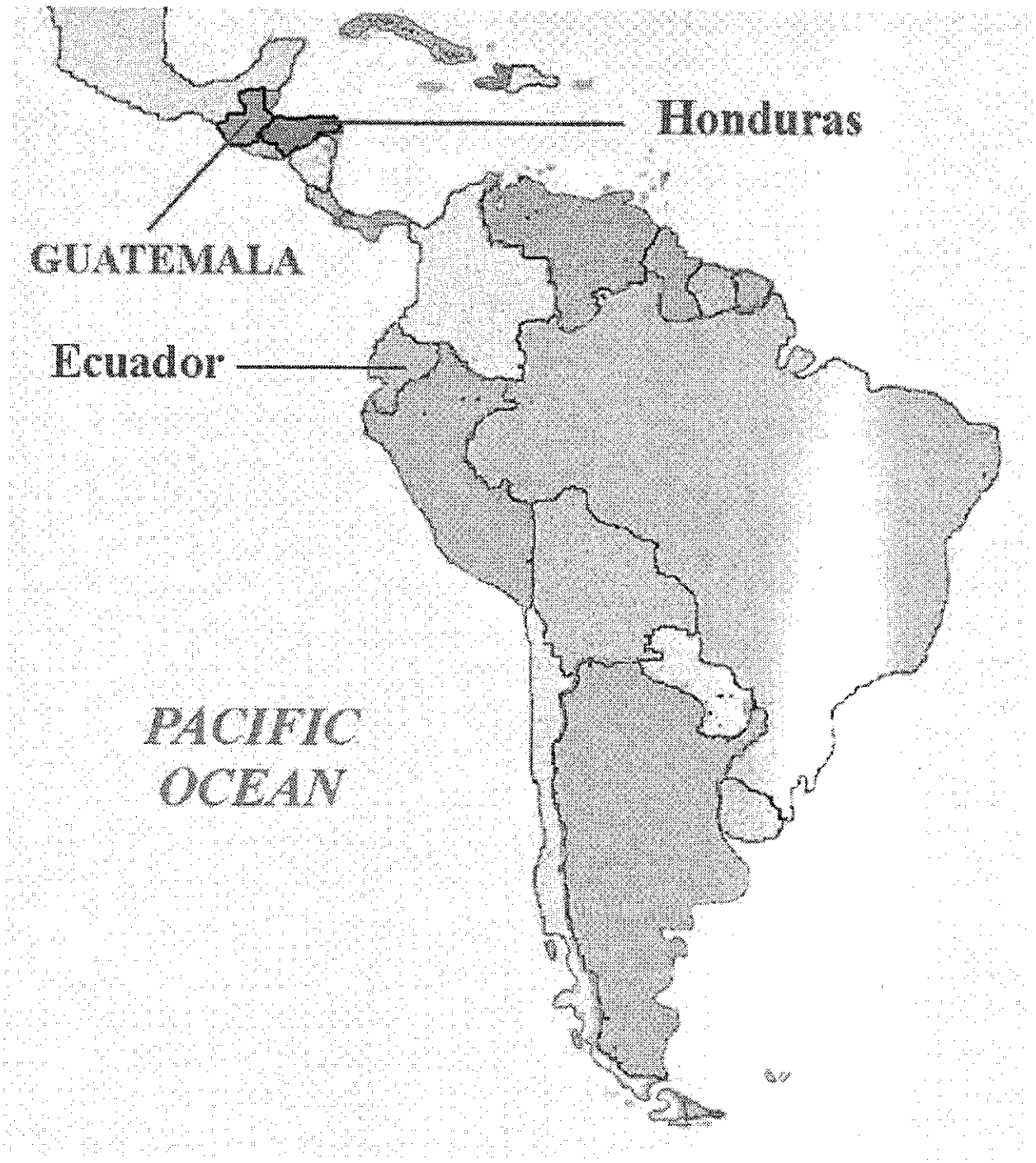
The IPM CRSP currently funds several graduate programs either in a collaborating host country university (UPLB) or US institutions. E. Gergon is pursuing a PH.D. in nematology, and M. Casimero is pursuing a Ph.D. in weed science, both at UPLB. Both students received additional training at Virginia Tech during Year 5. J. Recta is pursuing a Ph.D. in statistics at Penn State, while L. Cuyno is working towards 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 the IPM CRSP. PhilRice trains farmers in rice IPM and expanded into vegetable IPM in Year 5 through workshops and other training sessions in collaboration with IPM CRSP.

Both IRRI and AVRDC play key roles in networking with other countries in this region. Scientists involved with the IPM CRSP work throughout the region and can spread research results through visits to other countries and participation in workshops, meetings and other networking activities.

Networking is taking place between the IPM CRSP scientists and community organizations in the Philippines, such as NOGROCOMA, an onion growers' cooperative. Expansion of research activities in Bongabon came about as a result of these networking activities.



LATIN AMERICA

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

Investigators: Linda Asturias de Barrios[1], Brenda Tevalán[1], Dr. Glenn H. Sullivan[2], Flor Mencos[1], Mónica Berger[1], Hugo Alfaro[1], and Cecilia Skinner-Klée[1]

Collaborating Scientists: Sarah Hamilton[3], Guillermo Sánchez[4], Stephen Weller[2], Luis Calderón[5], Jorge Luis Sandoval[6], Alberto Chamorro[7], and Liliana Goldin[8]

Abstract

Research was conducted in two communities of Chimaltenango: Xenimajuyú in the municipality of Tecpán, and Xeabaj in the municipality of Santa Apolonia. This focused research enabled several participating institutions to strengthen their collaborations and to enhance their fieldwork as a team. The IPM CRSP Site Committee forecasts that both non-traditional agricultural exports (NTAEs) and crops for the domestic market will increase in those geographic areas, and that socioeconomic benefits will become more important impacts of the IPM-CRSP program during the coming years. Therefore, a decision was made to include both communities in the regional household survey, and to take its results as a baseline. It was also decided that the third community involved in NTAEs under a predominant cooperative regime in the regional survey should be in Year 6. The most likely selection will be affiliation with Cuatro Pinos Cooperative. This will allow us to compare the substantial data already collected on the cooperative's policy and regulations relating to pesticide use practices with members with those in our Year 5 research.

During Year 5 Estudio 1360 finished the community study in Xenimajuyú that was begun in late 1996. This community study was completed by collecting specific ethnographic information in order to design a regional survey questionnaire, by conducting a pilot survey to test the questionnaire, and by surveying one third of the regional household sample on July 1998.

A second community study was started in Xeabaj. Intensive fieldwork was done there, especially from May to August 1998. Two students from Del Valle University, who belong to the ESTUDIO 1360 team, lived in this community for two months. Other ESTUDIO 1360 members visited the community with several IPM-CRSP collaborators as part of joint activities. The ethnographic work was focused on seasonal calendars, pest and pesticide use on NTAEs, gender division of agricultural labor, production and commercialization of broccoli and snow pea, land tenure patterns, social organization, and local agricultural history. In order to make comparisons, data were also collected on nationally marketed crops such as carrots, cauliflower, tomatoes and cabbage. All of this qualitative information was complemented by a household survey conducted in August 1998, as part of the regional survey.

Introduction

In order to understand how snow pea is rejected through the commercialization chain, from the farmer's plot to the agroexport plant, and the potential socioeconomic impacts at the small farm household and community levels, farmers and intermediaries were interviewed in Xeabaj. Three technicians that have worked at agroexport plants were also consulted. This activity will be continued during Year 6 in order to make comparisons with other communities.

ESTUDIO 1360 and their closest collaborators concentrated efforts on the regional household survey in Year 5. In order to design the questionnaire, specific information was collected under guidelines provided by ESTUDIO 1360, the Site Committee, and Dr. Liliana Goldin. This information included structured interviews on economic ideology and perceptions of impacts of NTAEs. The Site Committee, Dr. Goldin, Dr. Hamilton, Dr. Weller and Dr. Sullivan revised several versions of the questionnaire. Dr. Hamilton joined the ESTUDIO 1360 team during the surveying process in Xenimajuyú and helped make crucial on- site decisions on sampling. She also supervised the design of the data entry and capacitated ESTUDIO 1360 personnel to perform some statistical analyses by using the Statistical Package for the

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Social Sciences software. After her return to the United States, the ESTUDIO 1360 team proceeded to conduct the survey in Xeabaj. In both communities a total of 141 households were surveyed. Data were fed into SPSS data entry files and some preliminary analyses were conducted. Dr. Hamilton came back to Guatemala in October to attend the IPM-CRSP workshop and to collaborate in gender and more complex analyses of the regional survey. ESTUDIO 1360, Ing. Chamorro (Soluciones Analíticas) and Ing. Sandoval (AGEXPRONT) organized four fieldwork days with farmers: one in Xenimajuyú and three in Xeabaj. They showed IPM CRSP results in snow peas and broccoli. They also provided solutions to farmers' problems on these crops and on strawberries. Others IPM CRSP collaborators joined during these field days.

During the last semester of Year 5, ESTUDIO 1360 played an important role in organizing the IPM CRSP Workshop held in Guatemala City on September 30 – October 2, 1998, and in preparing the publication of the paper abstracts. ESTUDIO 1360 prepared four papers for this workshop with the collaboration of local and USA researchers. The first focused on the production and commercialization of snow peas and includes socioeconomic impacts of the 1995-1996 leafminer crisis. The second presented results from three socioeconomic cases of snow pea producers. The third presented preliminary socioeconomic results from the survey conducted in Xenimajuyú and Xeabaj. The fourth analyzed gender issues by using data from the same baseline survey.

Objectives

The following objectives are included in the Year 5 Workplan for the Guatemalan Prime Site. To identify them in the Workplan, see the numbers inside the parentheses.

1. Assessment of socioeconomic and economic impacts on NTAE producers at the household and community level (I.2.c.4)
2. Descriptive analysis of the farmers' perceptions on pests, chemical pesticides, and pest management in NTAE crops (I.2.c.1)
3. Comparative analysis of phytosanitary and aesthetic criteria used at different points in the producer-intermediary-agroexport plant chain to reject snow peas (I.2.c.3)
4. Comparative analysis of cooperative policies regarding pest management regimes with actual practices used by farmers (I.2.c.2)

IPM Constraints

Current pesticide and IPM practices in both NTAEs and internally marketed crops were addressed in the research conducted in both Xenimajuyú and Xeabaj. The regional survey questionnaire included a section with roughly 24 questions on IPM practices for both types of crops. Results from this section will constitute a fundamental comparative baseline for the IPM CRSP in evaluating economic and socioeconomic impacts of NTAE production at the household and community levels. Gender and household labor issues also were addressed in this research.

Research Methods

Community studies in Xenimajuyú and Xeabaj 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 design the regional survey questionnaire which was divided into ten 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 and perceptions. The questionnaire went through a series of experts' revisions until consensus was achieved on the final version. A pilot application of the questionnaire was carried out in both communities. A random sample was selected from each community. Appointments were made in advance to interview household heads at their most convenient place and schedule. Completed pilot test questionnaires were edited for summary and analysis. Preliminary analyses were conducted to allow presentation in this annual report and at the IPM CRSP Seminar on September 30, 1998.

Research Results

Community Study: Xeabaj (Santa Apolonia, Chimaltenango)
Since data from the community study in Xenimajuyú were presented last year, in Year 5 we focused on qualitative results from Xeabaj such as seasonal calendars, pesticide use, and pests in snow peas and broccoli. Some farmers' perceptions about agrochemicals are also included (Tables 1-15).

Criteria used in the selection and rejection of snow pea in the commercialization chain. Snow pea is an export-oriented crop. Given the phytosanitary and aesthetic requirements it must meet for the export market, there is product along the commercialization chain that is rejected. These rejections are usually commercialized in the domestic market; some are discarded. The rejection significantly impacts small farmers, intermediaries, and agroexporters as it represents losses or lower profits for them. The criteria used by farmers and intermediaries in Xeabaj to select snow pea into the export chain were established by interviewing them, identifying the destination of their NTAE sales points, as well as the destination of the rejected product. To document the baseline criteria used by agroexporters, information was gathered from Cuatro Pinos and San Juan Agro Export, who are collaborating

entities of the IPM CRSP, Guatemala, although Xeabaj's snow pea is not commercialized through either of the above agroexport plants.

Research Impacts

A significant number of NTAE producers surveyed do not practice EPA status verification of pesticides used in their production. This was particularly the case for producers in the Xeabaj region. This has factors leading to this inadequate use of pesticides include growers perceived ineffectiveness of the approved agrochemical products, irresponsible advise from intermediaries, insufficient technical advise on accepted methods, intermediaries' lack of concern for pesticide residues, and farmers' dependency on intermediaries to transport and sell the production.

Xeabaj, where 80% of the producers are independent small farmers and only 19% are waged workers for someone else's production, has a higher enrollment in NTAE production strategies than Xenimajuyú. However, this production structure has led to greater reliance on agrochemical consultants for grower production management practices, and less use of accepted IPM practices. This has put households in the Xeabaj region at higher economic risk due to production rejections, which negatively impacts socioeconomic welfare at the household and community levels. Our Year 5 results, and our close collaborations at the community level, have helped establish change in the way small independent farmers perceive performance-proven IPM strategies; and how they use pesticides in their production regimes. Through close community level research collaborations small independent farmers see more clearly the negative impacts of improper pesticide use, and more readily embrace accepted IPM CRSP practices. Case studies conducted by G. Sánchez, S. Weller, and G. Sullivan served to strengthen growers' perceptions of accepted ICM practices to control pests and lower production rejections in snow peas.

Networking Activities

Workshop Participation

ESTUDIO 1360 played an important role in organizing the IPM CRSP Seminar held in Guatemala City on September 30 and October 1, 1998.

Research Investigator Exchanges

Dr. Sarah Hamilton and Dr. Liliana Goldin collaborated with ESTUDIO 1360 in several phases of the regional survey. Dr. Hamilton visited Xenimajuyú and Xeabaj with ESTUDIO 1360 staff and was able to monitor the survey process in the former community. She also trained ESTUDIO 1360 personnel in some statistical analyses by using SPSS. Dr. Hamilton will continue advising on statistical and gender analyses of the survey results during Year 6. Dr. Goldin will provide leadership in analyzing the data on economic ideology, which constitutes one of her specializations. She might come to work with ESTUDIO 1360 in early 1999.

Research Information and Product Exchange.

Impact of IPM CRSP recommended technology, including crop protection inputs and preinspection protocols. Dr. Guillermo Sánchez, Ing. Jorge Luis Sandoval, Ing. Alberto Chamorro and ESTUDIO 1360 participated in several informative meetings with farmers in Xenimajuyú and Xeabaj. The purpose of the meetings was to inform them about the results of IPM CRSP studies, as well as to incorporate more farmers into IPM-CRSP activities, such as use of tested IPM production practices.

Assistance given to collaborating scientists with research equipment, supplies and/or other support. In order to enhance the quality of IPM CRSP presentations at seminars, ESTUDIO 1360 trained some collaborators in using Power Point software. ESTUDIO 1360 will train other collaborators in using SPSS, during Year 6.

Publications and Presentations

A slide presentation was delivered at the IPM CRSP Symposium, Planning Workshop and Technical Committee Meeting that was held at VPISU, Blacksburg, Virginia on May 1998.

The following presentations were given at the III Seminar on IPM in NTAE crops held in Guatemala City on September 30 - October 1, 1998:

- Case studies: Small snow pea producers in Guatemala
- Socioeconomic regional survey: Preliminary data from two Kaqchikel communities
- Snow pea in Guatemala: Socioeconomic description of production and impact of the 1995-1996 leafminer crisis
- Gender and IPM adoption in the Guatemalan highlands: IPM CRSP baseline (Delivered by Dr. Hamilton)

Two Anthropology students from Del Valle University, who are members of ESTUDIO 1360, delivered a presentation at the V Conference of the Forum of Latinoamerican Students of Anthropology, Archaeology and History, on September 7-12, at the Escuela Nacional de Antropología e Historia, Mexico City. The title of the presentation was "Farmers Perceptions of Socioeconomic Impacts of NTAEs in a Community in the Guatemalan Highlands".

Table 1. Snow pea seasonal calendar in Xeabaj

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rainy and dry season												
Freeze												
Unusual hail storm 1998												
Regular cycles												
Planting season												
Use of irrigation upon need												
Leafminer problems increased		P	P	P	P							

Sign	Meaning	Sign	Meaning	Sign	Meaning	Sign	Meaning
	Dry season		Freeze		Planting		Irrigation
	Rainy season		Hail storm		Harvesting	P	Pest

In 1998 there was an unusual hailstorm during the third week of May. Most of the snow pea production had already been picked; therefore not many losses were reported. In the Chimaltenango and Sacatepéquez region, there are three regular crop cycles depending on watering conditions: August to October with rainfall, November to January with residual humidity, and February to April with irrigation. However, in Xeabaj, access to irrigation has allowed producers to plant in a scaled form from August to February. The planting season is extended depending on the farmers' expected date of the first rainfall, at which time, they want to have harvested all of their snow pea. They believe that the first rainfall in May is acid, oxidizes the plant and turns it black. Farmers may plant one to three times a year depending on land size, access to irrigation, capital, labor and other factors.

Table 2. Broccoli seasonal calendar in Xeabaj

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rainy and dry season												
Freezes												
Unusual hailstorm 1998												
First cycle					X							
Early first cycle					X							
Second cycle									X			
Irrigation as needed or residual humidity												
Pests: *Gusano nochero* (Affects more during transplanting)						P			P			

Sign	Meaning	Sign	Meaning	Sign	Meaning	Sign	Meaning	Sign	Meaning
	Dry season		Freeze		Planting	X	Transplanting seedling		Irrigation or residual humidity
	Rainy season		Hail storm		Harvesting	P	Pest		

In 1998 broccoli producers were affected by the May hail storm, for they lost their seedlings. Some farmers, who had planted earlier, lost their recently transplanted production. Producers organized into two groups in order to request credit from FONAPAZ, a government social fund supporting productive projects.

Table 3. Pests, pesticide use and farmers' perceptions in snow pea production in Xeabaj

Pest and Other problems	Chemical control (1 cap=25 mL)	Generic Names	Toxicity (class)	Recommended doses for 200 lts. Water	EPA status	Natural control	Some farmers' perception about this problem
Leafminer	1. EVISECT • ½ Bayer's capful in a bomb of 4 gallons, once a week 2. VERTIMEC • ¼ Bayer' capful in a bomb of 4 gallons, once every 15 days 3. BRAVO One Bayer pump every five days.	1. Thiocyclam Hidrogeno-xalato 2. Abemactin 3. Chlorothalonil	• II • IV • IV	• 400 gms./ *manzana* • 390cc./ *manzana* • 1-1½ Kg. Per *manzana*	• NO • NO • NO	1. YELLOW PLASTIC TRAMPS • 360 tramps per *cuerda** (one on every pole) 2. *Chile caballo*, one • handful chopped dissolved in one four-gallon pump twice throughout cycle. 3. Sunflower and *Flor de muerto*. These are planted around de snow pea' plot	• Vertimec is rarely used because it is very expensive. • They use Bravo for controlling this and other pest and diseases, even though they know it is a prohibited product. They said: "the intermediaries recommended us to use Bravo. The truth is that using this product, the leafminer does not affect the crop, but we know that we are cheating and the consequence is a low price. When an agroexport company know that we do not use Bravo, they help us.
Tortuguilla, chinche, pulgones, Thrips	1. BRAVO • 1 Bayer' capful in a bomb of 4 gallons every 5 days 2. BAYTROID 25 • (dosage measured same as Bravo) 3. THIODAN • (see Bravo) Thiodan is used upon the first flowers when Thrips are found.	1. Chlorothalonil 2. Cyfluthrin 3. Endosulfan	• IV • II • I b.	• 1-1½ kg./ *manzana* • 0.5 lt./ *manzana* • 1-1½ lts./ *manzana*	• NO • NO • YES		• Farmers believe Bravo is "hot"; they say that when they use it, Bravo is like an injection that warms the plant inside and makes it look livelier, except that sometimes the plants turn yellowish and discolored but without stains. • Farmers think these pests do not die. Therefore they have to "scare them away" with Thiodan or Bravo 500. In this way the insects do not touch the plant.
Spots	1. DITHANE • 3 kilograms for all the rainy season, it is applied every day. 2. ANTRACOL • 4 Bayer' capful a bomb of 4 gallons, every 15 or 20 days 3. MALATHION • (see Antracol)	1. Mancozeb 2. Propineb 3. Malathion	• IV • IV • IV	• 1-2.5 kg./ *manzana* • 1-1.5 kg./ *manzana* • 1.5-2 lt./ *manzana*	• NO • NO • NO		• Farmers think these products are good for fungus such as *Cenicilla, tizón temprano y tardío* and mildium that causes dryness.
Freeze	1. TRIPLE 20 (foliar) • 2 Bayer's capfuls in a bomb of 4 gallons, every 4 days or every week 2. FOSFAFOL • 2 Bayer's capfuls in a bomb of 4 gallons, every 4 days or every week	• Fertilizer 20-20-20 • Fertilizer 0-60-0	• IV • IV	• 3-4 lbs./ 2 *cuerdas* • 3-4 lbs./ *manzana*	• N/A • N/A		• Farmers reported that freezes cause less damage if they apply foliar fertilizers.

Sources: Farmers, column 2; AGEXPRONT and FIFRA (Farm Chemicals Handbook, Meister Publishing Co., Willoughby, Ohio, USA, 1997), column 3; FIFRA, AGEXPRONT and APHIS, columns 4, 5 and 6; farmers, columns 7 and 8.

Table 4. Pests, pesticide use and farmers´perceptions in broccoli production in Xeabaj

Pest and other problems	Chemical control	Generic Names	Toxi-City	Recom-mended doses	EPA status	Some farmer's perception about this problem
Gusano Nochero	1. TAMARON • 1 Bayer' capful in a bomb of 4 gallons, they apply every time the "*gusano nochero*" appears	1. Metamidophos	• II	• 0.4-1 lt./ *manzana*	• NO	• Farmers say that some birds eat the *gusano nochero* and therefore its populations have decreased. They say that the insecticide has to be spread in the early evening to be effective in killing the gusano.
Gusano Plutela and *Palomillas*	1. TAMARON • 1 Bayer' capful in a bomb of 4 gallons, once a week during the rainy season, twice a week during dry season 2. AMBUSH 10 or • THIODAN 1 Bayer' capful in a bomb of 4 gallons, once a week 3. EVISECT • (see Ambush and Thiodan)	1. Metamidophos 2. Permetrina • Endosulfan 3. Tiocyclam Hidrogeno-Xalato	• II • IV • I[a] • II	• 0.4-1 lt./ *manzana* • 1-1.5 lt./ *manzana* • 1-1.5 lt./ *manzana* • 400 gms/ *manzana*	• NO • NO • NO • NO	• They only use Tamaron during the beginning of the crop cycle because it is prohibited to use it after the broccoli has grown.
Argeño	1. DITHANE • 4 Bayer' capful in a bomb of 4 gallons, two times during the cycle. 2. ANTRACOL • (see Dithane)	1. Mancozeb 2. Propineb	• IV • IV	• 1-2.5 kg./ *manzana* • 1-1.5 kg./ *manzana*	• NO • NO	• Farmers think this product is less "curative" for the plant.

Sources: Farmers, column 2; AGEXPRONT and FIFRA (Farm Chemicals Handbook, Meister Publishing Co., Willoughby, Ohio, USA, 1997), column 3; FIFRA, AGEXPRONT and APHIS, columns 4, 5 and 6; farmers, columns 7 and 8.

Table 5. Common gender division of labor in broccoli production in Xeabaj

Agricultural practice	Gender division of labor		Type of labor
	Male	Female	
From day 1 Seedbed			
Turn the seed soil bed over	X		Family
Prepare soil bed	X		Family
From day 1 to 7			
Apply pesticides	X		Family
Make furrows	X		Family
Place the broccoli seeds	X	X	Family
Add sawdust over seeds	X	X	Family
From day 1 to 30 on Broccoli plot			
Plow the soil	X		Family and waged
Apply pesticides	X		Family and waged
Apply fertilizers	X	X	Family
Transplant	X	X	Family and waged
From day 30 to 90			
Turn the soil over to clean it	X		Family and waged
Apply fertilizers	X	X	Family
Apply pesticides	X		Family and waged
From day 90-110 Harvest			
Harvest	X	X	Family and waged
Apply pesticides	X		Family and waged

Table 6. Demographic data from Xeabaj

	f	%	*X*
Number of households in the community	138	100	
Number of households in the sample	54	39.1	
Number of households by residential plot			1.37 ± .73
Number of resident members per household			6.39 ± 2.71

Table 7. Socioeconomic data of household heads in Xeabaj by gender

	MALE		FEMALE	
	f	%	*f*	%
Total	51	100	52	100
Ethnicity	48	94.1	49	94.2
Kaqchikel				
Ladino	3	5.9	3	5.8
Religion				
Catholic	6	11.8	8	15.4
Charismatic	1	2.0	1	1.9
Protestant	40	78.4	39	75
None	4	7.8		
Linguistic competence				
Spanish	1	2.0	1	1.9
Kaqchikel			4	7.7
Bilingual	50	98.0	47	90.4
Primary occupation				
Agriculture	42	82.4	1	1.9
Commerce (non-agri)	3	5.9	2	3.8
Services	5	9.8	1	1.9
Industry	1	2.0		
Crafts			9	17.3
House chores			39	75.0
Secondary occupation				
Doesn't have a second occ.	23	45.1	29	55.8
Agriculture	10	19.6	5	9.6
Commerce (non-agri)	3	5.9	4	7.7
Services	13	25.5	2	3.9
Industry	2	3.9		
Crafts			6	11.5
Household chores			6	11.5

Table 7 presents a common gender division of labor in broccoli production in Xeabaj. Variations in this gender division of labor will be presented in the final report of the regional survey.

Table 8. Household head schooling in Xeabaj by gender

	MALE			FEMALE		
	f	%	*X*	*f*	%	*X*
Total	51	100		52	100	
Last school year attended						
Illiterate	4	7.8		10	19.2	
Literate and/or preschool	4	7.8		2	3.8	
To first grade	1	2.0		3	5.8	
To second grade	3	5.9		17	32.7	
To third grade	10	19.6		11	21.2	
To fourth grade	3	5.9		4	7.7	
To fifth grade	3	5.9		1	1.9	
To sixth grade	14	27.5		2	3.8	
To 1 secondary	3	5.9		1	1.9	
To 2 secondary	1	2.0		1	1.9	
To 3 secondary	1	2.0				
To 4-5 secondary	2	3.9				
To university	2	3.9				
Years of schooling			5.43 ± 3.20			3.08 ± 2.12

Table 9. Participation of Xeabaj households and household heads in organizations

	Household		Male heads		Female heads	
	f	%	*f*	%	*f*	%
Total	54	100	51	100	52	100
Cooperative	2	3.7	2	3.9		
Agricultural group	11	20.4	13	25.5	4	7.7
Committees (community develop)	7	13.0	5	9.8	4	7.7
Literacy	1	1.8			1	1.9
PAIN	2	3.7	1	2.0	1	1.9
CARE	1	1.8			1	1.9
G&T Communal Bank	2	3.7			2	3.9
No participation in organizations	28	51.9	30	58.8	39	75

Table 10. Land tenure, land planted with NTAE and land with access to irrigation in Xeabaj, by agricultural strategy (hectares)

Agricultural strategy	House-holds	Owned land	Rented land	Owned + rented land	Land planted with snow peas		Land planted with broccoli		Access to irrigation		
	f	*X*	*X*	*X*	*f*	*X*	*f*	*X*	*f*	%	*X*
SC+NTAE	21	2.55±7.02	0.19±0.25	2.74±6.99	18	0.33 ±0.76	4	0.48±0.59	16	48.5	0.51±0.96
SC+IC+NTAE	14	2.25±2.10	0.19±0.29	2.44±2.03	11	0.22 ±0.12	8	0.44±0.15	12	36.4	0.49±0.41
SC	13	0.85±0.75	0.16±0.25	1.01 ±0.69					2	6.06	0.17±0.08
SC+IC	2	2.99±3.59		2.99 ±3.59					2	6.06	0.34±0.16
IC+ NTAE	1		0.23	0.23	1	0.11			1	3.02	0.23
Do not plant	3										
Total	54	1.89 ±4.57	0.17 ±0.25	2.06±4.54	30	0.28 ±0.59	12	0.45±0.33	33	100	0.46±0.70

SC=self-consumption crops, IC=internally commercialized (domestic) crops, NTAE=non-traditional agricultural export

Table 11. Agricultural production in Xeabaj (May 97- April 98)

	IC Cabbage		IC Potato		NTAE Snow pea		NTAE Broccoli	
	f	%	*f*	%	*f*	%	*f*	%
Number of house-holds involved	8	14.8	14	25.9	30	56.6	12	22.2
Association of crops								
Alone	7	87.5	14	100	30	100	11	91.7
Associated	1	12.5					1	8.3
Labor								
Family	4	50	6	42.9	13	43.3	7	58.3
Waged	1	12.5	2	14.3	4	13.4	2	16.7
family + waged	3	37.5	6	42.9	13	43.3	3	25
Destination								
Sale	6	75	13	92.9	29	96.7	10*	90.9
self-consumption	1	12.5	1	7.1	1	3.3	1	9.1
sale + self cons.	1	12.5						
Commercialization								
Cooperative					1	3.3	1	10
Middleperson					25	83.3	1	10
regional market	1	16.7	6	46.2				
Supermarket							1	10
GuateCity market	5	83.3	7	53.8	1	3.3	1	10
Agroexporter					3	10	6	60
Seller								
Husband	6	85.7	10	71.4	23	76.7	11*	100
Wife					1	3.3		
Both	1	14.3	4	28.6	6	20		

* No information for one case

Table 12. Land planted and yield in Xeabaj by crop (May 97 – April 98)

	IC Cabbage	IC Potato	NTAE Snow Pea	NTAE Broccoli
Number of Households involved	8	14	30	12
Land planted				
X in *cuerdas*	1.13 ± .35	1.64 ± 1.08	2.52 ± 5.26	4.0 ± 2.95
X in hectares	0.13 ± 0.04	0.18 ± 0.12	0.28 ± 0.59	0.45 ± 0.33
Yield				
X by *cuerda*	2,637.5 units±1121.6	32.4 qq±13.51	15.3 qq±6.9	25.1 qq±5.3
X by hectare	23,382 units ±9,943.3	287.1 qq±119.8	135.6 qq±61.2	222.5 qq±46.9

Table 13. Prices of NTAEs paid to farmers from Xeabaj (May 97 – April 98)

	SNOW PEA	BROCCOLI
Households reporting	30	10
Average price	Q1.31 ± Q0.71 pound	Q0.57 ± Q0.04 pound
Highest price	Q3.00 per pound	Q0.63 per pound
Lowest price	Q0.40 per pound	Q0.50per pound

Table 14. Prices of internally commercialized crops paid to farmers from Xeabaj (May 97 – April 98)

	CABBAGE	POTATO
Households reporting	6	13
Average price	Q0.95 ± Q0.54 per unit	Q0.82 ± Q0.61 per pound
Highest price	Q1.66 per unit	Q1.80 per pound
Lowest price	Q.038 per unit	Q0.18 per pound

Table 15. Integrated pest management in Xeabaj

PRACTICE	Internally commercialized crops				Non-traditional agricultural exports			
	Total	Never	Some-Times	Always	Total	Never	Some-times	Always
	f	%	%	%	*f*	%	%	%
Uses rotation	16	12.5	18.8	68.7	36	11.1	13.9	75
Uses natural control	16	87.4	6.3	6.3	36	83.3	5.6	11.1
Counts pests before fumigating	16	75	6.3	18.7	36	77.8	8.3	13.9
Consults technician before fumigating with new products	16	68.7	12.5	18.8	36	41.7	33.3	25.0
Changes pesticide to avoid pests developing resistance	16	12.5	18.8	68.7	36	11.1	19.4	69.4
Uses sticky or color traps	16	81.3	18.7		36	52.8	19.4	27.8
Uses protection equipment	16	12.5		87.5	36	2.8	8.3	88.9
Verifies pesticide EPA status					36	5.6	11.1	83.3
Keeps register of pesticide application	16	62.5	12.5	25	36	44.4	16.7	38.9
Has had capacitating	16	56.3	18.7	25	36	38.9	16.7	44.4
"Calzar" for pest control	16	37.5	25	37.5	36	27.8	22.2	50
Cleans for pest control	16	12.5	12.5	75	36	11.1	5.6	83.3
Manages "*rastrojo*"	16	18.8	6.2	75	36	11.1	5.6	83.3

Training Output

Two Anthropology students from Del Valle University were trained in ethnographic fieldwork methods in Xeabaj. They and two advanced students from the same university (one from Sociology and another from Anthropology), all members of Estudio 1360, were trained in household survey. Dr. Hamilton facilitated the ESTUDIO 1360 team in some statistical analyses on SPSS.

Project Highlight

The low adoption of performance-proven IPM practices, and high reliance on agrochemical consultants, currently place small independent NTAE producers at high economic and socioeconomic risk. IPM CRSP research and technology transfers are key to the future enhancement of small independent NTAE producers' socioeconomic welfare, and for achieving sustainable economic growth in Guatemala's NTAE sector.

Trade Development in NTAE Crops: Guatemala's Future Market Competitiveness and Sustainability

Investigators: James W. Julian[1] and Glenn H. Sullivan[2]

Collaborating Scientists: Guillermo E. Sanchez[3] and Stephen C. Weller[2]

Abstract

Guatemala has established an ever-increasing presence in the non-traditional agricultural exports (NTAE) sector in the international marketplace during the last decade. Guatemala's total NTAE revenues have increased 24 percent during the period 1993 to 1996, reaching nearly $217 million USD in 1996. Our research in the IPM CRSP indicates that the NTAE sector in Guatemala continues to enjoy a regional advantage in horticultural crop production that is "performance targeted" for sale in North America and Europe. However, future development of economically sustainable expansion in the NTAE sector in Guatemala will depend significantly upon the industry's capacity to address increasingly important constraints to interregional trade. Non-economic constraints to trade based upon sanitary and phytosanitary regulations, if not addressed appropriately, can pose significant risks to future NTAE expansion in Central America. Our research suggests that these non-economic constraints already have had a negative impact on the competitiveness of Guatemala's vegetable exports to the United States. These issues will become increasingly more critical to sustainable expansion in the NTAE sector, as importing countries respond to domestic consumer demands for greater food safety and domestic producers, by tightening the performance requirements for imported food supplies. Our research finds that Costa Rica, a regional competitor, already has responded in a proactive manner, developing a more "market-driven" focus that emphasizes quality control through improved post-harvest strategies, pre-inspection, and Hazard Analysis and Critical Control Point (HACCP) compliance that help enhance market value of the export commodity and reduce the risk of detention, quarantine, and/or rejection in the recipient countries ports-of-entry. This response parallels the IPM CRSP pre-inspection program objectives in Guatemala and establishes the basis for comparative analysis of economic benefits.

Objective

To assess Guatemala's current market position and the potential constraints to future market competitiveness.

IPM Constraints

The importance of a proactive IPM based approach in addressing sanitary and phytosanitary constraints to trade for future expansion of NTAE markets, and the economic risks associated with non-compliance.

Research Methods

An assessment of import trade data from U.S. Department of Commerce, Central American regional economic and foreign trade data from the U.S. Department of Agriculture's Foreign Agricultural Service, U.S. import detention reports from the U.S. Food and Drug Administration and U.S. Customs Service, and U.S. import quarantine data form the U.S. Department of Agriculture's Animal and Plant Health Inspection Service was completed.

Research Results and Discussion

Our research suggests that Guatemala has been negatively impacted by non-economic constraints to trade, namely sanitary and phytosanitary import requirements. This has been witnessed in snow pea and raspberry. Guatemala's competitive position as a supplier of vegetables to the USA has been declining from 5th in 1992 to 12th in 1997 and appears to coincide with an increase in the number and frequency of shipments detained for sanitary and phytosanitary reasons at U.S. ports-of-entry. This evidence suggests that Guatemala would benefit for a proactive IPM based approach to addressing sanitary and phytosanitary requirements for importing into desired North American markets. A proactive IPM based approach would limit the use of agrochemicals and reduce the risks associated with food borne pathogens through the implementation of pre-inspection and HACCP base procedures thereby assuring the

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quality and wholesomeness required by an increasing number of importing countries.

Impact

The results of our research suggest that future expansion of NTAE trade to North American markets would be enhanced significantly through the implementation IPM based production procedures that improve the post-harvest quality and marketability of NTAE crops. IPM practices reduce the risks associated with non-economic constraints to trade through reducing the reliance upon agrochemicals to control pests. Also, these practices are often more cost effective than their agrochemical alternative for the small family farming unit to implement thus providing an economic incentive for implementation of these practices.

Publications and Presentations

Presentation

IPM CRSP Guatemala - Seminar III: Trade development in NTAE crops: Guatemala's future market competitiveness and sustainability

Papers

James W. Julian, Glenn H. Sullivan. 1998. Trade development in NTAE crops: Guatemala's future market competitiveness and sustainability. Purdue AES No. 15877.

James W. Julian, Glenn H. Sullivan, and Stephen C. Weller. 1998. Assessment of Potential Impacts from the elimination of methyl bromide in fruit and vegetable trade. HortScience, 33(5):794-7.

Project Highlight

The impacts of non-economic constraints to trade were evaluated through an assessment of U.S. import trade data. The assessment found that Guatemala's competitive position as a supplier of vegetables to the United States is declining, which coincides with an increase in sanitary and phytosanitary violations at U.S. ports-of-entry.

Evaluation of Baculovirus Sprayings for the Management of Lepidopteran Pests in Broccoli, Guatemala, 1997

Investigators: Humberto Carranza Bazini[1] and Stephen Weller[2]

Collaborating Scientists: Danilo Dardón Avila[1] and Albaro Orellana Polanco[1]

Abstract

The objective of the study was to determine the effectiveness of baculovirus sprays as control agents against *Plutella xylostella* and other common lepidopteran pests of broccoli. The baculovirus strain was obtained from the alfalfa measurer larva (*Autographa californica*) and the prodenia larva (*Spodoptera sunia*). Two field tests were established in the Departments of Chimaltenango and Jalapa from August to December 1997. Two treatments were included in the study, (1) plots treated with baculovirus sprays, and (2) plots treated with the standard management practice used by growers consisting of *Bacillus thuringiensis* (Bt) based commercial products. Adjacent plots of 400 m^2 each were used. The number of larvae,pupae and egg nests of lepidopteran moths were measured, including: *P. xylostella, Trichoplusiani, Leptophobia aripa, Spodoptera* spp. and *Estigmene acrea.* Data were also recorded on gross and net yield (mt/ha), and costs. "T" tests and partial economic budget analysis were carried out. Results indicated that baculovirus sprayings effectively control larval populations of *P. xylostella, T. ni* and *L. aripa* in the foliage, as they were kept under 6 larvae/25 plants (economic threshold used for Bt's sprays). However, at some points the insect pest density surpassed the above mentioned threshold, since the baculovirus sprayings did not reduce pests to lower than 6 larvae/25 plants. Baculovirus sprays are more expensive than the Bt's, however it is a viable alternative for the control of lepidopteran larvae. If managed adequately baculovirus can be incorporated into an integrated

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pest management program in broccoli, as an important component to prevent development of Bt resistance in the main lepidopteran species that infest broccoli.

Objective

To determine the effectiveness of Baculovirus extracted from the alfalfa measurer larva (*A. californica*) and from Prodenia (*S. sunia*) in the control of lepidoptera in broccoli crops.

IPM Constraints

Control of Lepidoptera in broccoli is difficult. Even though resistance to commonly used insecticides is prevalent, growers still use them as their main tool of control. Before biological control methods will be accepted they must be field tested and proven to be effective.

Research Methods

Space and Time: Two test areas were established: Panimacoc, Tecpán in Chimaltenango and another in Pino Dulce, Mataquescuintla, Jalapa from August to December 1997, establishing paired parcels of 400 square meters each and compared with "t" tests.

Treatments: One plot was treated with VPN-Ultra (polyhedric bodies of viral nuclear inclusions of *A. californica* and *S. sunia*) (Agrícola del Sol, Guatemala), at a dosage of 1 kg/ha. The other experimental unit was managed with other biological agents using intercalated applications of Dipel 2X (*B. thuringiensis* var. Kurstaki) and Xentari (*B. thuringiensis* var. Aizawai), at a dosage of 0.5 kg/ha.

Variables: Number of larvae – pupae – egg nests of Lepidoptera: Measured twice a week, beginning 15 days after transplanting with a systematic sampling at random in 25 plants per plot. The pesticide application threshold was 5 larvae of Lepidoptera in 25 plants. Monitored species were *P. xylostella, L. aripa, T. ni, Spodoptera* spp. and *E. acreae.*

Gross yield (kg/ha): The number and weight of harvested broccoli heads were registered.

Net yield (kg/ha): Quality control was determined from a 10% sample of the harvested heads. Heads containing more than 5 larvae and/or pupae of any of the Lepidoptera considered in the study were considered unfit for marketing.

Economic Production Records: Control of dosages, quantity of products and hand labor used were quantified economically.

Analysis: The "t" test for net and gross yield. Also, an economic analysis of partial budgets was carried out.

Research Results and Discussion

Larvae – pupae – egg nests of Lepidoptera in the Foliage: In Chimaltenango, populations of larvae, pupae and nests were present for *P. xylostella* (53%), *L. aripa* (28%), *Spodoptera* spp. (14%) and *T. ni* (7%), while in Jalapa levels for the species were: *P. xylostella* (92%), *T. ni* (7%) and *L. aripa* (1%). Together, less populations of Lepidoptera were found in Chimaltenango (24%) than Jalapa (76%).

In Chimaltenango the treatments controlled the populations of Lepidoptera on foliage for 2 weeks and were maintained under the threshold (more than 5 larvae – pupae – nests per 25 plants), when 4 applications of the baculovirus were made. Even though baculovirus treatment did control lepidoptera, their response was inconsistent in Jalapa. Some samples taken three days after treatment had lepidoptera populations greater than the established threshold, even though most of the time treatment resulted in decreased populations and less than the threshold levels. Ten applications were necessary to maintain control using the baculovirus treatment and 11 applications were required in the farmer's management. The above is because farmers used triple dosages of Bt' and other chemical products for lepidoptera control.

Populations of *Spodoptera* spp. and *E. acreae* did not reach adequate levels to evaluate effectiveness of the baculovirus. Comparing lepidoptera larvae in both treatments, higher incidence percentages were seen in baculovirus treatments than in the farmers' parcels. This was valid for *P. xylostella, L. aripa* and *Spodoptera* spp. In the case of *T. ni* the incidence was higher in the farmers parcel compared to the baculovirus treated plot.

Gross yield and quality control: Gross average yield was 14,562 kg/ha in the baculovirus treated plot and 14,301 for the farmer's. In Chimaltenango, baculovirus treated broccoli had some rejection, while there was no rejection from the farmer treatments. In Jalapa, 3 cuts were rejected in the baculovirus and 2 in the farmer's. *P. xylostella* was responsible for the rejections which suggests that it is necessary to generate a threshold specific for this pest as the one utilized in this research is for all the lepidoptera considered in this study. The net average yield was 8,893 kg/ha in the baculovirus and 11,651 in the farmer's (Table 1).

Table 1. Gross and net yields (kg/ha), evaluating baculovirus for the control of Lepidoptera in broccoli.

Treatment by Site	Gross Yield (kg/ha)		Net Yield (kg/ha)	
	Baculovirus	Farmer	Baculovirus	Farmer
Chimaltenango	15,652.32	15,875.72	13,102.62	15,875.72
Jalapa	14,562.41	14,301.22	4,683.52	11,671.08
Average	14,562.41	14.301.22	8,893.07	11,671.08

Economical Analysis: The analysis of partial budgets (Table 2) shows major net benefit in the farmer's management because of baculovirus' prices, and the applied dosages were higher compared to the products used by the farmers, averaging 7 applications in baculovirus to 7.5 applications for the farmer. The net yield was lower in the baculovirus treatments because of the rejection caused by *P. xylostella.* These results indicate that the baculovirus controls larvae of Lepidoptera in the foliage but that it should not be used as an only alternative in integrated pest management.

Table 2. Partial budget[1] analysis in the evaluation of baculovirus for the control of Lepidoptera.

	Jalapa		Chimaltenango		Average	
	Baculovirus	Farmer	Baculovirus	Farmer	Baculovirus	Farmer
Net yield (kg/ha)	4,683.52	7,426.44	13,102.61	15,875.72	8,893.07	11,651.08
Gross benefit (Q/ha)	6,182.25	9,802.90	17,295.46	20,955.95	11,738.85	15,379.43
Cost of products (Q/ha)	515.00	2,191.39	1,665.29	562.29	2,979.08	1,376.84
and labor cost per application (Q/ha)	5,460.87	599.50	138.00	138.00	326.00	368.75
Total variable costs (Q/ha)	5,460.87	2,790.89	1,803.29	700.29	3,305.58	1,745.59
Net benefit (Q/ha)	721.38	7,012.01	15,492.17	20,255.66	8,433.27	13,633.84

[1]To convert Quetzales (Q) to US $, an exchange rate of 6.5:1 (Q:$) must be applied.

Impact

Baculovirus strains from *A. californica* and *S. sunia* showed effectiveness for the control of larvae *P. xylostella, T. ni* and *L. aripa* in the foliage when populations did not surpass 6 larvae/25 plants. When the populations are higher than this threshold, it is necessary to incorporate other treatment products into the pest control program.

The use of baculovirus for the control of lepidoptera is an alternative that should be incorporated into an integrated pest management program in broccoli but should not be used as the sole management option. As part of an IPM program, baculovirus sprayings can help decrease development of resistance to Bt's in the short term.

Networking Activities

Bayer of Guatemala, through Ing. Alvaro Aguilar and Ing. Mario Maldonado, helped support activities for the control of white grub (*Phyllophaga* spp.) and of other insects in broccoli.

Publications and Presentations

XLVI PCCMCA Meeting presentation in Nicaragua, March-April 1998.

III Integrated Pest Management Seminar in Non Traditional Export Crops abstracts. Editors: Guillermo Sánchez, Linda Asturias, Danilo Dardón, IPM-CRSP, Guatemala.

Training Output

None

Project Highlight

The baculovirus obtained from *Autographa californica* and *Spodoptera sunia* showed effectiveness for the control of *Plutella xylostella, Trichoplusia ni,* and *Leptophobia aripa* with populations not exceeding 6 larvae/25 plants. The use of baculovirus is an alternative to be incorporated into an integrated pest management program for broccoli.

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

Investigators: Albaro Orellana Polanco[1], Humberto Carranza Bazini[1], and Stephen Weller[2]

Collaborating Scientists: Danilo Dardón Avila[1]

Abstract

From July to November 1997 two test sites were established in Chimaltenango and Jalapa with the objective of determining which isolates and/or commercial products based in enthomopathogenic fungi and entomophagous nematodes are effective biocontrols of white grubs (*Phyllophaga* sp. and *Anomala* sp.) in broccoli. In a completely randomized experimental design with three replications, three isolates of the fungus *Metarhizium anisopliae,* one of *Beauveria bassiana,* and one each of the nematodes *Steinernema* and *Diplogasteritus* were evaluated. The chemical control was Imidacloprid and a zero control check plot was also included. The variables measured were plant populations affected by white grub at 15, 30, 45 and 60 days after transplant (dat), commercial and reject yield (kg/ha). An individual site analysis of variance test was done, as well as a combined site ANOVA and the Duncan multiple mean comparison test. The individual ANOVA indicated that no statistical differences existed between treatments at Jalapa, but there were differences at Chimaltenango. In Jalapa, damage at the last reading (60 dat) varied from 22% in the chemical control Imidacloprid to 79% in the zero check. In Chimaltenango Imidacloprid treated plants had the least amount of damage at 15, 30, 45 and 60 dat (2% of damaged plants at 60 dat). The combined ANOVA indicated significant differences exist at the sites and in treatments. Damage observed at Jalapa was worse than at Chimaltenango, reaching a maximum of 66% and 21% respectively, at 60 dat. In conclusion, Imidacloprid was superior to the fungi isolates and nematodes. In the commercial yields of both sites (Jalapa and Chimaltenango) significant differences were found. The highest yield was obtained with the chemical treatment (Imidacloprid) with 11,717 and 14,387 kg/ha at Jalapa and Chimaltenango, respectively.

Objective

To determine which isolates and/or commercial bio-control products, based on entomopathogenous fungi or entomophagous nematodes, are efficient white grub management agents in broccoli.

IPM Constraints

White grubs are considered a major pest in the broccoli growing areas of Guatemala and its management is often impaired by inefficient control provided by the chemical agents regularly used. Since management of this pest is based mainly on chemical pesticides, it is necessary to evaluate field effectiveness of different biological control agents (either experimental or commercial products) that may provide a non-chemical approach for the management of control of white grub.

Research Methods

Location and Time of Planting: The experiment was conducted at two sites, one in the Department of Chimaltenango and the other in the Department of Jalapa, from July to November, 1997.

Experimental design: Broccoli fields highly infested with white grubs were selected and previous sampling was conducted to ensure the existence of an adequate white grub population and to determine the larval distribution. The experiment was a completely randomized design. Parameters measured were plant population at 15, 30, 45 and 60 days after transplanting and crop yield. Plant loss was only considered when white grub was the causal agent and, yields are expressed in kg/ha of export-quality broccoli heads. Yields and percentage of damaged plants at 15, 30, 45, and 60 days after application of the treatments were analyzed by ANOVA with Duncan's multiple comparison test for means.

Experimental Management: Management of the broccoli fields was based on the Integrated Pest Management Manual in Broccoli generated by the IPM ICTA-CATIE-ARF

[1] ICTA, Guatemala [2]Purdue University

Project (Morales, 1995). Testing took place on lands from collaborating farmers. Treatments were applied after transplanting to the base of the broccoli plantlet, covering the root area (Table 1).

Table 1. Treatments and dosage included in the white grub biological control experiments.

Treatment description (source)	Dosage
Metarhizium strain 1 (ICTA, Marcelo Velásquez)[1]	1.36 kg/ha
Metarhizium strain 2 (ICTA, Marcelo Velásquez)	1.36 kg/ha
Met 92, *Metarhizium anisopliae* (Agrícola El Sol)[2]	14 kg/ha
Baeuveria bassiana (Agrícola El Sol)	undetermined (1 petri dish)
Steirnerma spp. (La Garrucha)	71 million nematodes/ha = 28.39 kg/ha
Diplogasteritus	26.39 kg/ha
Chemical control, Imidacloprid (Bayer)	7g/15 l of water, 25 cc/plant
Check plot (control zero)	none

[1]Marcelo Velasquez is an ICTA microbiologist who has isolated several fungal strains from different parts of the country. Agrícola El Sol and La Garrucha are commercial distributors of biocontrol agents.

Plant population at 15, 20, 45 and 60 dat: Prior to the establishment of the field trials a random sampling was carried out in the broccoli fields. In Jalapa, 91% of the larvae found were *Phyllophaga obsoleta* and 9% *Anomala*, spp. In Chimaltenango, 36% were *P. obsoleta* larvae, 36% *P. valeriana*, and 28% *Anómala*, spp. Both genus are strictly rhizophagus, even though *Anómala* can be a facultative rhizophagus organism.

ANOVA results indicate that in Jalapa there were no significant differences ($p<0.05$) between treatments, in contrast to Chimaltenango where significant differences between treatments were detected (Table 2). In Jalapa the percentage of damage at 60 DAT was 22% in the chemical control (Imidacloprid) and 79% in the control plot. At Chimaltenango, the best treatment at 60 DAT was the chemical control (2.0% damage). The *Beauveria bassiana* isolate had the greatest damage (44.5%) at 60 DAT.

In all the readings, the combined ANOVA indicated that there were significant statistical differences between sites and between treatments, but no significant interaction (Table 2). Differences among sites were due to fact that white grub damage at Jalapa was greater (66%) than at Chimaltenango (21%) at 60 DAT.

Table 2. Summary of the individual (per site) and inter site ANOVA done on the percentage of damaged broccoli plants, by white grub, at 15, 30, 45 and 60 days after transplant.

Jalapa				
Damage (%)	**15 dat**	**30 dat**	**45 dat**	**60 dat**
Treatments[1]	NS	NS	NS	NS
CV (%)	51.31	42.33	39.35	33.06
Chimaltenango				
Damage (%)	**15 dat**	**30 dat**	**45 dat**	**60 dat**
Treatments	*	*	*	*
CV (%)	29.25	32.90	32.69	31.65
Combined				
Damage (%)	**15 dat**	**30 dat**	**45 dat**	**60 dat**
Locality	*	*	*	*
Treatments	*	*	*	*
Locality x Treatment	NS	NS	NS	NS
CV (%)	44.15	40.89	39.30	34.40

[1]Data was converted to the arcsine value prior to the ANOVA. Dat: Days after transplant; NS: Not significant; * : Significant ($p<0.05$). CV: Coefficient of variation.

The chemical control (Imidacloprid) was the most effective treatment at each site (Table 3). An explanation as to why the fungi and nematodes treatments were not different than the control plot is these organisms are more white grub species specific and that they require very precise environmental conditions after their application (such as soil humidity, organic matter contents) for best effectiveness. Another consideration is that during the experiments some periods of drought occurred that may have affected crop development. In addition to this, there is no defined effective dosage for the control of white grub in the field for some of the biological products tested. Further research on environmental effects and required dosage levels for the biologicals is warranted.

Table 3. Duncan test of the combined analysis for the % of damaged broccoli plants by white grub at 15, 30, 45 and 60 DAT. Chimaltenango and Jalapa, 1997.

Treatment	Percentage of Damaged Plants (%)			
	Days after Transplant (DAT)			
	15	30	45	60
Metarhizium 1	24.33 A	35.55 A	39.44 A	47.49 A
***Metarhizium* 2**	29.46 A	41.74 A	45.59 A	49.12 A
Met 92	22.41 A	33.63 A	40.38 A	42.95 A
Beauveria	26.36 A	41.81 A	46.30 A	50.78 A
Steinernema	17.51 A	37.76 A	42.24 A	46.76 A
Diplogasteritus	20.63 A	35.14 A	38.99 A	44.76 A
Imidacloprid	2.27 B	5.15 B	7.72 B	12.22 B
Check plot	38.94 A	45.67 A	49.87 A	53.09 A

Different letters following the percentage of damaged plants indicate that numbers are statistically different ($p<0.05$).

Results and Discussion

In the ANOVAS (Table 4) for Jalapa and Chimaltenango significant differences ($p<0.05$) were detected between commercial yields of the different treatments, the highest

yield treatment was Imidacloprid (11,717 and 14387 kg/ha in Jalapa and Chimaltenango, respectively).

Table 4. Summary of the individual (by site) and combined ANOVA done for export-quality and rejection yields in white grub bio-control field experiments in broccoli.

Source of variation	Locality					
	Jalapa		Chimaltenago		Combined	
	export	reject	export	reject	export	reject
Locality	*	*	*	NS	*	*
Treatment	*	NS	*	*	*	NS
Locality x Treatment					NS	NS
Variation coefficient %	76.76	113.83	43.63	41.56	54.86	85.85

Stars (*) indicate statistical difference ($p<0.05$) between yields of the listed sources of variation. NS: non-significant differences.

The combined ANOVA for commercial yields indicated significant differences ($p<0.05$) for locality and treatments (Table 5). Chimaltenango surpassed Jalapa with average locality yields of 8026 and 4351 kg/ha. The comparison of means over locality and treatment showed the chemical treatment Imidacloprid resulted in the highest yield (13249 kg/ha).

Table 5. Duncan's multiple comparison test for the combined ANOVA of locality and treatment.

Treatment (source)	Export-quality yield (kg/ha)
Metarhizium strain 1 (ICTA, Marcelo Velásquez)[1]	4680.71 A
Metarhizium strain 2 (ICTA, Marcelo Velásquez)	5061.61 A
Met 92, *Metarhizium anisopliae* (Agrícola El Sol)[2]	5040.95 A
Beauveria bassiana (Agrícola El Sol)	5261.74 A
Steirnerma spp. (La Garrucha)	5690.83 A
Diplogasteritus	5674.66 A
Chemical control, Imidacloprid (Bayer)	13249.01 B
Check plot (control zero)	4851.75 A

[1]Marcelo Velasquez is an ICTA microbiologist who has isolated several fungal strains from different parts of the country. Agrícola El Sol and La Garrucha are commercial distributors of biocontrol agents.

Impact

In this study the *Metarhizium* and *Beauveria* fungi isolates, and the *Steinernema* and *Diplogasteritus* nematodes, did not reduce white grub damage compared to the untreated control. The chemical control of Imidacloprid was the most effective treatment for the control of white grub.

Networking Activities

Bayer of Guatemala, Ing. Alvaro Aguilar and Ing. Alvaro Maldonado, supported the activities for this study of the control of white grub (*Phyllophaga* spp.) and of other insects in broccoli. Other collaborators were: ARF, Ing. Luis Alvarez; AGRIPLAN, Ing. Federico Matheu; ALCOSA, Ing. Erick Sunfelkd; INAPSA, Ing. José María Passarelli, members of the board of directors of the national committee of broccoli at the Asociación Gremial de Exportadores de Productos No Tradicionales (AGEXPRONT), Guatemala.

Publications and Presentations

XLVI PCCMCA (Central American Cooperative Project for the Improvement of Food Crops) Meeting in Nicaragua, March – April, 1998.

III Seminar on Integrated Pest Management in Non traditional Export Crops. Editors: Guillermo Sánchez, Linda Asturias, Danilo Dardón, IPM – CRSP 1998, Guatemala.

Training Output

None

Project Highlight

Additional research is required to specifically identify the appropriate dosage and effect of environment on the activity of biological fungal and nematode control agents for white grub in broccoli.

Identification of White Grub (Coleoptera: Scarabaeidae) Genera and Species that Cause Damage in Broccoli, Guatemala, 1997

Investigators: Humberto Carranza Bazini[1], Albaro Orellana Polanco[1], Danilo Dardón Avila[1], and Stephen Weller[2]

Abstract

In Guatemala white grub (Coleoptera: Scarabaeidae) causes serious losses in traditional and non-traditional crops. Farmers and exporting companies alike complain about the many losses caused by this pest. White grub genus and species that damage broccoli in different farming zones, are identified in this study. Losses are estimated with information provided by the farmers and through field surveys estimating the incidence (% infested plants) conducted by the research team. The study took place in the departments of San Marcos, Huehuetenango, Quetzaltenango, Sololá, El Quiché, Chimaltenango, Guatemala, Jalapa, Baja y Alta Verapaz. Sample collection took place during the months of August to November of 1996. It was determined that the most commonly found genera in larval state, in broccoli, were *Phyllophaga* sp. (70.97%) and *Anómala* sp. (24.30%) which are both phytophagous species. Other species were *Cyclocephala* (4.24%) and *Lygyrus* (0.47%), both harmless to the broccoli plants. *Phyllophaga* species found in the larval stage were *P. obsoleta* (71.63%), *P. menetriesi* (9.02%), *P. valeriana*(8.32%), *P. elenans*(2.28%) and *P. zunilensis* (0.92%). In adult specimens, *Phyllophaga* and *Anomala* were determined through specific white grub keys, both were also identified at the larval stage. From a total of 10 adult *Phyllophaga* specimens, 8 were *P. obsoleta,* 1 was *P. tumultosa,* and 1 specimen of *P. rufotestacea* (not known as plant pest). Farmers in our survey estimated that white grub damage can occasionally reach 100%. Damage estimates by the research team in the direct surveys varied between 1% and 95% with a national mean of 25%.

Objectives

To identify the genus(es) and species of white grub (Coleoptera: Scarabaeidae) which cause damage to broccoli in different agroecological zones of the country.

To estimate losses because of white grub in infested areas.

IPM Constraints

The soil borne insect pest commonly known as white grub comprises several different organisms belonging to the Scarabaeidae family (Coleoptera). Given that these organisms differ in habits and life cycles, it is extremely important to differentiate the main species attacking broccoli as management options may vary, based on the specific characteristics of each species.

Research Methods

Samplings were conducted in broccoli-producing areas known to be infested by white grubs. The Departments included in the survey were San Marcos, Huehuetenango, Quetzaltenango, Sololá, El Quiché, Chimaltenango, Guatemala, Jalapa, Baja Verapaz and Alta Verapaz. Field trips were coordinated between the research team and field supervisors working for the broccoli export companies operating in the different regions.

Data Gathering: To extract the white grub specimens from the soil, 0.27 m^3 soil cubes were taken from the base of broccoli plants located in heavily infested soils. In plots smaller than 0.7 ha, one sample was taken, composed of 5 subsamples. If the area to be sampled was larger that 0.7 ha, an additional 5 sub-samples were taken. The individual plant sampling procedure was done at random, but following a pre-determined route in the plot. In cases where no larvae were found in the samples, 10 symptomatic plants were collected to determine if the wilting was caused by white grub. The field trips took place from August to November, as during these months it is possible to find third instar larvae, the appropriate growth stage to differentiate between different genera and species.

Following soil extraction, larvae were placed in boiling water for three minutes and placed in 70% ethanol in a glass container. Live specimens were also collected and taken to insectaries to be raised into adults. The live larvae were placed into a plastic bucket containing organic matter and broccoli plants, caged in an organdi cloth box. The raising of white grub adults was done at ICTA's facilities in Quetzaltenango, Chimaltenango and Jalapa. Identification was done in collaboration with Dr. Anne Dix and Enio Cano

[1]ICTA, Guatemala [2]Purdue University

(Universidad del Valle). To estimate losses, white grub incidence ratings (% broccoli plant loss) were estimated and broccoli growers were also asked to estimate losses.

Research Results

A total of 87 samples were obtained between August and November 1996. The altitude of the sampled fields ranged between 1,400 and 2,800 meters above sea level. Topography of sampled lands was 19% level fields, 27% mixed topography and 55% with some degree of inclination. Sloped fields showed a greater incidence of white grub infestations. Farmer interviews showed that organic matter is applied to 85% of the broccoli fields. Fresh chicken manure is the main organic amendment used by 48% of the growers, followed by dehydrated chicken manure (37%), cow manure (7%), oak forest litter (2%), and no organic amendment (6%). Crops previous to broccoli in the same land were broccoli (39% of fields), corn (25%), potatoes (19%) and other vegetables (17%). Eighty-five of the sampled lands had corn residue. Forty-three percent of the growers identified white grubs as a very serious problem, 18% reported it as a serious problem and 39% considered it a minor pest.

White grubs were found in all the stages of broccoli plant development. It was determined that the most commonly found genus in the larval state, in broccoli, were *Phyllophaga sp.* (70.97%) and *Anómala sp.* (24.30%) which are both phytophagous species. Other species were *Cyclocephala* (4.24%) and *Lygyrus* (0.47%), both harmless to the broccoli plants. *Phyllophaga* species found in the larval stage were *P. obsoleta* (71.63%), *P. menetriesi* (9.02%), *P. valeriana*(8.32%), *P. elenans*(2.28%) and *P. zunilensis* (0.92%). In adult specimens, *Phyllophaga* and *Anomala* were determined through specific white grub keys, and both were also identified at the larval stage. From a total of 10 adult *Phyllophaga* specimens, 8 were *P. obsoleta,* 1 was *P. tumultosa,* and 1 specimen was *P. rufotestacea* (not known as plant pest). The estimated damages by the farmers can reach 100%. Estimated damages by the research team in the direct surveys varied between 1% and 95% with a national mean of 25%.

Impacts

In this study 5 white grub species of *Phyllophaga* and 1 of *Anomala* were detected. Given that different white grub species exhibit annual or bi-annual life cycles, the precise determination of the species attacking broccoli is necessary to implement adequate management strategies. The identification of the different species of white grub affecting broccoli in Guatemala will allow for the design and implementation of appropriate management methods.

Networking Activities

Bayer of Guatemala, Ing. Alvaro Aguilar and Ing. Mario Maldonado provided support in white grub control activities and other insects in broccoli. In addition, the following people and organizations collaborated: ARF, Ing. Luis Alvarez; AGRIPLAN, Ing. Federico Matheu; ALCOSA, Ing. Erick Sunfeld; INAPSA, Ing. José María Passareli, and the national broccoli committee of broccoli of the Asociación Gremial de Exportadores de Productos no Tradicionales (AGEXPRONT), Guatemala.

Publications and Presentations

XLVI PCCMCA (Central American Cooperative Project for the Improvement of Food Crops) Meeting in Nicaragua, March – April, 1998.

III Integrated Pest Management in Non Traditional Export Crops Seminar abstracts. Editors: Guillermo Sánchez, Linda Asturias, Danilo Dardón, IPM-CRSP 1998, Guatemala.

Training Output

Results will provide the basis for the design of training programs in white grub identification.

Project Highlight

The main white grub (Coleoptera: Scarabaeidae) genera affecting broccoli in Guatemala are *Phyllophaga, Anomala, Cyclocephala* and *Ligyrus*, which cause an average yield loss of 25%. Research can now be targeted to control these genera.

Spatial Distribution of *Brassica napus* as a Trap Crop for the Control of Lepidoptera in Broccoli (*Brassica oleracea var. italica*), Guatemala

Investigators: Humberto Carranza Bazini[1] and Stephen Weller[2]

Collaborating Scientists: Albaro Orellana Polanco[1] and Danilo Dardón Avila[1]

Abstract

This study was conducted to determine if *B. napus* was effective as a trap crop for lepidopteran pests in broccoli. Two field tests were established in 1997: one in the village of Panimacoc, Tecpán in the Department of Chimaltenango and the other in Pino Dulce, Mataquescuintla, Department of Jalapa. The treatments were (1) *B. napus* distributed at random inside the broccoli plots, (2) *B. napus* distributed around the broccoli plot, (3) *B. napus* distributed in rows inside the broccoli plot, and (4) the control plot (monocultured broccoli). The lepidopteran species monitored in this study were *Plutella xylostella, Trichoplusia ni, Spodoptera* spp. and *E. acreae,* and their effect on yield was recorded. Results indicate that none of the *Brassica napus* spatial arrangement had the desired effect of serving as a trap crop of lepidopteran pests in broccoli, as the populations of both larvae and pupa of *Plutella xylostella, Trichoplusia ni, Spodoptera* spp. and *E. acerae* behaved in the same manner in all spatial distribution at both sites. Yield with *B. napus* around the perimeter of the broccoli field and by rows was similar to the monocultured broccoli, while *B. napus* distributed at random in the broccoli plot negatively affected yield when compared it to the broccoli in monoculture.

Objective

Determine the effect of different spatial distributions of the trap crop *B. napus* for lepidoptera (*Plutella xylostella)* control in broccoli.

IPM Constraint

Use of trap crops in IPM production systems is not field tested and thus not readily accepted by growers. Field testing to demonstrate trap crop effectiveness and economy is necessary.

Research Methods

Place and Time: Two tests were established: one at Panimacoc, Tecpán, Chimaltenango, and the other at Pino Dulce, Mataquescuintla, Jalapa, from September to December 1997.

Experimental Design: Paired parcels of 300 square meters with 50 broccoli plants as sampling units each, separated by 10 rows of broccoli (to avoid interference between treatment). The treatments were (1) *B. napus* distributed at random inside the broccoli plots, (2) *B. napus* distributed around the broccoli plot, (3) *B. napus* distributed in rows inside the broccoli plot, and (4) the control plot (monocultured broccoli). The treatments evaluated appear in Table 1.

Table 1. Treatments and distribution of *B. napus* as a trap crop in broccoli fields.

Species	Distribution
Brassica napus	At random within the broccoli parcel
Brassica napus	Around the broccoli parcel
Brassica napus	In intercalated rows, every 6 trenches of broccoli
B. oleracea var. *italica*	Broccoli monoculture

Quantified factors (per plant): Number of larvae-pupae of *P. xylostella, T. ni, L. Aripa, Spodoptera* spp., *E. acreae* and total lepidoptera larvae. Gross and net broccoli yield (kg/ha).

Data: Because of the density of larvae and pupae population, weekly samples were taken starting 17 days after transplanting of broccoli. Each sample was taken from 50 plants per parcel, and sampling was systematic following a random selection of the starting point. For net yield, a quality control in each cut was done, counting number of larvae and/or pupae per sample in each cut, and the rejection threshold was 5 larvae and/or pupae per sample (per broccoli head).

Analysis: An individual ANOVA was done and combined for the number of larvae-pupae of *P. xylostella, T. ni, L. aripa, Spodoptera* spp., *E. acreae* and the total of Lepidoptera. For the ANOVA a completely random design was used with 50 repetitions (one plant of broccoli was considered a repetition).

[1] ICTA, Guatemala [2]Purdue University

Management: Agronomical recommendations of the Integrated Pest Management in Broccoli, IPM CRSP/ICTA=CATIE-ARF Project (1995) were used in each parcel. For the control of lepidoptera, commercial products with *B. thuringiensis* intercalating *Kurstaki* and *Aizavai* isolates were used. Marathon hybrid speedlings of broccoli were donated by "Pilones de Antigua" Company. For the *B. napus* trap crop, seedlings were planted 15 days before broccoli transplanting.

Research Results

Species and totals of larvae and pupa populations of lepidoptera: The ANOVA by species in Chimaltenango and Jalapa did not show significant differences between treatments. The ANOVA of the total lepidoptera of Chimaltenango showed significant differences between treatments where *B. napus* was planted in trenches with a mean number of 0.08 larvae/plant, which was lower than the other treatments. The combined ANOVA among sites indicated that there were no significant differences at P=0.05 for *P. xylostella, T. ni, Spodoptera* spp. and *E. acreae* (Table 2), when comparing larvae-pupa populations of each broccoli plant in each treatment.

Table 2. Summary of ANOVA of 4 treatments evaluated in Chimaltenango and Jalapa, by sites and combined, according to lepidoptera populations (species and total), 1997.

Source of Variation	*Plutella xylostella*	*Trichopusia ni*	*Leptophobia aripa*	*Spodoptera* spp.	*Estigmene acreae*	Total Lepidoptera
Chimaltenango						
Repetition	N.S.	N.S.	N.S.	N.S.	*	N.S.
Pest	**	N.S.	*	*	N.S.	**
Treatment	N.S.	N.S.	N.S.	N.S.	N.S.	*
C.V.	10.6	3.1	8.1	4.0	1.9	13.5
Jalapa						
Repetition	N.S.	N.S.	N.S.	No pest	No Pest	N.S.
Pest	**	**	**	"	"	**
Treatment	N.S.	N.S.	N.S.	"	"	N.S.
C.V.	16.1	5.4	4.1	"	"	16.8
Combination of Two Sites						
Repetition	N.S.	N.S.	N.S.	N.S.	*	N.S.
Site	**	*	**	**	*	**
Rep. by Site	N.S.	N.S.	N.S.	N.S.	*	N.S.
Pest	**	**	**	**	N.S.	**
Treatment	N.S.	N.S.	*	N.S.	N.S.	*
C.V.	13.9	4.4	6.5	2.8	1.4	15.5

N.S.: Not significant *: Significant at 5% probability **: Significant at 1% probability C.V.: Coefficient of Variation

In *L. aripa* there were significant differences at 0.05 between treatments by rows and at random having a minor population of larvae – pupae (Table 2). This indicates that in *L. aripa* the spatial distribution of *B. napus* is important when acting as a trap crop. It is probable that *B. napus* in rows had a major attraction for *L. aripa* adults because there were more eggs laid on the weed than in broccoli which increased the number of larvae and pupae. For lepidoptera, the combination of sites, indicates that there were significant differences at p=0.05 between treatments and that it was better to plant *B. napus* in rows (Tables 3 and 4).

The results suggest that to manage the lepidoptera complex using *B. napus*, the trap crop should be planted in rows which will decrease larvae and pupae populations on the broccoli foliage.

Table 3. Duncan test of total lepidoptera in 4 treatments evaluated in Chimaltenango Jalapa, 1997.

Treatment	Larvae/Plant Mean	Duncan at 5%
Broccoli monoculture	0.187	A
B. napus around broccoli	0.184	A
B. napus at random	0.147	AB
B. napus in trenches	0.134	B

Same letters do not differ statistically at 0.05

Table 4. Number of applications *B. thuringiensis* in 4 treatments in Chimaltenango and Jalapa.

Chimaltenango Site										Weekly Applications	
Treatment/Date	17/10	22/10	29/10	5/11	12/11	19/11	26/11	3/12	8/12	Total	No application
Monoculture	NA	Bt	NA	NA	NA	NA	NA	NA	Bt*	2	7
Around	NA	NA	Bt*	NA	NA	NA	NA	NA	Bt*	2	7
In trenches	NA	NA	Bt*	NA	NA	NA	NA	NA	Bt*	2	7
At random	NA	Bt	NA	NA	NA	NA	NA	NA	NA	2	7
Jalapa Site										Weekly Applications	
Treatment/Date	14/10	21/10	28/10	4/11	11/11	18/11	25/11	2/12	10/12	Total	No application
Monoculture	NA	NA	NA	*Bt*	NA	NA	NA	NA	Bt	3	6
Periphery	NA	NA	NA	Bt	NA	NA	NA	NA	Bt	3	6
In rows	NA	NA	NA	Bt	NA	NA	NA	NA	Bt	3	6
At random	NA	NA	NA	Bt	NA	NA	NA	NA	Bt	3	6

NA: No application Bt: *B. thurigiensis* Bt*: *B.t.* application

Yields: Gross yield was equal to net upon quality measures at harvest. None of the sampling heads in any treatment were rejected at cutting since no heads had more than 5 larvae-pupae/sample. In the individual analysis of yields among treatments there were no significant differences at Chimaltenango (Table 5). While at Jalapa, the monoculture treatment of broccoli was superior to *B. napus* planted in a random distribution, but similar to the other *B. napus* configurations.

In the combined ANOVA, significant differences between treatments were observed where broccoli monoculture, *B. napus* planted at the periphery of the broccoli and *B. napus* planted in trenches within the broccoli had similar yields and all were greater than *B. napus* planted randomly within the broccoli. The decrease in yields in the random *B. napus* treatment is due to light, space, and nutrient competition of the trap crop with the broccoli.

Table 5. Summary of the combined variance analysis, by site, of average yields from 4 Treatments, 1997.

Source of Variation	Chimaltenango	Jalapa	Combined
Site	-----	-----	N.S
Harvest cut (Rep)	*	*	**
Site x cut	-----	-----	*
Treatment	N.S.	*	*
C.V.	42.24	25.33	35.64

N.S.: Not significant *: Significant to 5% probability **: Significant to 1% probability C.V.: Coefficient of variance

Conclusions

The spatial distributions of *B. napus* did not function as a trap crop in *P. xylostella, T. ni, Spodoptera* spp. and *E. acreae* in an individual form. For *L. aripa*, a higher population was observed in *B. napus* placed in rows and at random. For *B. napus*, the spatial distribution by rows was a better trap crop for lepidoptera by reducing larvae-pupae populations per broccoli plant. *B. napus* placed in a random distribution reduced broccoli yields while broccoli grown in *B. napus* arrangements around the perimeter and in trenches had similar yield to broccoli monoculture.

Networking Activities

Bayer of Guatemala, Ing. Alvaro Aguilar and Mario Maldonado. Supporting activities for the control of white grub (*Phyllophaga* spp.) and of other insects in broccoli.

ARF, Ing. Luis Alvarez; AGRIPLAN, Ing Federico Matheu; ALCOSA, Ing. Erick Sunfeld; INAPSA, Ing. José María Passarelli; Asociación Gremial de Exportadores as a supporting domestic committee.

Publications and Presentations

XLVI PCCMCA Meeting presentation in Nicaragua, March-April 1998.

III Integrated Pest Management Seminar on non traditional crops for exportation. Editors: Guillermo Sánchez, Linda Asturias, Danilo Dardón, 1998 IPM-CRSP, Guatemala.

Training Output

None

Project Highlights

Spatial distribution of *Brassica napus* in rows was a superior trap crop configuration for attracting Lepidoptera in general, reducing larvae-pupa populations per broccoli plant.

Use of Wild Crucifers as Trap Crop for the Control of *Plutella xylostella* in Broccoli (*Brassica oleracea* var. *italica*)

Investigators: Humberto Carranza Bazini[1] and Stephen Weller[2]

Other Collaborating Scientists: Albaro Orellana Polanco[1] and Danilo Dardón Avila[1]

Abstract

The objective of this study was to determine if wild crucifer species attract *Plutella xylostella* moths, and to evaluate them as potential trap crops. Two completely enclosed (in anti-aphid cloth) test plots were established, one located at the "Centro Universitario de Oriente" (CUNSURORI) in the Department of Jalapa (October 1997 to February 1998), and the other at the ICTA station at

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Chimaltenango from (April to July 1997). A completely randomized design with 5 treatments and 10 replications was utilized. The wild crucifer species included *Raphanus raphanistrum* (mustard, wild raddish), *Brassica rapa* = *Brassica campestris* (mustard, white mustard, "mostacilla"), *Brassica napus* (mustard, wild beet), *Brassica nigra* ("castilla" mustard, "colocha" mustard) and *Brassica oleracea* var. *italica* (broccoli) as the control. Approximately 250 adult laboratory-reared *P. xylostella* moths were released into each of the enclosures at the time broccoli was transplanted. Counts of eggs, larvae and pupa/plant were taken twice a week from the transplant date until the beginning of harvest operations. Results indicate that *P. xylostella* prefers *B. napus* to deposit eggs and complete the larval and pupal stages, with a general mean of 30 *P. xylostella* eggs per plant, surpassing by 53% the general *P. xylostella* mean found on broccoli. *B napus* was also the species that hosted more *P. xylostella* larvae and pupa, surpassing broccoli by 60% and 51%, respectively. Compared to the rest of the wild crucifers, *B. napus* was also statistically more attractive to *Plutella xylostella*; however *B. nigra* and *B. rapa* also showed acceptable attraction values and were superior or similar to broccoli's attracting capacity. Further evaluation of *B. napus* as a potential trap crop under field conditions has begun by H. Carranza Bazini (ICTA) and is reported in this annual report. Studies will also be designed to further evaluate several spatial distribution of *B. napus* in the field in order to maximize its potential as a trap crop. *B. nigra* and *B. rapa* also have potential as trap crops and will be evaluated in the eastern areas of Guatemala where they are most prevalent.

Objective

Determine whether the evaluated species of wild crucifers have an attractive effect for *Plutella xylostella* that will permit the use of these weeds as trap crops for the target insect pest in broccoli production.

IPM Constraints

Trap crops have not been shown to be effective alternatives to current insecticide use for control of *P. xylostella*. Trap crops must be thoroughly tested and shown to not only be effective, but economically acceptable alternatives.

Research Methods

Time and place: Two tests were established inside experimental cages, one at the experimental station of the Centro Universitario de Suroriente –CUNSURORI- in Jalapa, from November 1996 to February 1997, and the other at ICTA experimental station in Chimaltenango from April to July 1997.

Experimental Design: The design used was completely random with 5 treatments and 10 replications. The experimental units were individual plants planted directly in the ground.

Treatments

Common name	Scientific name
- Mustard, wild raddish	*Raphanus raphanistrum*
- Mustard, white mustard, "mostacilla"	*Brassica rapa (B. campestris)*
- Mustard, wild beet	*Brassica napus*
- Mustard, curly mustard	*Brassica nigra*
- Broccoli	*Brassica oleracea var. itálica*

Response variables: Number of eggs, larvae and pupae of *P. xylostella* per plant.

Obtaining data: 2 weekly counts were taken beginning 10 days after freeing the pupae inside the experimental cages for a period of 30 days. Samples were taken from all the plants including weeds and broccoli.

Analysis: A variance test was done individually and combined into a factorial model in which "A, B, and C" factors were sites, lectures and treatments, respectively. The "B" and "C" factors in parcels divided in "A" factor. Data were previously square root transformed and the Tukey test for multiple comparison of means was applied to the significant variables.

Experimental management: Experimental cages were built, similar to a plastic greenhouse of 20 x 40 m dimensions and the trap crop treatments were planted 30 days before the broccoli was transplant into the cages. After the broccoli was transplanted, 200 pupae of *Plutella xylostella* were collected from the remains of nearby broccoli fields or host weeds. The collected pupae were released inside the experimental cages 30 days after transplanting (when weeds and broccoli were flowering). Infestation readings were started 10 days after freeing the pupae, during the period in which the pest completes its lifecycle and the preference of the adults for any of the different treatments can be observed. No pest control was applied in the experimental area.

Research Results and Discussion

Number of eggs per plant: The behavior of *P. xylostella* females for preference of depositing eggs on weeds and broccoli was significant. *B. napus* was the species most preferred by diamondback moths during the test, having an average of 29.6 eggs/plant which differed from the other species and was 53% higher than the general mean of eggs on the broccoli (15.7 eggs/plant). *B. nigra* was more attractive to the adults than broccoli, but less attractive than *B. napus*. The broccoli was similar for egg deposition to *B. rapa* while *R. Raphanistrum* was least attractive to adults.

Number of larvae per plant: The preference for egg deposition is related to the number of larvae of *P. xylostella* and it is at this stage that it is generally recommended to use the biological insecticides based on Bt's. The largest number of larvae was found on *B. napus,* which was higher than all other species with an average of 24.1 larvae/plant, and was 60.4 % higher than the broccoli mean of 9.4 larvae/plant. *B. nigra* and *B. rapa* were similar to broccoli, while *R. raphanistrum* had the lowest number of larvae/plant (6.7).

Number of pupae per plant: The number of pupae was similar in all the treatments for the 40 to 71 day period after broccoli transplanting. *B. napus* had an average of 12.8 pupae/plant, which was higher than the general mean on broccoli of 6.2 pupae/plant. *B. nigra* and *B. rapa* also had higher number of pupae than broccoli at 9.9 and 7.6 pupae/plant, respectively. The least preferred or attractive plant was *R. raphanistrum* with an average of 2.2 pupae/plant.

Impacts

The species *B. napus* showed the greatest potential as a trop crop for *P. xylostella* egg deposition, and eventual larval and pupal development of the diamond back moth (*P. xylostella*) in broccoli.

B. nigra and *B. rapa* also have potential as trap crops for *P. xylostella.* We recommend, and H. Carranza Bazini has begun testing, *B. napus* in spatial distribution experiments at the field level in broccoli production for its potential as a trap crop for *P. xylostella.*

Networking Activities

Bayer of Guatemala personnel, Ing. Alvaro Aguilar and Ing. Mario Maldonado supported these activities for the control of white grub (*Phyllophaga* spp.) and of other insects in broccoli. Other collaborators included: ARF, Ing. Luis Alvarez; AGRIPLAN, Ing. Federico Matheu; ALCOSA, Ing. Erick Sunfeld; INAPSA, Ing. José María Passarelli, and the domestic committee for Broccoli from the Asociación Gremial de Exportadores.

Publications and Presentations

XLVI PCCMCA (Central American Collaborative Project for the Improvement of Food Crops) Meeting presentation in Nicaragua, March-April 1998.

III Integrated Pest Management Seminar on Non Traditional Crops for Exportation. Editors, Guillermo Sánchez, Linda Asturias, Danilo Dardón, IPM-CRSP, Guatemala.

Training Output

None

Project Highlight

Brassica napus showed excellent potential as a trap crop for *Plutella xylostella* in broccoli production, and further testing concerning its spatial distribution in broccoli crops has begun.

Use of Plastic Mesh (antivirus clothing) for the Integrated Management of Whiteflies (*Bemisia tabaci*) in Tomato at El Progreso, Guatemala

Investigators: Mario Morales[1] and Richard Edwards[2]

Other Collaborating Scientists: Danilo Dardón[1] and Luis Calderón[1]

Abstract

Planting of tomatoes in many areas of Guatemala was abandoned because of crop loss due to the whitefly – gemnivirus complex. The Institute of Agricultural Science and Technology (ICTA) jointly with other supporting organizations, generated a 22-component IPM program focused to allow continued tomato production in Guatemala.

The use of plastic mesh was not included in the 22 tactic program, as it needed to be validated for effectiveness. The objectives of this research were to: (1) validate under farmer's conditions whether

[1] ICTA, Guatemala [2] Purdue University

surrounding IPM managed tomato plots with a 2-meter tall plastic screen had a significant impact on the management of the whitefly –virus complex; and (2) determine crop profitability using this new technology.

The experiment was carried out at four sites from December 1997 to June 1998. Management for plastic mesh plots included the 22 point IPM program, while the farmers comparison used the traditional method of high insecticide inputs. Results show the use of a 2 meter height plastic mesh (50 mesh pore) coupled with use of insecticides based on population sampling, had the following effects compared to the conventional system: (1) reduction of whitefly population by 50% and virus incidence by 30%; (2) yield that surpassed the farmer control by 5,500 kg/ha; (3) a reduction in the number of insecticide applications from 30 to 12; and (4) a benefit/cost relation of 2.58 for IPM plot in contrast to 1.40 for the farmer control.

The use of plastic mesh incorporated into an integrated management program can significantly reduce adult whitefly populations and virus incidence, and reduce variable production costs and increase yield and profitability.

Objectives

To determine the efficiency of including 50-mesh plastic screen for the reduction of whitefly populations and tomato leaf curling incidence.

To determine the economic implications of implementing this technology.

IPM Constraints

Whitefly damage in tomato production is destroying the industry. Field proven IPM strategies must be tested for grower acceptance and then developed for easy grower use.

Research Methods

Tomato plots were established at Aldea El Upayon and Llano de Morales in Sanarate, El Progreso during December 1997 through August 1998. Field trials were distributed as paired plots of two treatments (use of plastic screen and the farmers' technology). Crop management was according to either the IPM-managed program or the traditional farmer high insecticide management. Descriptions and dates of all activities in the two plots were recorded. Weekly samples of 50 plants with viral symptoms and of the number of adult whiteflies per plant were measured. Partial budgets of both treatments were analyzed economically, by "t" tests of Student, and by orthogonal contrasts.

Research Results and Discussion

The following results pertain to the Aldea El Upayon site from December 1997 through February 1998. (Other results will be presented in the future). Table 1 shows the economic comparison between treatments and include partial costs (variable costs) and an economic analysis. Yields were superior in the plastic screen plot + insecticides in rotation of chemical groups (IPM program), and production costs were also less than the conventional farmer program. The benefit:cost relation was 3.54 with the use of plastic screen, while the farmer's technology was 1.33, showing that for every $1.00 invested, a return $ 3.54 can be expected in the IPM program compared to only $1.33 with the traditional farmer used technology.

Table 1. Partial budget of tomato crop, comparing the use of plastic screen and the farmer's technology, to reduce damage of whitefly virus at Aldea El Upayon, Sanarate, El Progreso from December 1997 to February 1998.

DESCRIPTION	TREATMENTS	
	Integrated Pest Management	Control (Farmer)
Average yield (kg/ha)	43,534.00	32,495.00
Adjusted yield (kg/ha) 10%	39,180.60	29,245.50
Gross field benefit (Q/ha)	39,180.60	29,254.50
Plastic mesh costs and materials (Q/ha)	2,767.50	-----
Hand labor cost for management (Q/ha)	350.00	-----
Cost of insecticides (Q/ha)	4,909.42	10,936.81
Hand labor costs of applications (Q/ha)	600.00	1,600.00
Total variable costs (Q/ha)	8,626.92	12,536.81
Net benefits (Q/ha)	30,553.68	16,708.69
Benefit/cost relation	3.54	1.33

Whitefly populations were less in the parcels using plastic mesh, consequently reducing pesticide applications to 10 instead of the 24 used with the farmer technologies. Whitefly populations influence directly the percentage of virus incidence and severity of the viral complex. At 52 days after planting (dat) the farmer's treatment had a 61% virus incidence rate compared to 40% with the use of plastic screen, which caused yield differences (Table 2).

Table 2. Percentages of plants with curling, mosaic or other viral symptoms. Treatments evaluated in tomato crops at Aldea El Upayon, Sanarate, El Progreso from December 1997 through February 1998.

Samples (Days after transplant)	TREATMENTS	
	Screen + Integrated Management	Farmer
	Plants with Virus	
	%	%
20	4.41	6.79
28	6.37	10.19
36	7.84	16.60
44	17.15	27.18
52	39.70	60.67

The use of plastic mesh incorporated into an integrated management program caused a reduction of adult whitefly populations and viral incidence transmitted by whitefly,

along with a reduction of variable costs in the IPM plots compared to the technology used by the farmer which resulted in a 60% reduction in the number of insecticide applications required for whitefly management.

Impact

The establishment of plastic screens surrounding tomato plots represents another whitefly management option for farmers. When integrated with other IPM tactics, the inclusion of peripheral plastic screens will allow farmers a more sustainable and environmentally friendly tomato production system where costs and total number of insecticide applications are substantially lowered.

Networking Activities

Bayer of Guatemala, Ing. Mario Maldonado, Ing. Alvaro Aguilar, provided technical information and rational use of Imidacloprid.

Universidad del Valle de Guatemala, Dr. Guillermo Sánchez, Licda. Margarita Palmieri assisted in identification of species and biotypes of whitefly.

Universidad de San Carlos de Guatemala, Agronomy Faculty, Dr. Luis Mejía, assisted in identification of virus in tomato.

Publications and Presentations

III Integrated Pest Management Seminar abstracts of non traditional crops for exportation. Editors: Guillermo Sánchez, Linda Asturias, Danilo Dardón, 1998 IPM-CRSP, Guatemala

"La Mosca Blanca", Luis Calderón, Agricultura Magazine

Training Output

None

Project Highlight

The use of plastic mesh for pest management in tomatoes reduced adult whitefly populations and incidence of virus transmitted by whitefly, which reduced variable costs compared to the technology used by the farmer and increased yield and profit.

Integrated Pest Management of Whitefly in Tomato at El Progreso, Guatemala, 1997-1998

Investigators: Mario Morales[1], Danilo Dardón[1], and Richard Edwards[2]

Collaborating Scientist: Luis Calderón[1]

Abstract

Guatemala is among the countries that have suffered the crisis caused by whitefly, *Bemisia* spp., in tomato crops. Yield losses in some areas of the country are between 60 and 100%. ICTA and other institutions generated a technological package consisting of 22 integrated pest management (IPM) practices for a solution to this problem. The validation of these IPM practices was conducted among the tomato growers. The objectives of this research were to: (1) determine the effect of 3 or more tactics in the effective management of the whitefly – gemnivirus complex in relation to tomato yield and productivity, compared to the traditional management practices used by the tomato growers in eastern Department of El Progreso. The tactics to be validated in an integrated format were: (1) seedbeds covered in a foamy cloth (anti-aphid covering), (2) tomato seedling grown in newspaper transplant plugs, (3) use of sorghum barriers planted 45 days before tomato transplant, (4) use of plastic traps covered with automobile motor oil every 8 days as sticky agent, and (5) rotational use of insecticides (rotating chemical groups) and sampling of whitefly populations. The above tactics were compared to the traditional growers' practices which included: (1) purchased tomato seedlings, (2) no sorghum barriers, (3) no yellow traps and (4) programmed use of insecticides (without rotating

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chemical groups) and with no scouting of insect populations.

Both IPM and growers' technologies were economically compared through 600 m^2 neighboring plots. The tomato management, with the exception of the whitefly IPM components, were based on the growers' traditional practices. The experiments were conducted from December 1997 to August 1998 in two sites: San Agustin Acasaguastlan and Sanarate, both in the Department of El Progreso. The results obtained from the IPM technology in comparison to the tomato growers' were the following: (1) IPM-based production costs of US $ 1,900.00/ha in comparison to US $ 2,600.00/ha in the growers' control, (2) IPM-based profits of US $ 2,300.00/ha in comparison to US $ 570.00/ha obtained by the grower, and (3) IPM-based pesticide sprayings were reduced to 13 compared to 19 and 24 spraying done at San Agustín Acasaguastlán and Sanarate, respectively. The results in this study show that the integration of the IPM practices successfully managed whitefly populations, increased tomato yields and profits, and reduced applications of insecticides which results in decreased risk to human health and the environment, and crop production costs.

Objective

The objective of this research was to determine the effect of 3 or more tactics in the effective management of the whitefly – gemnivirus complex in relation to tomato yield and productivity, compared to the traditional management practices used by the tomato growers in eastern Department of El Progreso.

IPM Constraints

IPM strategies must be field tested before grower acceptance will be widespread. The field testing must show ease of use, economic return, and effectiveness for reducing pest levels.

Research Methods

Two tests were established: one at Finca Monte Grande, Aldea Llano de Morales in Sanarate, and the other at Aldea Magdalena in San Agustín Acasaguastlán, both of the Department of El Progreso, from December 1997 to August 1998. Plots were planted on the same date, each covering an area of 600 m^2.

Integrated management of four technologies for whitefly control included: (1) tomato seedbeds covered in a foam cloth (anti-aphid covering); (2) tomato seedlings grown in newspaper transplant plugs; (3) use of sorghum barriers within tomato fields planted 45 days before tomato transplant; (4) use of yellow plastic traps covered with automobile motor oil every 8 days as sticky agent in tomato fields; and (5) rotational use of insecticides (rotating chemical groups) and scouting of whitefly populations to determine when threshold number dictated insecticide application.

Control plot management (growers' technology) included: (1) seedlings produced in a traditional open seedbed with chemical control based on insecticides, or transplant plugs either bought or produced locally; (2) no sorghum barriers in tomato fields; (3) no yellow sticky traps; and (4) use of insecticides (without chemical rotations) and no pest monitoring.

Research Results and Discussion

Results (Table 1) obtained from IPM technology in comparison to the tomato growers' were as follows: (1) IPM-based productions costs were $1,900.00/ha compared to $2,600/ha in the control; (2) IPM-based profits were $2,300.00/ha compared to $570.00/ha in the control, and (3) IPM-based pesticide sprayings were reduced to 13 compared to 19 and 24 spraying done at San Agustín Acasaguastlán and Sanarate, respectively in the controls.

Table 1 shows economical difference based on averages between IPM and grower technology. IPM does increase variable costs because of the use of barriers + traps + samplings + use of several insecticides depending on the chemical group, however gross yield and reduction in number of pesticide applications resulted in greater income in the IPM based program.

Table 1. Partial budgets in tomato crops, comparison between integrated management suggested by ICTA and the collaborating growers', Sanarate and San Agustín Acasaguastlán, El Progreso, 1997-1998.

DESCRIPTION	TREATMENTS	
	IPM-based	Control
Gross Yield (kg/ha)	29.835.06	22,296.82
Yield adjusted to 10% (kg/ha)	26,851.55	20,067.14
Gross field benefits ($/ha)	4,195.55	3,135.49
Cost of seedlings ($/ha)	677.08	989.57
Yellow traps (nylon), setting and maintenance ($/ha)	294.61	Not used
Cost of sorghum barriers and maintenance ($/ha)	76.04	Not used
Cost of insecticides ($/ha)	767.10	1,394.83
Cost of hand labor for sprayings ($/ha)	93.75	187.50
Variable cost for treatment ($/ha)	1,908.57	2,571.90
Net benefit ($/ha)	2,286.98	563.62
Benefit/cost relation	0.19 = 119%	0.03 = 21%
Transplant (seedling) cost ($)	Cartridge 0.02	Cartridge 0.02

Growers spray more insecticide than recommended by ICTA for the management of whitefly complex – virus (Table 2). Table 2 shows the large reduction in the number of insecticide applications in the IPM program from 24 and 19 to 13 in Sanarate and San Agustín Acasaguastlán, respectively.

Table 2. Pesticide list, dates of applications and dosage applied to IPM-based tomato management, and growers' management at El Progreso, 1997-1998.

Days after Transplant	Product	Dosage of Product	Applied in Integrated Management MB	Applied by Grower	
				Sanarate	S.Agustín
1	Evisect	200g/20 liters	Yes	Yes	Yes
3	Vydate +				
	Volatón	25 + 25 cc/liters	No	Yes	No
	Vydate	25 cc/20 liters	No	No	Yes
5	Tamaron	25 cc/20 liters	No	Yes	Yes
7	Confidor	1 meas/20 liters	Yes	Yes	Yes
9	Thiodan	25 cc/20 liters	Yes	No	Yes
	Decis	25 cc/20 liters	No	Yes	No
12	Thiodan +	25 + 12.5 cc/			
	Evisect	20 liters	No	Yes	No
14	Tamaron	25 cc/20 liters	No	Yes	No
	Evisect	10 g/20 liters	No	No	Yes
16	Drawin +	25 + 25 cc/			
	Herald	20 liters	Yes	No	No
	Vydate	25 cc/20 liters	No	Yes	No
18	Decis	25 cc/20 liters	No	Yes	No
	Tamaron	25 cc/20 liters	No	No	Yes
20	Confidor	1 meas/20 liters	Yes	Yes	Yes
23	Tamaron	25 cc/20 liters	No	Yes	No
	Thiodan	Same	No	No	Yes
25	Evisect	10 g/20 liters	No	Yes	No
	Confidor	1 meas/20 liters	No	No	Yes
27	Thiodan	25 cc/20 liters	Yes	Yes	No
	Vydate	25 cc/20 liters	No	No	Yes
29	Tamaron	25 cc.20 liters	No	Yes	Yes
31	Vydate	25 cc/20 liters	No	Yes	No
	Lannate	25 cc/20 liters	No	No	Yes
35	Tambo	25 cc/20 liters	Yes	No	Yes
	Thiodan +	25 cc + 10 g/			
	Evisect	20 liters	No	Yes	No
38	Decis	25 cc/20 liters	No	Yes	No
43	Evisect	10 g/20 liters	Yes	No	No
	Tamaron	25 cc/20 liters	No	Yes	No
	Metasystox	25 cc/20 liters	No	No	Yes
50	Tambo	25 cc/20 liters	Yes	No	No
	Evisect	10 g/20 liters	No	Yes	Yes
57	Drawin +	25 + 25 cc/			
	Herald	20 liters	Yes	No	No
	Tambo	25 cc/20 liters	No	Yes	No
	Vigilante	25 cc/20 liters	No	No	Yes
62	Evisect	10 g/20 liters	No	Yes	No
	Thiodan	25 cc/20liters	No	No	Yes
65	Thiodan	25 cc/20liters	Yes	No	No
	Decis	25 cc/20 liters	No	Yes	No
72	Herald	25 cc/20 liters	Yes	No	No
	Evisect	10 g/20 liters	No	Yes	Yes
80	Evisect	10 g/20 liters	Yes	No	No
	Thiodan	25 cc/20 liters	No	Yes	No
Number of Total Applications			13	24	19

Impact

The four technologies for the integrated management (MIMBU) of whitefly complex – virus resulted in: (1) reduction in the number of insecticide applications; (2) decrease in cost of production and an increase in profitability; and (3) lower levels of whitefly populations and lowered incidence of viral symptoms in plants.

Networking Activities

Bayer of Guatemala, Ing. MarioMaldonado and Ing. Alvaro Aguilar, provided technical information and rational use of Imidacloprid.

Universidad del Valle de Guatemala, Dr. Guillermo Sánchez and Licda. Margarita Palmieri, assisted in identification of species and bio-type of whitefly.

Universidad de San Carlos de Guatemala, Agronomy Faculty, Dr. Luis Mejía, assisted in identification of virus in tomato.

Publications and Presentations

III Integrated Pest Management in Non Traditional Export Crops Seminar, September 30 – October 1, 1998, presentation. Editors: Guillermo Sánchez, Linda Asturias, Danilo Dardón, ICTA IPM-CRSP, Guatemala.

Training Output

None

Project Highlight

The results in this study show that the integration of the IPM practices successfully managed whitefly populations. Tomato yields and profits increased with the implementation of the improved technology, and applications of insecticides can be reduced therefore decreasing the risks to human health, the environment and the crops production costs.

Identification of the Causal Agent of a Foliar Disease Affecting Melons in "La Fragua" Valley in Zacapa, Guatemala

Investigators: Cynthia Ralda[1], Guillermo E. Sánchez[1], and Stephen Weller[2]

Other Collaborating Scientists: Richard Edwards[2] and Margarita Palmieri[1]

Abstract

Some areas of the Motagua River valley, in the eastern Department of Zacapa in Guatemala have been continuosly planted with melon for the last 10 years, increasing the risk of augmented pest pressure over the crop. In addition, the environmental conditions during the rainy season have favored the appearance of new diseases in the last 2 years, causing significant losses. Growers suspected a new bacterial pathogen to be the cause of the main foliar symptoms that suddenly appeared in melon fields. This situation motivated the melon growers to search for technical support in studies focusing on the identification of the causal agent(s) promoting the foliar symptoms. The IPM CRSP-Universidad del Valle (UVG) team responded by conducting a series of trips to the area and meetings with the field technicians in charge of the melon field operations, where a strategy for the identification of the causal agent was designed. The most severe outbreaks in the field were associated to angular leaf spots on cantaloupe melons and watermelons. During these field trips symptom-containing samples from 5 participating companies were collected and taken to UVG laboratories for identification purposes. Additional samples were collected and transported to UVG by field technicians working for the growing companies. The laboratory procedures included (1) symptom recording, (2) observations under light microscopy, (3) gram and flagella staining, (4) growth on selective media, (5) biochemical reactions and nutrient utilization, (6) hypersensitive response on tobacco and, (7) serology (Enzyme linked immunosorbent assay), where applicable. Out of 58 samples, 48 bacterial colonies with features typical of pathogenic bacteria were detected. Of these, 19 were identified as *Pseudomonas syringae* pv *lachrymans*, causal agent of the angular leaf spot in cucurbits. Seventeen isolates were identified as *Erwinia*, belonging to the *herbicola* or *quercina* species. Five bacterial colonies were identified as *Xanthomonas* (associated to leaf spots in melon) and 7 other colonies belonging to different *Pseudomonas* sp. (*pseudoalcaligenes, putida, cepacea*). Results show that the main cause of the bacterial outbreaks is *Pseudomonas syringae* pv *lachrymans*, although *Xanthomonas* was also associated with the symptoms. Bacterial leafspots caused by *Xanthomonas campestris* pv *cucurbita* have been detected in other cucurbits but not melons, however our results suggest that, in Guatemala, *Xanthomonas* may be a pathogen of cantaloupe

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melons. Further studies into this possibility are recommended.

Objective

To identify the pathogenic agent causing the newly discovered foliar diseases in melons.

IPM Constraints

The fertile lands of the Motagua River Valley in Zacapa have been cropped with melons continuously for the last 10 years, increasing the risks of severe pest outbreaks. In the last four years, climatic and environmental conditions have favored the appearance of bacterial foliar diseases causing important economic losses. The severity of the outbreaks motivated the local growers, exporters, and the IPM CRSP team to search for the causal agent of these diseases as a first approach to design of adequate integrated management programs.

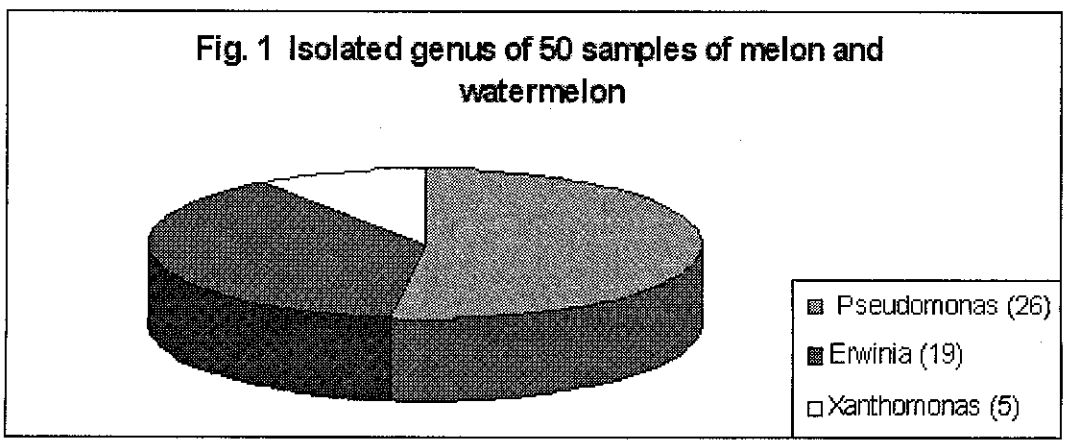
Research Methods

The study included a field phase and a laboratory component. During the field stage, trips were taken to the Motagua River Valley from October to November 1998, to collect samples from diseased plants. Samples were collected from plants representing all the growth stages of the crop. The laboratory procedures included (1) symptom recording, isolation of the bacterial pathogen, (2) observations under light microscopy (oozing), (3) gram and flagella staining, (4) growth on selective media, (5) biochemical reactions and nutrient utilization, (6) serology (Enzyme linked immunosorbent assay), where applicable and, (7) live tissue assays (potato and immature pear assays).

The identification was undertaken according to: 1) chemical and structural characteristics from the cellular wall (Gram Tincion); 2) presence or absence, number and disposition of flagellum (silver nitrate flagellum staining); 3) form, colony coloration and metabolic properties (general and selective culture media); 4) quick and specific detection (ELISA'S serologic samples and API methods).

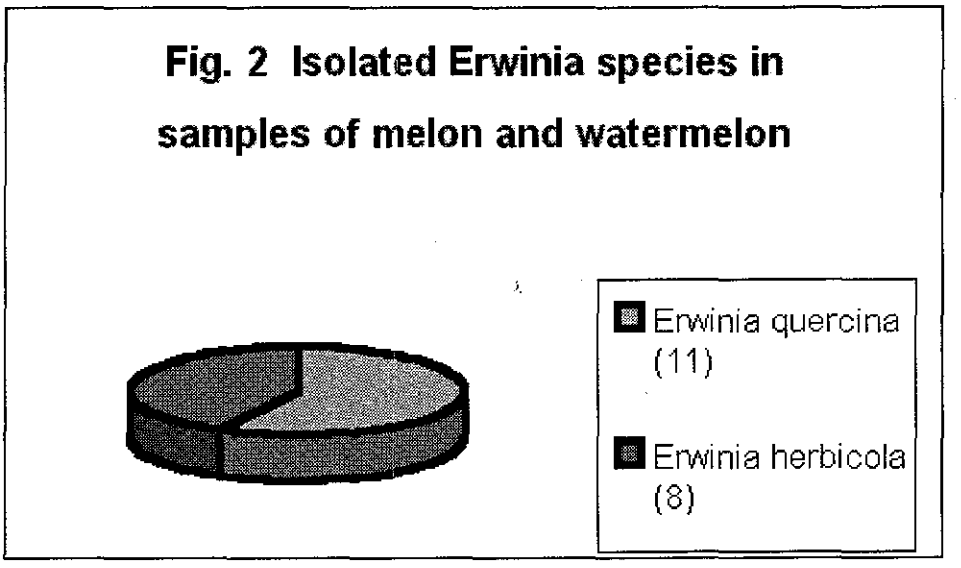
Research Results and Discussion

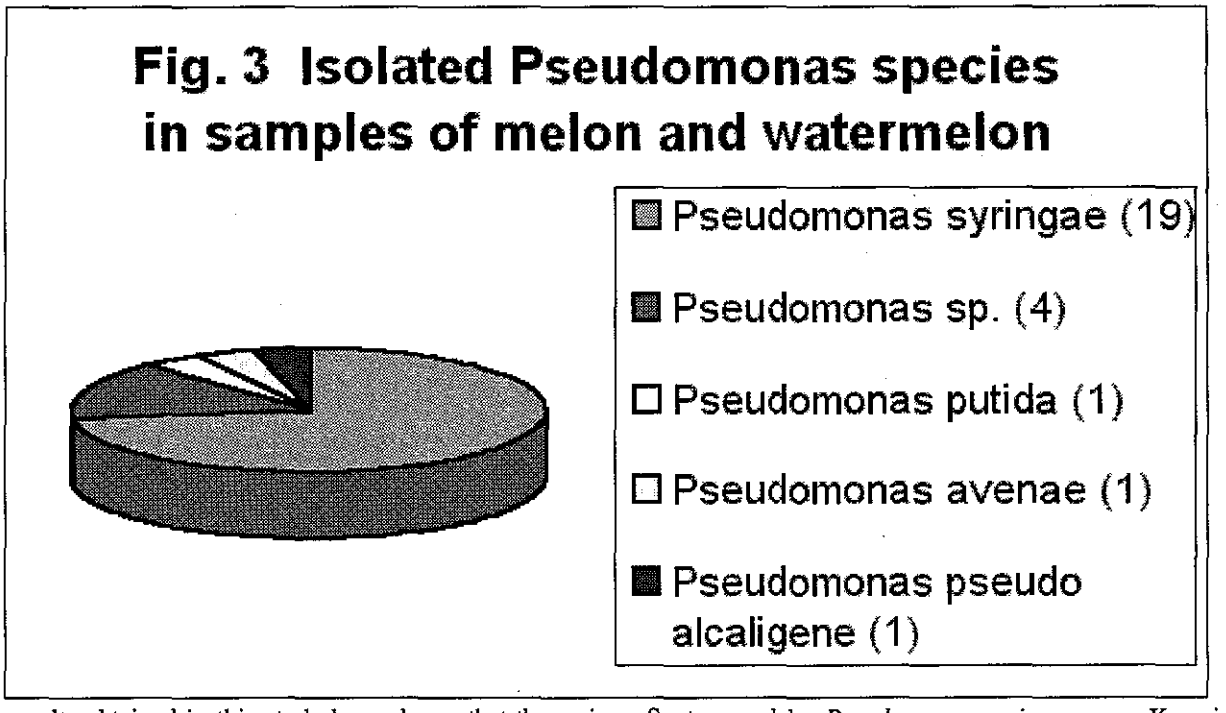
One hundred and twenty bacterial isolates were initially obtained from 58 samples collected from 5 different field locations. Of these, 50 were considered for further studies as the remaining 70 did not exhibit characteristics typical of plant pathogenic organisms. As Figure 1 shows, of the 50 colonies isolated, 26 belonged to the genus *Pseudomonas*, 19 to the genus *Erwinia*, and 5 to the genus *Xanthomonas*.



In relation to the pathogenic species identified in melon (Figures 2 and 3), the greatest number of colonies (19) were identified as *Pseudomonas syringae* p.v. *lachrimans* which is in agreement with the most commonly recorded symptoms (Angular Leaf Spot); 5 colonies were identified as *Xanthomonas*, not previously reported as a pathogen in Numbers in parentheses indicate the number of colonies isolated for each species.

melons. The remaining isolates were identified as avirulent bacteria in melons, mainly *Erwinia quercina* (11 isolates). *E. quercina* is an oak pathogen brought into the site probably through contaminated speedlings produced in the highlands. Eight colonies were identified as *Erwinia herbicola* and 1 isolate as *Pseudomonas putida*.





The results obtained in this study have shown that the main disease affecting melons during the rainy season is Angular Leaf Spot caused by *Pseudomonas syringae* sp. *lachrymans*. Interestingly, *Xanthomonas* spp bacteria were also recovered from diseased tissue, being in some samples the only organism recovered. These results suggest that a *Xanthomonas* organism capable of infecting melons may exist in Guatemala. Studies to further analyze this possibility are warranted.

Impact

The results obtained in this study have shown that the principal disease affecting melon plantations is Angular Leaf Spot caused by *Pseudomonas syringae* sp.. Knowing and understanding the causal agent for the outbreaks of the main bacterial disease in melons will allow the planning and implementation of adequate integrated pest management programs to reduce economic losses.

Networking Activities

III IPM CRSP, Integrated Pest Management on Non-Traditional Agricultural Export Crops, Sept. 30 and Oct. 1, 1998, Guatemala City, Guatemala

Publications and Presentations

Ralda, C. 1998. Identificación de enfermedades bacteriales en melón. Tesis. Universidad del Valle de Guatemala. Guatemala, 70 pp.

III IPM CRSP, Integrated Pest Management on Non-Traditional Agricultural Export Crops, Sept. 30 and Oct. 1, 1998, Guatemala City, Guatemala

Training Output

This research was conducted as the thesis requirement (in partial fulfillment of the requirements for the Licentiate degree) of Cynthia Ralda, a student majoring in Biology at Universidad del Valle de Guatemala.

Project Highlight

IPM CRSP research conducted in the Motagua River valley of Guatemala determined that the main foliar disease affecting melons in the rainy season (September-December) is angular leaf spot, caused by *Pseudomonas syringae* pv. *lachrymans*. Research also identified the presence of *Xanthomonas* spp., previously not known to infect melons.

Effect of Eight Anti-bacterial Chemicals on the In Vitro Growth of *Pseudomonas syringae* pv *lachrymans*

Investigators: Laura S. Vergara[1], Guillermo E. Sánchez[1], and Stephen Weller[2]

Collaborating Scientist: Margarita Palmieri[1]

Abstract

Angular leaf spot, caused by *Pseudomonas syringae pv lachrymans* (PSL) has become a serious disease threatening the production of Guatemalan melons exported to the USA. Melons are grown in the Motagua River valley located in eastern Guatemala, where land is subjected to intensive annual plantings of this crop and environmental conditions are favorable for disease development during the rainy season. Growers, who obtain 2 harvests (rainy and dry season cycles) in an 8-month period, rely mainly on the spraying of antibiotic and copper-based chemicals for the management of the disease, therefore increasing the risk of acquired resistance by PSL to the commonly used bactericides. Recently, chemical distribution companies have begun promoting the use of new bactericides based on different active ingredients (iodine, ammonium and citrus extract). For these reasons, 8 different bactericides were tested in vitro to determine their effect on the growth of PSL using the disc diffusion sensitivity assay (DDS). Fifty µl aliquots of each bacterial solution (10^9 cfu) were dispersed over petri dishes containing Muller-Hinton (MH) medium. The bacterial spreads were challenged with sterile disks saturated with the 8 bactericides at 5 different concentrations, 0, 0.25, 0.75, 1.25 and 2.0 times the average recommended commercial dosage. After a 15 hour incubation period 3 diameter readings were taken from the inhibition halos induced by the different chemicals. A completely randomized design with 3 replications was utilized. ANOVA and Duncan's multiple range test showed that the three antibiotics were the most effective inhibitors, followed by Timsen, Vanodine and Kilol all of them statistically different to each other. Under the conditions of the DDS assay, the copper compounds showed variable or no growth inhibition capacity of the PSL colonies. The bacterial isolate was also a significant factor in the inhibitory capacity of the bactericides as three separate statistical groups, showing varying levels of sensitivity, were detected. In conclusion, the antibiotic-based bactericides are the most effective inhibitors, followed by the inorganic compounds and finally the copper-based products. The differential response exhibited by the 5 bacterial isolates warrant further studies to determine whether resistance to the most commonly used bactericides has developed. The positive in vitro inhibitory effect shown by ammonium and iodine justify further in

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vivo tests to determine their possible inclusion in the phytosanitary programs utilized by melon growers as part of a rotational spraying program against angular leaf spot.

Objectives

To determine the in vitro sensitivity of 4 PSL isolates to 8 different commercial antibacterial compounds. The specific objectives were to determine: (1) if isolate origin has an effect on the in vitro sensitivity, (2) if the 8 antibacterial compounds have varying effects on the in vitro growth of PSL and (3) the effect of antibacterial concentration on the in vitro growth of PSL.

IPM Constraints

The fertile lands of the Motagua River Valley in Zacapa have been cropped with melons continuously in the last 10 years, increasing the risks of severe pest outbreaks. In the last four years, climatic and environmental conditions have favored the appearance of bacterial foliar diseases causing important economic losses. Growers, who obtain 2 harvests (rainy and dry season cycles) in an 8-month period, rely mainly on the spraying of antibiotic and copper-based chemicals for the management of angular leaf spot, therefore increasing the risk of acquired resistance by PSL to the commonly used bactericides. Recently, chemical distribution companies have begun promoting the use of new bactericides based on different active ingredients (iodine, ammonium and citrus extract). If these new chemicals are effective inhibitors of the pathogen, the risk of resistant PSL isolates to copper and antibiotics may be diminished as they are incorporated into current angular leaf spot management programs.

Research Methods

Eight different bactericides where tested in vitro to determine their effect on the growth of PSL using the disc diffusion sensitivity assay (DDS) (Table 1). Fifty µl aliquots of each bacterial solution (10^9 cfu) were dispersed over petri dishes containing Muller-Hinton (MH) medium. The bacterial spreads were challenged with sterile paper disks saturated with the 8 bactericides at 5 different concentrations, 0, 0.25, 0.75, 1.25 and 2.0 times the average recommended commercial dosage. After a 15 hour incubation period 3 diameter readings were taken from the inhibition halos induced by the different chemicals. A completely randomized design with 3 replications was utilized. The areas of inhibitions (mm^2) obtained after the 15-hour incubation period were subjected to ANOVA and Duncan's multiple range test.

Table 1. Commercial names, active ingredients and recommended dosage of antibacterial compounds included in the *Pseudomonas syringa* pv *lachrymans* in vitro sensitivity assays.

Bactericide	Active Ingredient	%	Recommended Dosage
Agrimicin 100	Streptomycin sulfate Oxytetracycline	15.0 1.5	400 ppm
Bacter-Stop	Streptomycin sulfate Oxytetracycline	12.6 6.7	1 kg/ 1000 l
Farmacine	Oxytetracycline chlorhydrate	6.03	200 gr/100 l
Kocide	Copper hydroxide	77	1.75 a 2.5 Kg/Ha
Phyton 27	Copper sulfate·5 H_2O	24.0	1.5 cc/l
Timsen	n-alquil dimethyl bencyl ammonium	40.0	400 ppm
Vanodine	Iodine	5	1ml/750 ml
Kilol L DF 11%	Citrus seed extract	11	2.5-5ml/l of water

Research Results and Discussion

All three of the factors tested proved to have a highly significant ($p<0.01$) effect on the bacterial inhibition halos (Table 2).

Table 2. Analysis of variance for the diameters of inhibition (mm^2) obtained in the in vitro sensitivity assays conducted on *Pseudomonas syringae* pv *lachrymans*, collected in melon fields of the Motagua River Valley in Zacapa, Guatemala. 1997-98.

Source of variation	DL	Sum of squares	Mean Squares	F calc	Prob>F
Isolate (A)	4	885576	221349	383.96	0.0000
Bactericide (B)	7	3051823	435974	756.11	0.0000
AB	28	1237318	44189	76.64	0.0000
Concentration (C)	4	2418847	604711	1048.74	0.0000
AC	16	470023	29376	50.95	0.0000
BC	28	1473135	52611	91.24	0.0000
ABC	112	605501	5406	9.38	0.0000
Error	400	230642	576.6		
Total	599	1.04E+07			

The source of origin of the tested isolate was highly significant, as well as the bactericide and its concentration. The highly significant interaction isolate x bactericide (AxB) proves that PSL isolates respond differently to the antibacterial products included in the experiment.

Duncan's multiple range test also provided important information. Regarding the 5 different PSL isolates tested, Table 3 shows that two of the isolates (51C and 35C) were categorized in the same statistical group, as they expressed the largest growth inhibition to antibacterials. In contrast, colony 51 C showed a much smaller response to antibacterials as its mean inhibition halo was only 57 mm^2, a three-fold reduction in contrast to the most sensitive bacteria.

Table 3. Duncan's multiple range test for the variable "isolate" representing bacterial colonies obtained from 5 different melon grower/shipper companies.

Isolate	mean inhibition area (mm^2)	Duncan's $p<0.05$
51C	161.88	a
35C	161.27	a
38C	121.72	b
8C	111.72	c
39C	57.62	d

The bactericides tested in this study all showed statistically significant differences in their capacity to elicit growth inhibition halos from PSL. As seen in Table 4, all of the bactericides were categorized in different statistical groups, as PSL average inhibition halos ranged from 242 mm^2 (Agrimicin) to 33 mm^2 (Phyton).

Table 4. Duncan's multiple range test for the variable "bactericide" and its effect on the inhibition halos exhibited by *Pseudomonas syringae* pv *lachrymans*.

Bactericide[1]	Mean inhibition Area (mm^2)	Duncan's $p<0.05$
Agrimicin	241.82	a
Bacter-stop	210.48	b
Farmacina	162.77	c
Vanodine	118.37	d
Timsen	100.89	e
Kilol	68.35	f
Kocide	46.88	g
Phyton	33.28	h

Please refer to Table 1 for a description of the active ingredients for each of the evaluated bactericides.

As expected the different concentrations played a highly significant ($p<0.05$) role in determining the size of the inhibition halos. Table 5 shows that at a concentration equal to 0, no inhibition was observed (33.17 mm^2 is the area of the sterile disks). In contrast, the concentration at twice the recommended dosage resulted in a average inhibition area of 210 mm^2, a 3-fold increase with respect to the 0.25 bactericide concentration.

Table 5. Duncan's multiple range test for the variable "concentration" and its effect on the inhibition halos expressed by *Pseudomonas syringae* pv *lachrymans*.

Concentration[1]	m inhibition area (mm^2)	Duncan's $p<0.05$
2	210.11	a
1.25	171.74	b
0.75	122.34	c
0.25	76.93	d
0	33.17	e

[1]Concentration is expressed in terms of the average recommended dosage. Thus the average dosage recommended commercially is equal to a concentration of 1.0 and 2.0 is equal to twice the average recommended doses.

The results obtained in this research show that under the in vitro conditions of the study, bacterial colonies show varying responses to 8 different antibacterial products. However, as different active ingredients may exhibit varying diffusion rates, further studies are underway, in which the different bacterial colonies will be placed in direct contact with the bacterial solution. Following an incubation period, bacterial isolates will be rated based on colony recovery percentage from the bacterial+bactericide solution.

Impact

The antibiotic-based bactericides are the most effective in vitro inhibitors of PSL, followed by the inorganic compounds (Iodine and ammonium) and finally the copper-based products. The differential response exhibited by the 5 bacterial isolates warrant further studies to determine whether resistance to the most commonly used bactericides has developed. The positive in vitro inhibitory effect shown by ammonium and iodine justify further in vivo tests to determine their possible inclusion in the phytosanitary programs utilized by melon growers as part of a rotational spraying program against angular leaf spot.

Networking Activities

III IPM CRSP, Integrated Pest Management on Non-Traditional Agricultural Export Crops, Sept. 30 and Oct. 1, 1998, Guatemala City, Guatemala

Constant communication and collaboration with five grower/exporter companies, all members of the melon committee of the Guild of exporters of non-traditional products (AGEXPRONT)

Publications and Presentations

Ralda, C. 1998. Identificación de enfermedades bacteriales en melón. Tesis. Universidad del Valle de Guatemala. Guatemala, 70 pp.

III IPM CRSP Seminar. Sept. 30 and Oct. 1, 1998, Guatemala City, Guatemala.

Training Output

This research was conducted as the thesis requirement (in partial fulfillment of the requirements for the Licentiate degree) of Laura Vegara, a student majoring in Biochemistry at Universidad del Valle de Guatemala.

Project Highlight

UVG/IPM CRSP laboratory research conducted with *Pseudomonas syringae* pv. *lachrymans* showed that this pathogen responds differently to 8 commercial antibacterial products. The ammonium-based antibacterial "Timsen"

exhibited good antibacterial characteristics, therefore its inclusion into the IPM programs for melons would benefit the farmers as a reduction in the number of applications of antibiotics and copper based products will decrease the probabilities for the appearance of copper or antibiotic-resistant PSL strains.

Evaluation of *Phytoseiulus persimilis* as Biocontrol for Tetranychid Mites in Raspberries

Investigators: Guillermo E. Sánchez[1] and Roger N. Williams[2]

Collaborating Scientist: Dan Cahn[3]

Abstract

In Guatemala, two-spotted mites (*Tetranychus* sp.) represent the main arthropod pest affecting raspberries. Mite infestations are difficult to control due to the lack of satisfactory control measures. Releases of the predatory mite *Phytoseiulus persimilis*, at three different rates (30,000; 60,000 and 120,000 individuals/ha) were done in a raspberry plantation located in the central highlands of Guatemala (Parramos, Chimaltenango). The effectiveness of these *P. persimilis* densities was compared to an untreated plot (no release of beneficial mites). Treatments were replicated five times in a randomized complete block design. *Tetranychus* counts were done 4 times, at intervals of 15-20 days, the first being 1 day before the release of the biocontrol agent. No significant differences were found in *Tetranychus* populations between the different treatments. The lack of success, in contrast to the results obtained in 1997, may be attributed to the lack of proper crop management given to the raspberry fields, caused by the market restrictions restraining Guatemalan raspberry exports from May to August 1998.

Objective

To evaluate the effectiveness of three different rates of the predatory mite *Phytoseiulus persimilis* in controlling populations of tetranychid mites in raspberries.

IPM Constraints

Infestations by phytophagous mites are a significant problem in many crops grown in the tropics and in Guatemala they are the main arthropod pest affecting raspberries. The presence of favorable environmental conditions for population buildup and the lack of labeled miticides in raspberries have made it difficult to satisfactorily control this pest. Control measures such as biocontrol through release of predatory mites (*P. persimilis*) may provide new ways of two-spotted mite management. The advantage of this treatment is that only the target pest is controlled, and chemical pesticide use is reduced in the food source and the environment.

Research Methods

Experiments were established in Parramos, Department of Chimaltenango in raspberriy fields of the Summit variety. Treatments consisted of 3 *P. persimilis* rates (30,000; 60,000 and 120,00 mites/ha.) and a zero control check plot. *P. persimilis* were released on March 2, 1998, approximately 6-8 weeks before maximum expected *Tetranychus* damage. No chemical insecticides or miticides were sprayed on the plots where the biocontrol agent was released.

Treatments were established in a randomized complete block design with 5 replications. Gross plot area was 2,500 m^2 with the sampling area (net plot) in each experimental unit equal to 200 m^2. Within the net plot and following a random cross (two diagonal lines) pattern, 10 leaflets were taken from the mid-portion of the raspberry plants for direct *Tetranychus* counts. The initial pre-release count however was determined from a 20-leaflet sample.

A total of 4 two-spotted mite counts were done, the first 1 day prior to the release of the biocontrol and then three more at approximately 15-20 day intervals. Raspberry yields were to be included as part of the experimental data, but local developments associated with Cyclospora outbreaks in the U.S. forced an early conclusion of the experiment.

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Research Results

Results showed no significant differences between treatments (Table 1). The pre-release data gathered on February 18th showed that each leaflet contained between 2.56 and 6.48 *Tetranychus*. By March 28th, spider mite populations increased similarly throughout the different treatments, with the exception of the 30,000 persimilis/ha treatment. As can be observed in Figure 1, *P. persimilis* populations decreased significantly by the April 14th reading, due to a general application of insecticides conducted by the field manager, who decided to apply pesticides prior to pruning the entire field.

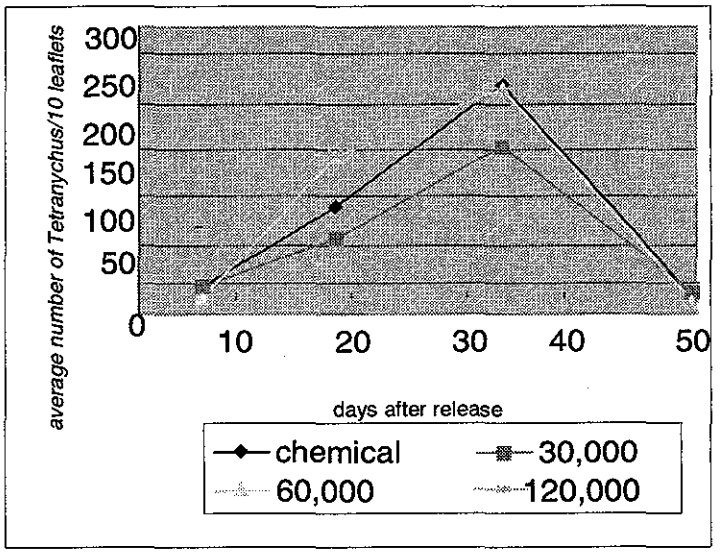
Table 1. Average *Tetranychus* counts[1] (5 replications) per date of sampling in *P.persimilis* biocontrol experiments in raspberry. Chimaltenango, 1997.

Treatment	Average number of *Tetranychus*/10 leaflets			
P. persimilis/ha	18-Feb	13-Mar	28-Mar	14-Apr
Chemical control	38.4	120.6	247	27
30,000	36.8	88.4	182.6	31.2
60,000	25.6	172.4	243.4	21.4
120,000	64.8	174.8	239.4	14

[1]Numbers represent the average of 5 replications of the total *Tetranychus* count obtained from a sample size of 10 raspberry leaflets per treatment.

Results obtained in this experiment contrast with the 1997 results in which the two largest *P. persimilis* densities showed satisfactory control of spider mites. Experiments in 1998 were conducted in the same geographic area but at different farms. In contrast to the previous year's experiment, the raspberry fields in 1998 were not tended adequately showing unequal growth among plots, inadequate soil moisture and excessive weeds and dust. The difference in care provided to the raspberry plants by its managers may have affected the outcome of this experiment.

Figure 1. Average numbers of two-spotted mites (*Tetranychus* spp.) in *P. persimilis* biocontrol field trials in raspberry. *P. persimilis* were released at 30 x 10^3, 60 x 10^3 and 120 x 10^3 individuals/ha. *Tetranychus* counts are the average of 5 replications in which 10 leaflets were sampled per treatment and total *Tetranychus* numbers determined by direct observation.



Impacts

This research suggests that effectiveness of P. persimilis as a biocontrol agent may lie, among other factors, on the general health of the raspberry fields. For adequate control to be achieved it may be necessary to provide adequate growing conditions to the plant, along with favorable conditions to the tetranychid mites, such as dust-free plant surfaces and sufficient soil moisture.

Publications and Presentations

Presented at the III IPM CRSP Seminar held in Guatemala City, 30 September - 1 October 1998.

Training Output

Two Universidad del Valle senior students majoring in Agricultural Sciences were trained in sampling techniques, data collection and tabulation.

Project Highlight

Phytoseiulus persimilis offers potential as a biocontrol agent for tetranychid mites in raspberries, however, plant health and environmental conditions can be important in the total control effectiveness obtained.

Evaluation of *Metarhizium anisopliae* and *Beauveria bassiana* as Biological Control of *Liriomyza huidobrensis* in Snow Pea

Investigators: Fernando Solís[1] and Stephen Weller[2]

Collaborating Scientists: Richard Edwards[2] and Danilo Dardón[1]

Abstract

Snow peas require the use of pesticides to control leafminer, which can cause cosmetic damage to the product and reduce its marketability. The tolerance level for leafminer damage to the snow pea pod for export is practically zero. The use of beneficial organisms as biological controls could help reduce the levels of leafminer fly populations and pod damage, and also contribute to reduction in insecticides use. The ICTA – IPM CRSP research team therefore conducted field studies during the dry season (summer) between the months of November through March, 1997. The objectives were to establish whether the entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* would reduce leafminer fly adult populations and in turn reduce the damage caused by the larval mining on leaves or the snow pea pods. Test sites were located at ICTA La Alameda, and Victoria Farm, Patzicía. The experimental design was a randomized complete block with 4 replications and 4 treatments, consisting in sprayings of: 1) *Metarhizium anisopliae*, 2) *Beauveria bassiana*, 3) standard check (agrochemicals) and 4) zero control plot (without insecticides). The evaluated parameters were (1) number of leafminer adults per plant, (2) numbers of leafminer tunnels (mines) per plant, and (3) the percentage of pods with leafminer damage. Statistically significant differences were detected between the numbers of leafminer adults in the zero control plots at both Chimaltenango and Patzicía (5.25 and 10.45 leafminer adults/plant, respectively), in contrast to the other three treatments (average of 3.4 and 4.6 leafminer adults/plant, at Chimaltenango and Patzicía, respectively). No differences were found among the percentage of damaged pods between any of the treatments, which ranged between 4% and 7%.

Objectives

(1) To determine if application of the the entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* reduce populations of the leafminer fly in snow peas.

(2) To determine if these fungi reduce the amount of damage (tunnels in snow pea pods) in the harvested product.

IPM Constraints

The excessive use of insecticides has brought about important negative side effects such as build up of insect populations previously considered minor pests, disruption of the natural balance between organisms and build up of resistance among insect pests. In order to counter these negative impacts, new insect pest management tools must be devised. Among available choices, the use of effective biological control agents has the greatest potential. If efficient entomopathogens can be found, pesticide applications may be significantly reduced during production of export crops such as snow peas.

Research Methods

Time and place: This investigation took place at two sites: La Alameda Experimental Station, at Chimaltenango (1.740 masl) and Farm La Victoria, Patzicia (2.010 masl), in the dry season (summer) in the months of November to March, 1997. The commercial firm AGRIBODEGAS distributes two biological insecticides: Metabiol composed of native isolates of *Metarhizium anisopliae* and Brocabiol with *Beauveria bassiana* as its active ingredient. Dosage use and frequency of application were as prescribed by the distributor. These biologicals were compared with the traditional management and the agrochemicals as recommended by AGEXPRONT's snow pea committee.

Experimental design: Randomized complete blocks with 4 treatments and 4 replications. The evaluated treatments were:

[1] ICTA, Guatemala [2] Purdue University

1. - *Metarhizium anisopliae* (750 g/mz)
2. - *Beauveria bassiana* (500g/mz)
3. - chemical control (agrochemical)
4. - Check plot (water applications).

Volume of water similar to the chemical.

Response variables:

1. - Number of leafminer adults per plant
2. - Number of tunnels per plant
3. - Percentage of pods showing leafminer tunnels (%)

Data was analyzed by ANOVA and means separated using Tukey's multiple comparison.

Research Results

Presence of adult leafminer flies on snow pea plants: The data indicates that the biological insecticides performed similar to the chemical insecticides for the control of leafminer adults. This is a very valuable finding for the development of an integrated pest management program for snow peas. Statistically significant differences were detected between the numbers of leafminer adults in the zero control plots at both Chimaltenango and Patzicía (5.25 and 10.45 leafminer adults/plant, respectively in contrast to the other three treatments which did not differ significantly (average of 3.4 and 4.6 leafminer adults/plant, at Chimaltenango and Patzicía, respectively).

Table 1. Average number of adult leafminer flies per plant according to the applied treatments on snow peas in two localities of Chimaltenango.

Treatments	Chimaltenango	
	ICTA	Patzicia
Metabiol (*M. anisopliae*)	3.31 a	4.65 a
Brocabiol (*B. bassiana*)	3.46 a	5.02 a
Chemical control	3.45 a	4.08 a
Check plot	5.25 b	10.45 b

Numbers with same letters do not differ significantly at 0.05 level

Damage by leafminer fly to plants: Similar to data for leafminer adults, the average number of leafminer tunnels on the snow pea plant leaves was significantly reduced by the Metabiol, Brocabiol, and chemical methods in contrast to the check plot (Table 2).

Table 2. Average number of leafminer tunnels per plant according to the applied treatments on snow peas in two sites of Chimaltenango.

Treatments	Chimaltenango	
	ICTA	Patzicia
Metabiol (*M. anisopliae*)	6.5 a	8.0 a
Brocabiol (*B. bassiana*)	6.6 a	8.3 a
Chemical control	6.3 a	8.5 a
Check plot	8.6 b	10.6 b

Numbers with same letters do not differ significantly at 0.05 level

Leafminer damage on snow pea pods: No statistical differences were found among the percentage of damaged pods between any of the treatments with a range of damage between 4% and 7%. These numbers were lower than for leaf tissue which might indicate that pods are not the preferred tissue for egg oviposition. The number although low, is still not acceptable for export quality snow peas, therefore, additional research with these biologicals is warranted to improve control of larvae on the pods.

Table 3. Average percentage of damage on pods done by leafminer flies according to the applied treatments on snow peas in two sites of Chimaltenango.

Treatments	Chimaltenango	
	ICTA	Patzicia
Metabiol (*M. anisopliae*)	3.2 a	6.2 a
Brocabiol (*B. bassiana*)	3.0 a	6.1 a
Chemical control	3.2 a	6.6 a
Check plot	3.8 a	6.9 a

Numbers with same letters do not differ significantly at 0.05 level

Impact

Data from this study demonstrated that fungal biocontrol agents have an effect similar to chemical insecticides in the management of leafminer flies in snow peas. This is an important finding as a reduction in the amount of pesticides applied to food crops has a beneficial effect on the environment and will help producers to reduce their costs of production. In addition final consumers will benefit as a safer food supply is made available.

Networking Activities

This research was conducted in cooperation with the snow pea committee at the Guild of exporters of non traditional products (AGEXPRONT).

Publications and Presentations

XLVI PCCMCA (Central American Cooperative Project for the Improvement of Food Crops) Meeting in Nicaragua, March – April, 1998.

III Seminar on Integrated Pest Management in Non traditional Export Crops. Editors: Guillermo Sánchez, Linda Asturias, Danilo Dardón, IPM – CRSP 1998, Guatemala.

Project Highlight

Experiments conducted in snow peas in the Guatemalan highlands showed that application of commercially available formulations of the biological insecticides *Metarhizium anisopliae* and *Beauveria bassiana* controlled leafminer populations as effectively as chemical insecticides. These findings will provide farmers with non-chemical options for the management of insect pests that will help reduce the negative impacts of chemical overuse and provide a safer food supply to consumers.

Development of IPM Strategies for the Control of the Pea Leafminer *L. huidobrensis* (Blanchard) on Snow Peas

Investigators: P. Phillip Lamport[1] and Stephen C. Weller[1]

Collaborating Scientists: C. Richard Edwards[1], Guillermo E. Sánchez[2], Glenn H. Sullivan[1], and Fernando Solis[3]

Abstract

Snow peas have recently become a very important NTAE crop in Guatemala. This crop has allowed many small farmers to become more involved in export agriculture. In the past few years the pea leafminer *Liriomyza huidobrensis* has become a very important pest of snow peas grown in the Guatemalan highlands. A decrease of $4.2 million of export snow peas in 1996 can be mainly attributed to leafminer damage. The leafminer causes both a reduction in yield and most importantly, cosmetic damage to the snow pea pods. This damage reduces the market value of the crop. The few insecticides that have been proven effective for leafminer control are not labeled for use in snow peas. A lack of an effective leafminer control method as well as the upcoming changes in US import phytosanitary standards make it essential that new control methodologies be found. My research, which is funded by the IPM CRSP, aims at developing safe and profitable IPM based production systems that minimize leafminer infestations. The first experiment determined if there was any difference in susceptibility to leafminer infestations among the available snow pea cultivars. Our results indicate that there is no difference among the level of damage done to each cultivar. The second experiment studied the effect of organic and plastic mulches on the leafminer life cycle. Results indicate that both oak litter mulch and plastic mulch had an effect on the development of leafminers.

The snow pea variety studies were conducted at Purdue University during the spring of 1998.The mulch study was conducted at the ICTA experimental station in La Alameda, Chimaltenango, Guatemala during the summer of 1998. We are currently conducting laboratory experiments to investigate the possibility of using fava beans as a trap crop and experiments using the organic insecticide Neem.

Objectives

1. Determine if snow pea leafminer shows an oviposition preference between the available snow pea cultivars.

2. Determine if an organic or plastic soil surface mulch has an effect in interrupting the life cycle of the pea leafminer.

IPM Constraints

Leafminer damage can result in a reduction in yield as well as cosmetic damage to the snow pea pods. The economic damage that this insect inflicts is a major concern for Guatemalan snow pea growers. Currently, there are no effective management techniques to control this pest. The management techniques studied in this report aim at developing safe and profitable IPM based production systems that minimize leafminer infestations.

Research Methods

Snow pea cultivar experiment: The snow pea cultivars used in the experiment were 1) Oregon Sugar Pod II; 2) Mammoth Melting Sugar; 3) Snowflake; 4) SP2; 5) Oregon Giant; and 6) A glossy mutant field pea (not available commercially). Plants were grown in 15 cm pots inside a growth chamber in an APHIS approved containment facility. When the plants were 4 weeks old, one plant of each variety was placed inside a plexiglass cage. Thirty five leafminer pupae were placed inside each cage. Adult leafminers emerged and were left inside the cage to feed and reproduce until they died (adults live up to ten days). Once the adults were dead, the plants were cut and placed in collecting cups to allow larvae to emerge from each plant during a seven day period. Emerging larvae were counted and data were analyzed by ANOVA with mean separation by Tukey's mean separation test. The experimental design was a randomized complete block design with five replications.

Effect of mulch on leafminer life cycle: The leafminer life cycle requires the use of soil in order for the completion of the pupal stage. Leafminer larvae burrow into the soil in order to pupate. This experiment studied the effect that

[1] Purdue University [2] Universidad del Valle de Guatemala [3] ICTA

ground mulches have on the completion of the leafminer life cycle.

Snow pea seeds were sown directly into soil in two rows of six plants each for each experimental unit. The soil was treated with captan as well as 15-15-15 fertilizer. For the plastic mulch treatment, seeds were sown into holes made in the plastic. Once the seeds germinated, the proper soil mulch was applied to each experimental unit. The snow peas were then covered with cages made of a wood skeleton and mesh screen to prevent infestation of the plants. Copper hydroxide was applied once every two weeks from outside the cage during the growth of the plant for treatment against diseases. Once the plants were 18 inches tall, 42 days after planting, ten leafminer adults of each sex were released inside the cage. These adults were allowed to mate and reproduce inside the cages until they died. The cages remained in place for one month. After one month the plant material was cut, weighed and placed in collecting containers. The number of second generation emerging larvae from each set of plants was counted. Data were analyzed by completely randomized one-way analysis of variance and means were separated using Tukey's mean separation test.

Results

Snow pea cultivar experiment: The results of this experiment indicate that there is no difference in the amount of oviposition between the available varieties. Field experiments conducted by IPM CRSP testing varieties not tested in this experiment indicated that some varieties might be less susceptible to leafminer infestations. We will conduct further laboratory experiments using these snow pea varieties, to confirm initial field results.

Variety	larva/g of fw
(1) OSP II	2.16a
(2) MMS	1.35a
(3) SF	3.80a
(4) OG	2.03a
(5) SP2	2.94a
(6) glossy	2.33a

Effect of mulch on leafminer life cycle: Our results indicate that the plastic mulch and oak mulch treatments were more effective in reducing the amount of second generation larvae that emerged from the snow peas. Treatments were compared on the basis of number of emerging larvae per mg. of fresh weight per female released. The analysis of the data using ANOVA and Tukey's mean separation test (5%) indicated that there is no significant difference between the treatments, although there were treatment effect trends as indicated. We will conduct further experiments to study the effect of these mulches on leafminer larvae in a laboratory setting to observe if there is a true influence on leafminer life cycle by the plastic and oak mulch.

Treatment	avg. # of mines	Avg. lar./ fw (mg) / female[1]
Plastic	36.3a	0.83a
Wheat	45.0a	3.17a
Oak	46.8a	0.59a
Bare ground	40.5a	2.25a

[1]Data was analyzed as number of larvae per fresh weight of plant tissue per adult leafminer released. Some adult females died on the way to the field and thus this parameter was used to adjust to differences in number of females in each cage.

Impacts

This study aims at finding profitable and effective IPM methods that minimize leafminer infestations. The selection of a less susceptible host variety is an important step towards reducing leafminer damage. The use of mulches to interrupt the leafminer life cycle, if effective, could be an inexpensive means of control. Both of these pest management techniques have minimal effect on the environment and are readily available to growers. Our future work will concentrate on more extensive studies with cover mulches, trap crops and biological insecticides.

Networking Activities

This project is a collaboration between researchers at Purdue University, ICTA and Universidad del Valle.

III IPM CRSP Seminar, Sept. 30 and Oct. 1, 1998, Guatemala City, Guatemala.

Publications and Presentations

III IPM CRSP Seminar, Sept. 30 and Oct. 1, 1998, Guatemala City, Guatemala

Training Output

Phillip Lamport, M.S. graduate studies, Purdue University

Project Highlight

Cultivar selection and ground applied mulches are readily available IPM techniques which could reduce the amount of damage done by leafminers to the snow pea industry.

Integrated Management of Snow peas (*Pisum sativum*) in the Guatemalan Highlands

Investigators: Guillermo E. Sánchez[1], Stephen Weller[2], and Ing. Jorge Luis Sandoval[1]

Collaborating Scientists: Richard Edwards[2] and Glenn Sullivan[2]

Abstract

The livelihood of more than 18,500 farmers in Guatemala's central highlands depends on production of export pea crops. From August 1997 to May 1998 an integrated insect pest management strategy was evaluated at several locations and tested against the traditional management practices utilized by farmers (control plots). The evaluations were conducted in 13 commercial-sized field plots (1,100 m^2). IPM tactics included weekly leafminer samplings, threshold-based applications of insecticides, usage of the mobile sticky trap "torito", and row hilling. Improved agronomic practices include among others, adequate land selection, soil test based-fertilization programs, and certified seed planting. The control plots were managed under the traditional conditions of the growers, consisting mostly of programmed insecticide sprayings and fertilization. The insect pest levels remained similar in both the IPM-based and farmers' plots. However, large differences existed on the types and quantities of pesticides applied to the plots. The ICM plots were only treated with EPA-labeled chemicals while some growers sprayed unlabeled pesticides. In contrast to the farmers' management criteria, the average numbers of insecticide applications were reduced by 50% in the ICM plots. In addition export quality yields ranged between 3,500 – 11,950 kg/ha, exceeding the control plots by 10-50% and the average national snow pea yields by up to 100%. The export peas ICM program has proven to be a reliable and effective approach to obtain high-quality yields and increased profits, under an environmentally friendly and sustainable crop management strategy.

Objective

The objective of this study was to evaluate under typical field conditions the applicability of a snow pea holistic management program allowing the production of export-quality snow peas under current international market regulations.

IPM constraints

In the recent past, snow pea has been affected by a series of negative factors, the latest being excessive pod infestations by leafminers (*Liriomyza huidobrensis*) which have cost exporters hundreds of thousands of dollars in quality loss, extended cold storage and fumigation expenses. Other serious problems include the spraying of pesticides not labeled for snow peas such as metamidophos (organophosphate insecticide) and chlorothalonil (chlorinated fungicide).

Research Methods

Location of Integrated Crop Management (ICM) plots: Twelve plots were located at three different "municipios" (equivalent to county) in the Department of Chimaltenango, the largest snow pea producing Department in Guatemala. One plot was established in Santiago Sacatepequez part of the Sacatepequez Department. At each of the sites, 1,100 m^2 ICM test plots were established, sown with snow peas (cultivar Oregon sugar pod II). In addition, control plots of the same dimensions were also planted for both crops. The control plots were entirely managed by the producer and were used to compare the results obtained between the ICM and the growers' technology.

An agronomist was assigned as field researcher to each of the sites and was in charge of implementing all production aspects, scouting and data collection in the ICM plots. Field management criteria included site selection, land preparation, planting, fertilization, trellising, pest management, harvest, post-harvest and data collection guidelines.

Pest Scouting and Management: Pest scouting, including insects, pathogens and weeds was conducted twice a week in both the ICM and control plots. Establishment of damage thresholds was based on previous research and the team members expertise when consistent data was not available. Pesticide applications were based on these predetermined economic damage thresholds. Main insects pests to be monitored were thrips (*Frankliniella* spp.) and leafminers (*Liriomyza huidobrensis*). Main diseases included

[1] Universidad del Valle de Guatemala [2] Purdue University

Ascochyta leaf and pod blight (*Ascochyta pisi*), Fusarium wilt (*Fusarium oxysporum* f.sp. *pisi*) and powdery mildew (*Oidium* spp). Pest management was based on scouting, cultural practices, chemical spraying and etological control (yellow sticky traps). All chemical applications included only pesticides with EPA label of approval for edible pods. In the case of fungicides, these were limited to ferbam, sulphur, copper oxychloride and ziram, applied every 4-15 days depending on whether environmental conditions were favorable for disease development.

Research Results and Discussion

As in previous results, insect pest and disease incidences were similar in both the ICM and farmer-managed plots (results not shown). The main harmful organisms were leafminer flies (*Liriomyza huidobrensis*), thrips (*Frankliniella* spp.) and Ascochyta leaf and pod blight (*Ascochyta pisi*). Yields obtained during the test trials showed that snow pea production in the ICM plots were either larger or similar to the yields obtained by the farmer (Table 1). The only exception was found in Tres Cruces were the farmer's yield was 1.52 times the yield obtained in the ICM plot. In general however the average yield (7178 kg/ha) obtained in the ICM fields is 1.2 times the national average (6,000 kg/ha), while the test plot yields were very similar to this number (6,187 kg/ha).

Table 1. Snow pea yields obtained in 13 integrated crop management (ICM) and 8 farmer control plots.

Locality[1]	Planting Date	Yields (kg/ha)	
		ICM Plot	Test Plot[2]
Xenimajuyu 1a	August, 1997	3540	1812
Xenimajuyu 2	August, 1997	8077	
Xenimajuyu 3	August, 1997	9529	
Xenimajuyu 4	August, 1997	7680	
Xenimajuyu 5	August, 1997	6866	
Chuchuca	August, 1997	11958	9362
El Sitio 1	August, 1997	9254	9091
El Sitio 2	August, 1997	7075	5080
Balanya[3]	August, 1997	6148	
Tres Cruces	August, 1997	3652	5564
Xeabaj	August, 1997	5059	4725
Xeabaj 2	January, 1998	4749	3624
Santiago Sacatepequez	February, 1998	7350	6953

[1] With the exception of Santiago Sacatepequez, all localities are in the Department of Chimaltenango.
[2] Localities not showing test plot yields either did not include one or fields were lost due to severe pest damage.
[3] The test plot at Balanya did not reach the harvesting stage as it was severely damaged by leafminer.

Figure 1 shows the number of insecticide sprays on the ICM and test plots. In the ICM plots the number of sprayings varied between 2 and 7 in contrast to the farmers whose numbers ranged between 7 and 17 sprays. These results indicate that it is possible to reduce, depending on pest incidence, the number of insecticide applications by up to 80%. In Balanya, even though the numbers show an equal amount of pesticide applications, the farmer did not harvest the plot as it was severely affected by leafminers. In contrast the ICM plot was harvested successfully, achieving a total yield slightly above the national average (Table 1). The results expressed in Figure 1 do not show the number of insecticide sprays at 4 sites as these were localities where results for the farmer plot were not obtained. The total number of sprays in the ICM plots at these localities ranged between 4 and 6 applications.

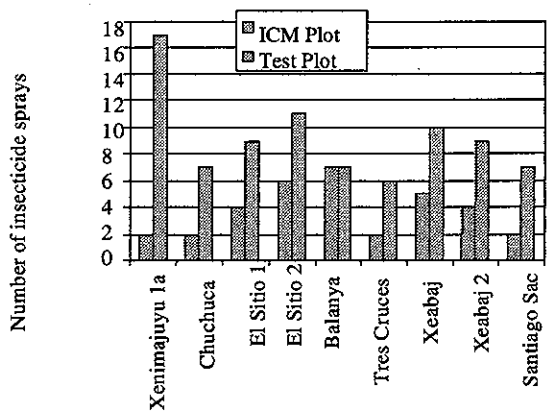


Figure 1. Number of insecticide sprays applied in the integrated crop management (ICM) and farmer snow pea plots established in 9 different sites.

As in the previous trials conducted in 1996, the results obtained in these commercial-sized fields show that production of export-quality snow peas, under current international market regulations, is achievable in the Guatemalan highlands.

Impact

Through this study, Guatemalan farmers and field technicians working for export companies observed that production of export-quality snow peas is possible under current market regulations. This is a substantial achievement as it demonstrates that numbers of insecticide sprayings can be reduced in the production of snow peas for export. Consumers in the US and other markets will benefit from the distribution of this technology among growers and technicians as a safer food supply with reduced pesticide concentrations will be made available.

Networking Activities

1998 Annual Technical Committee Meeting, May 1998, VPI&SU, Blacksburg, Virginia.

III IPM CRSP Seminar, Sept. 30 and Oct. 1, 1998, Guatemala City, Guatemala.

Publications and Presentations

1998 Annual Technical Committee Meeting, May 1998, Virginia Tech, Blacksburg, Virginia.

III IPM CRSP Seminar, Sept. 30 and Oct. 1, 1998, Guatemala City, Guatemala.

Project Highlight

The "integrated crop management" (ICM) system developed by the IPM CRSP in Guatemala increased export-quality snow peas yields by 20%, while reducing the number of insecticide sprayings by 50%.

Comparison of Snow Pea (*Pisum sativum*) Cultivars in Relation to Leafminer (*Liriomyza huidobrensis*) Infestation and Yield

Investigators: Phillip Lamport[1], Jorge Luis Sandoval[2], Guillermo E. Sánchez[2], and Stephen Weller[1]

Collaborating Scientist: Richard Edwards[1]

Abstract

Infestations by leafminer 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 (OSP) has exhibited high susceptibility to the attack of leafminers. With the objective of comparing leafminer infestations and yields of several snow pea cultivars, field trials were established in Xenimajuyú and Zaragoza, (Department of Chimaltenango), during the dry season of 1998 . Treatments consisted of cultivars OSP (as control), Snowflake, Sugar Lace, SP6 and SP18. Treatments were replicated four times following a randomized complete block design. The factors evaluated in this study were snow pea export-quality yield and leafminer larval populations at 35, 60 and 85 days after planting. Leafminer populations were monitored twice a week and insecticide sprayings based on a 10 adult leafminers per meter threshold.

Statistical analysis included ANOVA and Least Significant Difference (LSD) test for planned mean comparisons. The 5 cultivars under study exhibited significant differences ($p<0.01$) in the levels of leafminer larval infestations. The most susceptible variety to leafminer larvae infestation was SP6 (257 total larval count) in Xenimajuyu and OSP (230 larvae) in Zaragoza. The most consistent cultivar was SP18 which exhibited the lowest levels of infestation at both sites, significantly different ($p<0.05$) from the control. Regarding the yields obtained from the different cultivars, it was evident at Xenimajuyú that the most productive cultivar was Snowflake with 2142 kg/ha more production than the control variety, OSP (7674 kg/ha). Other than Sugar Lace, with statistically significant less production (5753 kg/ha) than the control, the remaining cultivars (SP 16 and SP 18) showed similar yields to that of OSP.

At Zaragoza the best yielding cultivar was Snowflake, at 9470 kg/ha, compared to 8060 kg/ha for the control. The other cultivars under study yielded significantly less than Oregon Sugar Pod II.

Objective

To compare the yields and levels of leafminer infestation in 5 snow pea cultivars.

IPM Constraints

Infestations by leafminer 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 leafminers. The introduction of tolerant or resistant cultivars would be a great step towards a holistic and fully integrated leafminer management program in snow peas in Guatemala.

[1] Purdue University [2] Universidad del Valle/IPM CRSP, Guatemala

Research Methods

Field trials were established in Xenimajuyú and Zaragoza, two localities of the Department of Chimaltenango, during the dry season of 1998 (February to May). Treatments consisted of 5 cultivars, including Oregon Sugar Pod II (as control), Snowflake, Sugar Lace, SP6 and SP18. The last two are genetic lines imported from Europe by a local seed distributor. Individual experimental plots were 22 m^2 and contained 4 snow pea rows each 5 m long. Treatments were replicated four times following a randomized complete block design.

Factors evaluated in this study were snow pea export-quality yield and leafminer larval populations at 35, 60 and 85 days after planting. Two-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. Leafminer populations were monitored twice a week and insecticide sprayings based on a 10 adult leafminers per meter threshold. Statistical analysis included ANOVA and Least Significant Difference (LSD) test for planned mean comparisons. Insect data was transformed logarithmically before applying the statistical analysis.

Research Results

The 5 cultivars under study exhibited significant differences ($p<0.01$) in the levels of leafminer larval infestations. As Tables 1 and 2 show, the most susceptible variety to leafminer larvae infestation was SP6 (257 total larval count) in Xenimajuyu and Oregon Sugar Pod II (230 larvae) in Zaragoza. The most consistent cultivar was SP18 which had the lowest levels of infestation at both sites, significantly different ($p<0.05$) from the control (Oregon Sugar Pod II).

Table 1. Total *L. huidobrensis* larval counts[1] in snow pea cultivar experiment at Xenimajuyú, Chimaltenango. Guatemala, 1998.

Cultivar	Block				average
	I	II	III	IV	
Oregon	183	202	190	209	196
Snow flake	168	184	209	205	192
SP6	197	190	459	180	257
SP18	124	108	117	110	115*
Sugar Lace	143	145	161	174	156

Numbers followed by star indicate significant differences (LSD, α=0.05) between that specific treatment and Oregon Sugar Pod II (control treatment). [1]Numbers refer to the total count of leafminer larvae obtained following three sampling dates.

Table 2. Total *L. huidobrensis* larval counts[1] in snow pea cultivar experiment at Zaragoza, Chimaltenango. Guatemala, 1998.

Cultivar	Block				average
	I	II	III	IV	
Oregon	221	228	236	236	230
Snow flake	192	191	218	223	206
SP6	200	211	229	225	216
SP18	113	110	120	121	116*
Sugar Lace	135	148	163	198	161*

Numbers followed by star indicate significant differences (LSD, α=0.05) between that specific treatment and Oregon Sugar Pod II (control treatment). [1]Numbers refer to the total count of leafminer larvae obtained following three sampling dates.

Regarding the yields obtained from the different cultivars, it was evident at Xenimajuyú that the most productive cultivar was Snowflake with 2142 kg/ha greater production than the control variety, Oregon Sugar Pod II. Other than Sugar Lace, with statistically significant less production (5753 kg/ha), the remaining cultivars (SP 16 and SP 18) showed similar yields to that of the control plants (Table 3).

Table 3. Yields (kg/ha) of 5 snow pea cultivars at the field experiment located in Xenimajuyú, Chimaltenango. Guatemala, 1998.

Cultivar	Block				Average
	I	II	III	IV	
Oregon	8,273	6325.4	7968.6	8127.9	7674
Snow flake	10743.8	9297.6	8993.2	10228.4	9816*
SP6	8126.3	8248.6	8004.1	6993.7	7843
SP18	7003.9	6818.18	7376.3	6948.4	7036
Sugar Lace	6121.7	5963.8	5141.1	5785.12	5753*

Numbers followed by star indicate significant differences (LSD=966 kg/ha, α=0.05) between that specific treatment and Oregon Sugar Pod II (control treatment).

At Zaragoza the highest yielding cultivar was Snowflake, with 9470 kg/ha compared to 8060 kg/ha for the control. The remaining cultivars had yields significantly lower than Oregon Sugar Pod II (Table 4).

Table 4. Yields (kg/ha) of 5 snow pea cultivars at the field experiment located in Zaragoza, Chimaltenango. Guatemala, 1998.

Cultivar	Block				Average
	I	II	III	IV	
Snow flake	9690	9377	9686	9129	9470*
Oregon	8692	8719	7999	6832	8060
SP6	7675	8349	6959	8128	7778*
SP18	7506	7121	6013	6578	6804*
Sugar Lace	5177	5003	4188	6130	5124*

Numbers followed by star indicate significant differences (LSD=1019 kg/ha, α=0.05) between that specific treatment and Oregon Sugar Pod II (control treatment).

Results from this study show that Snowflake is a more productive cultivar than Oregon Sugar Pod II, although it

exhibits a similar degree of susceptibility to leafminer infestations. The new genetic material SP18 yielded similarly to the control cultivar in one of the two localities, however, it had significantly less leafminer infestation than the control, and had the lowest degree of infestation of all cultivars evaluated.

Impacts

This research suggests that SP18, a newly introduced cultivar, may be an effective option for snow pea production in areas heavily infested with *L. huidobrensis* or, during the dry season plantings when leafminer population build-up are common in the Guatemalan Highlands. Snowflake, a cultivar that was introduced into Guatemala a few years ago, is worthy of further studies, as it outperformed all the other cultivars. During the rainy season Snowflake may be an attractive alternative to Oregon Sugar Pod II. Having cultivar options other than Oregon Sugar Pod II (in terms of productivity and attractiveness to leafminer infestations) should prove valuable to farmers and the snow pea industry. A more diverse genetic background for snow peas in the field should decrease the risks for future pest outbreaks.

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.

Publications and presentations

None

Training Output

Phillip Lamport, M.S. Purdue University helped establish these studies.

Project Highlight

Snow pea cultivar trials in Chimaltenango showed that the Snowflake is a more productive variety, compared to Oregon Sugar Pod II the preferred cultivar by growers. A newly introduced cultivar, SP18, exhibited significantly smaller levels of leafminer (*L. huidobrensis)* infestations compared to the other 5 cultivars studied.

Evaluation of Integrated Management Tactics on Leafminer Population and Yield in Snow Pea

Investigators: Ing. Jorge Luis Sandoval[1], Phillip Lamport[2], Guillermo E. Sánchez[1], and Stephen Weller[2]

Collaborating Scientist: Richard Edwards[2]

Abstract

The objective of the research was to compare the individual and combined effect of the mobile sticky trap "torito", wheat straw mulch, soil-based insecticide applications and foliar insecticide sprays on leafminer populations and yield of field grown snow pea. The experiment was established in April 1998 at Xenimajuyú, Tecpán, Department of Chimaltenango. Treatments consisted of the following insect pest management tactics either individually or in combination: (1) mobile sticky trap (MST), (2) wheat mulch placed at planting, (3) dibrom applications to the soil (insec(s)) and, (4) foliar sprayings of insecticide chemicals (insec (f)) labeled for use in snow peas. These treatments were compared against a check plot, not subjected to any insect management strategy. Plots were established in a randomized complete block design with a total of 11 treatments with 4 replications. The factors evaluated in this study were snow pea export-quality yield, leafminer larval populations at 30, 60 and 85 days after planting and adult fly population on the snow pea plants, determined through readings taken

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twice a week. There were significant differences between treatments for the number of recovered larvae, ranging from 174 to 827 total larvae per treatment. The numbers of adult leafminer flies found on the surface of the plants were also significantly different. Plants in check plots exhibited total adult counts of 1052 flies while the MST treated plants had the lowest number (354 total flies). Yields were statistically similar ranging from 10.10 MT/ha (Mulch+insec(s)) to 7.72 MT/ha (check plot). Results from this study show that the combination of different tactics, including the mobile sticky trap and mulch can reduce the need for chemical insecticides for the management of leafminer is snow peas. Incorporation of such novel IPM tactics into current snow pea production practices will facilitate the implementation of quality control programs oriented to enhance the safety of the food supply originating from Central American countries.

Objective

To compare the individual and combined effect of the mobile sticky trap "torito", wheat straw mulch, soil-based insecticide applications and foliar insecticide sprays on leafminer populations and yield of field grown snow pea.

IPM Constraints

Insecticide sprayings are the preferred arthropod pest control tactic utilized by Guatemalan snow pea growers. The excessive use of chemical pesticides has enhanced the importance of pests previously considered as minor problems, such as leafminer flies (*L. huidobrensis*), and has disrupted the natural balance among the arthropod community in the snow pea agroecosystem, which has hastened the build-up of insecticide resistance among both target and non-target insects. Therefore, the introduction of new and effective non-chemical approaches for the management of insect pests in snow peas is of utmost importance for maintaining the sustainability and competitiveness of this Guatemalan NTAE crop in the international market.

Research Methods

The experiment was established in April 1998 at Xenimajuyú, Tecpán, Department of Chimaltenango, 60 miles west of Guatemala City. Treatments consisted of the following insect pest management tactics either individually or in combination: (1) mobile sticky trap (MST), designed from the fixed yellow trap in which a sticky, yellow plastic tunnel is brushed over the snow pea plants, (2) wheat soil surface mulch placed at planting, (3) dibrom applications to the soil (insec(s)) and, (4) foliar sprayings of insecticide chemicals (insec (f)) labeled for use in snow peas. These treatments were compared against a check plot, not subjected to any insect management strategy.

Plots were managed according to the Integrated Crop Management guidelines devised by the IPM CRSP team. The insect pest management, targeted mainly against leafminers was conducted according to the treatments included in the field trial. Both the MST and insec(f) treatments were applied based on a 10 adult flies/row-meter threshold. Insect scouting was conducted three times a week. In treatments combining MST and insec(f), the application of these tactics was conducted on a rotational basis. Insec(s) consisted of two dibrom soil sprayings carried out at 40 and 65 days after planting. Dry wheat straw was utilized as the mulch treatment placed on the soil at the time of planting and covering the entire space between rows. Plots were established in a randomized complete block design with a total of 11 treatments with 4 replications. 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 leafminer larval populations at 30, 60 and 85 days after planting. Two-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. Larvae where emerging from the tissue were counted daily for a period of 7 days. Adult counts were made twice weekly by randomly selecting a 1 m long section in either of the two middle rows and counting the number of adult leafminers present within the section.

Research Results

The numbers of larvae emerging from the samples collected in the various treatments demonstrated that the different management tactics impacted leafminer populations significantly ($p<0.01$). The treatment having the greatest number of larvae was the check plot which had no insect pest management tactic (Table 1). In contrast, the treatment with the lowest numbers was the combination of MST+insec(s)+insec(f). An interesting result was that the MST alone treatment was not significantly different to the MST+insec(s)+insec(f) suggesting insecticide use could be reduced.

Table 1. Treatment description and total larval counts in the leafminer integrated management trials conducted in Zaragoza, Chimaltenango, 1998.

Treatment		Total larval counts[1]				
Description	Number	Block I	Block II	Block III	Block IV	average
soil insecticide (insec(s))	1	291	281	307	315	298.50
foliar insecticide (insec(f))	2	261	256	254	248	254.75
Mulch (straw)	3	373	458	454	485	442.50
Mobile sticky trap (MST)	4	198	207	211	194	202.50
MST+insec(s)	5	190	214	197	200	200.25
Mulch+Insec(s)	6	353	381	363	362	364.75
MST+Mulch	7	200	204	208	201	203.25
MST+Mulch+insec(f)	8	204	202	192	188	196.50
MST+insec(s)+insect(f)	9	163	181	178	173	173.75
Mulch+Insec(s)+insec(f)	10	233	248	219	242	235.50
Check plot	11	763	731	925	892	827.75

[1]Total larval counts are based on three sampling dates, 30, 60 and 85 days after planting. Two hundred grams of mid-plant tissue were taken in each sample for a total sample weight of 600 g of tissue.

Similar results were obtained for counts of leafminer adults on the snow pea plants. The lowest adult population was present in the MST plots, with nearly a three-fold reduction in leafminer adult numbers compared to the check plots. The differences between the various MST treatments and the insec(s), insec(f), wheat mulch and check treatments were highly significant ($p<0.01$) (Table 2). Snow pea yields were statistically similar ($p>0.05$) in all treatments evaluated. Yields ranged from 7.72 MT/ha (Check plot) to 10.10 MT/ha (treatment 6) (Table 3).

Table 2. Treatment description and total adult counts[1] in the leafminer integrated management trials conducted in Zaragoza, Chimaltenango, 1998.

Treatment		Total adult counts per meter-row				
Description	Number	Block I	Block II	Block III	Block IV	average
soil insecticide (insec(s))	1	890	770	675	911	811.50
foliar insecticide (insec(f))	2	695	775	1007	786	815.75
Mulch (straw)	3	715	419	727	860	680.25
Mobile sticky trap (MST)	4	380	375	288	375	354.50
MST+insec(s)	5	417	411	445	207	370.00
Mulch+Insec(s)	6	760	615	710	714	699.75
MST+Mulch	7	407	510	507	411	458.75
MST+Mulch+insec(f)	8	309	360	390	415	368.50
MST+insec(s)+insect(f)	9	308	370	397	415	372.50
Mulch+Insec(s)+insec(f)	10	518	570	517	377	495.50
Check plot	11	1098	1240	870	1002	1052.50

[1]Numbers are based on readings conducted twice a week throughout the crops cycle.

Table 3. Yields of snow pea plots subjected to different leafminer integrated management tactics. Zaragoza, Chimaltenango, 1998.

Treatment		Yields (MT/ha)				
Description	Number	Block I	Block II	Block III	Block IV	average
soil insecticide (insec(s))	1	7.54	10.18	7.19	7.91	8.20
foliar insecticide (insec(f))	2	7.59	6.80	8.79	7.98	7.79
Mulch	3	10.79	8.98	8.74	9.96	9.62
Mobile sticky trap (MST)	4	9.52	10.84	7.20	10.39	9.49
MST+insec(s)	5	7.62	10.32	7.87	8.93	8.68
Mulch+Insec(s)	6	11.56	7.94	11.44	9.45	10.10
MST+Mulch	7	10.40	8.01	10.39	7.92	9.18
MST+Mulch+insec(f)	8	8.36	11.22	10.43	7.60	9.40
MST+insec(s)+insect(f)	9	10.10	6.98	10.06	7.57	8.68
Mulch+Insec(s)+insec(f)	10	11.90	7.78	8.78	7.59	9.01
Check plot	11	6.31	9.07	7.24	8.25	7.72

Impact

The results show that a combination of different leafminer control tactics, including the mobile sticky trap and mulch, can reduce the need for chemical insecticides in snow pea production. The incorporation of such novel IPM tactics into current snow pea production will facilitate the implementation of quality control programs oriented to enhance the safety of the food supply originating from Central American countries.

Networking Activities

III Seminar on the Integrated Pest Management on non-traditional export crops. Sept 30 and Oct. 1, 1998, Guatemala City, Guatemala.

Publications and Presentations

III Seminar on the Integrated Pest Management on non-traditional export crops. Editors: Guillermo Sánchez, Linda Asturias, Danilo Dardón, 1998 IPM-CRSP, Guatemala.

Training Output

Phillip Lamport, graduate student, M.S. Program, Department of Horticulture and Landscape Architecture, Purdue University.

Project Highlight

The utilization of the mobile sticky trap "torito" in combination with wheat straw mulch and insecticides applications, as components of a leafminer integrated management program in snow peas, allowed for significant reductions in leafminer damage to plants while decreasing the total amounts of pesticide being applied to the crop.

Policy Analysis and Pesticide Manual

Investigators: M. Bolanos[1], P. Espinosa[2], G. Norton[3], and T. Yamagiwa[3]

Abstract

A study was conducted of the policies affecting pesticide use in Ecuador. Nominal rates of protection (NPR's) and equilibrium exchange rates were calculated to quantify the degree of pesticide subsidy or tax in Ecuador from 1987 to 1996. The results indicated that the subsidy on pesticides has decreased substantially over the period to less than 5%. A demand function for pesticides was estimated to quantify the effect of price distortions on pesticide demand, but a statistically significant function was not obtained rendering quantification difficult. Three training manuals on the correct use of pesticides and recognizing symptoms of pesticide poisoning were edited.

Objectives

To document current government policies that influence pesticide use and incentives to adopt IPM in Ecuador, to quantify the effects of those policies on pesticide use, and to edit three training manuals on the correct use of pesticides and recognizing symptoms of pesticide poisoning.

IPM Constraints

Pesticide policies can have a strong influence on the incentives for farmers to adopt alternative IPM practices. Both direct and indirect policies can subsidize or tax pesticides. Earlier studies had indicated significant subsidies to pesticides but both macroeconomic and sectoral policies have been changing over the past 10 years. In addition, training manuals are needed for both agricultural and health workers as evidenced by the incorrect application of pesticides and the large number of poisonings in Ecuador.

Research Methods, Results, and Impacts

Representatives from ten organizations in Ecuador interested in pesticide issues were interviewed to obtain information for identifying policies influencing pesticide use and the data for calculating subsidies and taxes. Exchange rate policies, agricultural credit policies, tariffs, and sales taxes were the primary policies influencing pesticide use.

Nominal Rates of Protection (NPR's) were calculated to quantify the degree of pesticide subsidy in Ecuador from 1991 to 1996. Equilibrium exchange rates were computed first to determine the indirect and total NPR's in addition to

[1] Ministry of Agriculture [2] CIP [3] Virginia Tech

the direct NPR's. The computed equilibrium exchange rates from 1987 to 19996 indicated a decreasing trend in Sucre over-valuation. The direct NPR's indicated a small tax on pesticides due to tariff and customs tax, and the indirect NPR's indicated a decreasing trend in subsidies due to the reduction in Sucre overvaluation. The net result was a reduction in pesticide subsidy over the period. The overall reduction in pesticide prices due to price and exchange rate distortions in 1996 was only 3.5%; it is likely that some additional subsidy is occurring due to subsidized credit.

A demand function was then estimated to quantify the effect of price distortions on pesticide demand; however, a significantly significant function was not obtained making it difficult to draw quantitative conclusions.

Networking Activity

G. Norton traveled to Ecuador in March to discuss research with colleagues there. Patricio Espinosa traveled to the Philippines to observe IPM CRSP activities at that site.

Publication

Yamagiwa T.J. "Analysis of Policies Affecting Pesticide Use in Ecuador", MS Thesis, Virginia Tech, February, 1998

Training Output

Takayoshi Jose Yamagiwa completed a Masters degree in Agricultural and Applied Economics at Virginia Tech

Research Highlight

Pesticide subsidies in Ecuador due to both direct and indirect causes has declined over the past 10 years to less than 5% and should pose no significant constraint to IPM adoption in that country.

Development of Program Components for the Integrated Management of Pests and Diseases of Potato in Ecuador

Development of potato varieties with long lasting horizontal or multigenic resistance to late blight (*Phytophthora infestans*)

Investigators: H. Andrade[1], X. Cuesta[1], F.M. Cárdenas[1], E. Carrera[1], F. Merino[2], M. Pumisacho[2], C. Sevillano[2], and Michael Ellis[3]

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 in cooperation with local potato growers during the planting cycle 1997-98.

Methodology

Evaluation of potato clones with local growers is being conducted at two locations. One in the community of Santa Martha de Cuba (parish of the same name) at an altitude of 2800 m, and the other in La Palestina, at an altitude of 3150 m, (Julio Andrade parish), in the canton of Tulcán, Province of Carchi. Twelve clones with horizontal resistance to the late blight and 23 clones with vertical resistance were evaluated in Santa Martha, and 16 clones with horizontal resistance and 21 clones with vertical resistance were evaluated in La Palestina during the 1997-98 planting cycle. 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 clones 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.

[1] INIAP – Santa Catalina [2] UVTT Chimborazo, Cotopaxi y Carchi [3] Ohio State University

Evaluations were conducted 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 both 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 in Santa Martha enabled the research team to understand the environment and lifestyle of the community, from the perspective of the growers.

The appraisal considered small-scale farmers (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 San 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 o 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.

Growers at La Palestina are also small-scale farmers, who grow potatoes in a system very similar to the one described for Santa Martha de Cuba. The main difference between the two communities is the type of rotation, and fallow period (two-three years) between two crops of potato. Other farmers use a rotation of potato-bean- corn.

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 to evaluate potato clones

Meetings with farmers were organized 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. In both

locations, groups consisted of young growers (age 20-30), with leadership skills and a strong interest in working for their community.

Training

Meetings were used to initiate the training process of growers that formed the evaluating groups. Emphasis was placed on strengthening their production skills and knowledge about the potato crop. A curriculum for the training program on late blight is being developed. At this point we have the first session ready, where horizontal and vertical resistance of clones to late blight is explained through simple comparative drawings. This first approach was evaluated favorably by the farmers.

Participatory evaluations with the growers

Some advances have been made regarding the process of participatory evaluation. A cooking quality test was conducted at harvest on all selected clones from all evaluations. Growers pointed out that it is important to evaluate the cooking quality of the clones from the very beginning of the evaluation process. Due to the importance of cooking quality, they felt it was important to not lose time in later evaluations with clones that are not good for cooking. The PNRT suggested to test the clones in all cycles for frying quality, dry matter and specific density, in order to identify the ones that have a good processing potential.

Clone selection

Santa Martha de Cuba

Clones were selected at flowering based on the characteristics previously described. Clones selected from the first evaluation 95-35-1; 95-85-4; 95-68-1; 95-12-2; 95-61-1; 95-68-3, and 95-8-2. Clones selected from the second evaluation were CHP-40; CHP-154; CHP-141; CHP-70; CHP-94, and CHP-3. And from the third evaluation, the selected clones were P-32; P-175; P-84, and P-65. According to the farmers, the best clone in the multiplication parcels was 0-10.

At harvest time, farmers selected seven clones from the first evaluation: 95-68-3 (17.5ha t/ha); 95-85-4 (17.6 t/ha); 95-61-1 (13.4t/ha); 95-59-5 (22.3 t/ha); 95-95-5 (13.4t/ha); 95-68-1 (16.1 t/ha), and 95-43-5 (14.8t/ha). Selection criteria included high yields, good market value, late blight resistance, pink-red skin color, yellow-beige pulp color, and uniform size. Nine clones were slected from the second evaluation: CHP-141 (30. t/ha); CHP-70 (14.7t/ha); CHP-82(23.6t/ha); CHP-154 (16.1t/ha); CHP-40 (15.2t/ha); CHP-97 (12.3t/ha); CHP-94 (14.5t/ha); CHP-3 (15.3 t/ha), and CHP-65 (8.8 t/ha). Five clones were selected from the third evaluation: P-41-5 (17.9 t/ha); P-175 (11.7t/ha); P-6-3 (29.1 t/ha); P-84-1 (24.2 t/ha), and P-40-3 (26.2t/ha). The best clone according to the farmers in the multiplication parcels was 0-10 (27.1 t/ha) (Table 1). In cooking evaluations several clones were not acceptable to growers.

Table 1. Yields of the Potato Clones Evaluated by the PNRT in Cooperation with Potato Growers in Santa Martha de Cuba and La Palestine, Carchi. 1998

Clones	SANTA DE CUBA Yield average t/ha	MARTHA LA PALESTINA Yield average t/ha
First evaluation		
95-68-3	17.5	60.0
95-85-4	17.6	28.0
95-61-1	13.4	39.5
95-59-5	22.3	39.8
95-95-5	13.4	28.5
95-68-1	16.1	39.5
95-43-5	14.8	
95-35-23		49.1
95-95-9		36.1
95-8-2		74.8
95-35-1		30.0
95-12-2		68.4
Second evaluation		
CHP-141	30.0	58.6
CHP-70	14.3	37.2
CHP-82	23.6	23.6
CHP-154	16.1	16.1
CHP-40	15.2	20.7
CHP-97	12.3	12.3
CHP-94	14.5	25.5
CHP-3	15.3	25.4
CHP65	8.8	33.0
CHP-231		38.6
CHP-38		23.0
Third evaluation		
P41-5	17.9	24.6
P-175	11.7	13.1
P-6-3	29.1	38.0
P-84-1	24.2	36.5
P-40-3	26.2	46.4
P-21-1		38.8
P-101-2		47.6
Multiplication plots		
O-10	27.1	42.3
O-5		39.1

La Palestina

According to the farmers, the best clones of the first evaluation at flowering were: 95-35-1; 95-8-2; 95-61-1; 95-59-5; 95-68-1, and 95-68-3. From the second evaluation the selected clones were: CHP-94; CHP-154; CHP-70; CHP-40;

CHP-231; CHP-97; CHP-3; CHP-141, and CHP-82. And from the third evaluation the best clones were: P-21-1; P-32; P-41-5; P-101-2; P-40-3, and P-175. From the multiplication trial, 0-10 and 0-5 were selected as probable varieties for the region.

At harvest time, the farmers selected 11 clones from the first evaluation: 95-35-23 (49.1 t/ha); 95-95-9 (36.4 t/ha); 95-8-2 (74.8 t/ha); 95-35-1 (30 t/ha); 95-68-1 (39.5 t/ha); 95-59-5 (38.8 t/ha); 95-12-2 (68.4 t/ha); 95-61-1(39.5 t/ha); 95-85-4 (28 t/ha); 95-95-5 (28.5 t/ha), and 95-68-3 (60 t/ha). Selection criteria were very similar to those used in Santa Martha. From the second evaluation eight clones were selected: CHP-70 (37.2 t/ha); CHP-94 (25.5 t/ha); CHP-65 (33.t/ha); CHP-231 (38.6 t/ha); CHP-38 (23 t/ha); CHP-40 (20.7 t/ha); CHP-3 (25.4 t/ha), and CHP-141 (58.6 t/ha). Six clones were selected from the third evaluation: P-41-5 (24.6 t/ha); P-84-1 (36.5 t/ha); P-21-1 (47.6 t/ha); P-40-3 (46.4 t/ha); P-101-2 (47.6 t/ha), and P-6-3 (38 t/ha). From the multiplication trials, selected clones were 0-10 (42.3 t/ha), and 0-5 (39.1 t/ha) (Table 1.) In the cooking quality tests, several clones were not acceptable to the growers.

Biological control of the Andean weevil *Premnotrypes vorax* on potato with *Bacillus thuringiensis*

Investigators: P. Gallegos[1], Sandra Garcés[1], and Roger Williams[2]

Collaborator: Jeovanny Susquillo[3]

Abstract

The Andean weevil of potato (*Premnotrypes vorax*) is the most economically important insect pest attacking potatoes in Ecuador. It can affect 100% of the crop. With the need to protect their investment and increase yields, farmers commonly use insecticides that are highly toxic to control this pest. This represents a high risk for the farmers and consumers, as well as the enviroment.

The Instituto Nacional de Ciencias Agropecuarias (INIAP) has devleoped a strategy for integrated control of this pest. As a result, the amount of insecticide used for its control has decreased significatively, and the products that are used are less toxic than those used traditionally by the growers. In order to further reduce insecticide use, we feel it is important to explore the possibility of biological alternatives for controlling this pest.

This study was iniciated as laboratory experiments to evaluate the efficacy of biorational insecticides for controlling this pest. The most effective products in laboratory experiments were later evaluated in the field.

Objective

To identify at least two products of low mammalian toxicity, that adequately control the Andean weevil of potato.

Hypothesis

There are no products available that are less toxic to mammals and as efficient in the control of the Andean weevil of potato, than those currently recommended.

Methodology

Product selection

The first step in the process was to select products of biological origin with a DL50 higher than 1000 mg/kg. The products included in the study are shown in Table 1. An additional control treatment was included in the study. Other insecticides that have the desired characteristics will be evaluated in the future.

[1] DNPV-INIAP [2] Ohio State University [3] UVTT-Carchi-INIAP

Table 1. Name, toxicity level and recommended rate for products used to control the Andean weevil.

Name of the product	a.i.	Oral DL50	Concentration %
Spinosad	Actinomyces *Saccha ropolyspora spinosa*	> 5000 mg/kg	0.40
Raven	*Bacillus thuringiensis* strain EG7673	biological	0.45
Naturalis-L	*Beauveria bassiana* strain G.H.A.	biological	3.00
Cryolite		10000 mg/kg	5.55
Control	Sodium fluoaluminate	-	-

Laboratory test

Efficacy of selected products. The products shown in Table 1. were diluted with water to obtain the desired concentrations. Potato leaves were placed into the dilutions for 5 seconds, after which they were placed in petri dishes along with 10 *P. vorax* adults. After 12 hours, leaves were replaced with leaves without insecticide. The mortality of the insects was evaluated after 2 and 6 days.

A completely randomized design with four replications per treatment was used to evaluate the products.

Evaluation of efficacy of Naturalis-L at lower concentration rates. The first test that was conducted with this product was based on a high concentration. Therefore subsequent trials were conducted to evaluate concentrations lower than 3%. Concentrations evaluated were 2, 1.5, 1 and 0.5%.

A completely randomized design with three replicatins per treatment was used for this study. A completely randomized design with three observations per treatment was used. The test was conducted as described above.

Field test. The two products that gave the best results in the laboratory trials (Spinosad 0.4% and Naturalist-L 3%) were tested in the field. Field experiments compared the efficacy of these two materials with currently used (highly toxic) insecticides.

All materials were sprayed on leaves and stems of potatos, which were placed on the soil, and afterwards covered with a 30x40 cm cardboard to create an insect trap. Traps such as these are used to collect the adults of *P. vorax* (Gallegos *et al.*, 1997).

Traps were placed in four growers' fields in the area of San Gabriel-Carchi. These fields had been previously planted with potatoes, and therefore it was assumed that adult *P. vorax* would be present.

The evaluation of adult mortality was completed 8 days after placement of the traps. A completely randomized block design with 4 replications was used to evaluate the products. Each trap was considered an experimental unit.

Results

Laboratory test

Product efficacy. The ANOVA for the percentage adult mortality rates of the Andean weevil for all four treatments and the control were highly significant for both sampling dates. The variability coefficient for these trials was of 19 and 26% for each sampling date, respectively. The results of Tukey's test for this same variable are shown in Table 2.

Table 2. Tukey's test (5%) for the comparison of means of percentage adult mortality rates of *P. vorax* as a response to each treatment, after two and six days. Santa Catalina, 1998.

Products	% Mortality	
	After 2 days	After 6 days
Spinosad	16.16 b	95.0 a
Raven	10.00 c	25.0 b
Naturalis-L	26.18 a	80.0 a
Cryolite	10.00 c	25.0 b
Control	10.00 c	b

Concentration of Naturalis-L. The ANOVA for the adult mortality rates did not differ significantly with the rate of concentration of the Naturalis-L.

The highest concentration of the product (2%) resulted in 46% adult mortality; the control resulted in 37%, and the treatments with lower concentrations of the product had between 6 and 16% adult mortality.

Field trials. Table 3 summarizes the results of the ANOVA of the number of dead insects in the traps for each treatment.

Table 3. ANOVA for the number of dead adult *P. vorax* in the traps, in all four locations. Carchi, 1998.

Sources of variability	Degrees of freedom	CM			
		Loc 1	Loc 2	Loc 3	Loc 4
Total	15				
Replicates	3	1.620	2.652	1.285	1.215
Treatments	3	16.041 **	5.085 n.s.	0.252 *	10.634 *
Error	9	0.131	2.124	0.302	2.533
C.V. %		8.27	37.12	25.77	44.72

Table 4 shows the results of Tukey's test for the adult mortality rates in three locations.

Table 4. Tukey's test at 5% for mean separation of the number of dead insect adults in the traps in the locations 1,3 and 4. Carchi, 1998.

Products	Number of dead adults per trap		
	Locality 1	Locality 3	Locality 4.
Naturalis-L	1.00 b	6.75 b	1.75 b
Spinosad	29.50 a	29.50 ab	2.50 b
Profenofos	30.25 a	19.00 ab	3.75 ab
Acefato	25.50 a	13.00 a	8.00 a

The ANOVA for all three locations combined shows highly significant treatment differences, with a variability coefficient of 11.89%. The results of Tukey's test at 5% for

the number of dead insects in the traps on the fields of the three growers are shown in Table 5.

Table 5. Combined Tukey's test at 5% for all three locations on the number of dead adult *P. vorax*. Carchi, 1998.

Products	Averages
Naturalis-L	3.17 b
Spinosad	20.50 a
Profenofos	17.60 a
Acefato	15.50 a

Discussion

Product efficacy

The evaluation of the percentage of dead adults of *P. vorax* in all treatments is highly significant at 2 days after the beginning of the study. This means that the products have an immediate effect on the control of the insects. These results are consistent 6 days after initiation of the experiment, and death rates were greatly increased with an increase in time from 15 to 95% with Spinosad, and from 60 to 80% with Naturalis-L. This confirms the biological nature of these materials.

Raven and Cryolite did not provide satisfactory control and were not significantly different from the untreated control.

Concentrations of Naturalis-L.

The initial concentration of this product was 3%, which turned out to be too high, and therefore smaller concentrations of this product were evaluated in the study.

The concentrations between 2 and 0.5% of the product were statistically not significant, which suggests that a reduction of the initial dose is not effective for the control of the insect. In these lower concentration, the product may have had only repellent effects, as the mortality rates are similar to those of the control. The 2% concentration resulted in 46% mortality, and the control resulted in a 37% of mortality.

Field trials

The differences between the treatments were significant in three out of four of the farmers' fields in Carchi. The effect of the treatments could not clearly be seen, because of the high variability, and the low pest population density.

The results of the mean separation by Tukey's test at 5% show that Spinosad had a similar effect to the best chemical alternatives available up to now: Profenofos and Acefato.

Good performance of Spinosad for control of *P. vorax* was observed at all three locations. Of great interest is the fact that the evaluation was conducted 8 days after the experiment was initiated. Thus Spinosad has a residual effect similar to that of Profenofos and Acefato inside traps under field conditions.

Conclusions

- The laboratory test allowed the rapid evaluation of the efficacy of the products tested against adult Andean weevils.
- Concentrations of Naturalis-L lower than 3% did not result in an acceptable level of control.
- Naturalis-L at the 3% concentration was not effective under field conditions.
- Spinosad provided effective control under both, laboratory and field conditions.
- Spinosad used in traps may be an adequate control measure for *P. vorax*.
- Spinosad may be a good alternative to Acefato y Profenofos, due to its less toxic effects on mammals.

Recommendations

- Develop further studies to evaluate Spinosad applied as a foliar application or in traps under field conditions as a control of *P. vorax*.

Development of Integrated Pest Management Alternatives for the Main Pests and Diseases of Plátano (Plantain)

Investigators: Jorge Mendoza[1], Carmita Suárez[1], Michael Ellis[2], and Roger Williams[2]

Abstract

The main cause of low quality and productivity of plátano (plantain) (var. Barranganete) in the region of "El Carmen" was attributed to pests and diseases, as was determined from field trips and participatory analysis with plátano growers in the area. In response to these problems, studies were initiated to determine the importance of plátano pests and their natural enemies, and to develop alternatives for managing black sigatoka (*Micosphaerella fijiensis*).

A total of 20 species, including insects, mites and nematodes, have been found to be harmful to plátano. The most important pests are the banana weevil (*Cosmopolites sordidus*), the Metamasius weevil (*Metamasius hemipterus*) and the nematode (*Radopholus similis*). The earwig, *Plaesius javanicus* (Dermaptera) and the entomopathogen, *Metarhizium anisopliae* are good natural enemies of the banana weevil. These insect are commonly controlled using traps made from pseudostems of harvested plants. There is inadequate of knowledge of the nematode to determine its importance as a pest and to develop control methods on plátano. Leaf pests are of little importance in plátano. The populations of the caterpillar *Antichloris (=Ceramidia) viridis*; saddleback caterpillar (*Sibine apicalis*); owlmoth caterpillars (*Caligo teucer* and *Opsiphanes tamarindi*), and bagworm (*Oiketicus kirbyi*) have been kept low, with averages of less than one larva per leaf. This level of control is attributed to the efficacy of natural enemies. A pest of increasing importance is the whitefly (*Aleurothrixus floccosus*), where large populations have been observed (up to 47 nymphs per 50 cm^2 of leaf area). Predators and parasitoids have been observed to successfully control whitefly, with natural death rates as high as 81.6%. The most important natural enemies are the parasitoids of the genus *Encarsia* (Hymenoptera), and the predators like syrphids, lacewings, lady beetles and spiders.

In respect to the management of the black sigatoka (second experiment), plants sprayed with fungicides have the largest number of functional leaves (level ≤3 in the Stover scale).

Objectives

1. Collect and identify the natural enemies of the main insect pest for plátano.
2. Determine the degree of control of these pests by their natural enemies.
3. Determine the efficacy of alternative management practices in the control of black sigatoka (*Micosphaerella fijiensis*)

IPM Constraints

Pests and diseases are the leading causes of low productivity of plátano in Ecuador. The socioeconomic characteristics of the plátano growers demand the urgent implementation of integrated pest management strategies that can effectively reduce the damage of pests and diseases in a way that is ecologically appropriate and economically profitable.

Research Methods

Studies to determine the main pests of plátano and their natural enemies were conducted in a plantation located at the highway Quevedo-Buena Fé, km. 13. This plantation is representative of the plátano plantations in the region, where chemical pesticides are not applied, with the exception of localized herbicide applications, like glyphosate.

As part of this study, the dynamics of the main pest populations and their damage on the plant were evaluated every two weeks. Specimens of each pest type are being collected to determine their natural parasitism and relative importance. This on-going study was initiated in March 1997.

The sampling procedure used for the study depends of the pest's habits. In the specific case of the banana weevil (*Cosmopolites sordidus*) and the Metamasius weevil (*Metamasius hemipterus*), traps with banana pseudostems are used, and the degree of damage is evaluated by examining the corms of the harvested plants using a scale of

[1] INIAP, Ecuador [2] Ohio State University

1-5. In the case of the mealybug (*Pseudococcus* sp.) the number of individuals is counted in an area 100 cm^2 in the base of the pseudostem. In the case of leaf pests, the number of harmful and beneficial insects in all developmental stages are counted on the sixth leaf of plants that are close to flowering. To determine populations of plant parasitic nematodes, soil and root samples were collected from five randomly select plants that were close to flowering. Samples were collected at one month intervals from April through November in 1997 and from February through September in 1998. In the laboratory the percentage of damage to roots and the population and species present of nematodes was determined for 100 grams of roots per plant.

To assess the damage of black sigatoka (*Micosphaerella fijiensis*), an experiment was established in the farm "Serpiente de Oro", located in the region of El Carmen, in the province of Manabí. This study was initiated in May 1998, with the following treatments:

1. Diseased leaves are removed, fungicides are applied
2. Diseased leaves are removed, fungicides are not applied
3. Diseased leaves are not removed, fungicides are applied
4. Diseased leaves are not removed, fungicides are not applied (control)

In the treatments including the removal of leaves (sanitation), leaves that have more than 50% of their surface infected (necrotic) are removed. This is done every two weeks. Fungicide application consists of four applications during the rainy season with intervals of 15 days between applications. Fungicides being tested are: Tilt at 0.41/ha; Benlate at 0.25 kg/ha, and Calixin at 0.61 plus Tilt at 0.411 ha. Each of these fungicide treatments are mixed with agricultural oil (*15 l/ha*), water (*35 l/ha*) and Tritón X-45 (*150 cc/ha*).

Data Analysis

A graphic descriptive analysis has been used to observe the fluctuations in time of the pest populations, and the importance of their natural enemies. Preliminary information on the incidence of the black sigatoka in all four treatments is also presented.

Research Results and Discussion

Table 1 shows a list of all the species of harmful insects, mites and nematodes that were observed in the plátano plantation. Of these, the species of most importance as pests in plátano production are the banana weevil (*Cosmopolites sordidus*), the Metamasius weevil (*Metamasius hemipterus*) and the nematode *Radopholus similis*.

The largest populations of *C. sordidus* and *M. hemipterus* were observed in March and April of 1997, when an average of 21 and 24 adults per trap were captured, respectively. After this date, the populations started decreasing until December 1997, when an average of 1.1 and 0.7 adults per trap were captured of *C. sordidus* and *M. hemipterus*. The highest fluctuation in the populations of these insects occurred during the months of less rainfall. However, because of the climatic phenomena of "El Niño", the typical dry period did not occur during the time of this study.

Table 1. Harmful insects, mites and nematodes found in the plátano plantations. Buena Fé, 1997-1998.

HARMFUL ORGANISMS		
Common name	Scientific name	Type of damage
Banana weevil	*Cosmopolites sordidus*	Corm borer
Metamasius weevil	*Metamasius hemipterus*	Corm borer
Mealybug	*Dysmicoccus brevipes*	Sucking insect
Caterpillar	*Antichloris (=Ceramidia) viridis*	Defoliator
Owlmoth caterpillars	*Caligo teucer*	Defoliator
Leaf feeding moth	*Opsiphanes tamarindi*	Defoliator
Saddleback caterp.	*Sibine apicalis*	Defoliator
Bagworm	*Oiketicus kirbyi*	Defoliator
Leaf feeding moth	*Spodoptera latifascia*	Defoliator
Black locust	*Estigmene* sp.	Defoliator
Whitefly	*Aleurothrixus floccosus*	Sucking insect
Scale insect	*Aspidiotus destructor*	Sucking insect
Loritos	*Cicadélidos*	Sucking insect
Thrips	*Thrips* sp.	Rasping insect
White grubs	*Phyllophaga* spp.	White grubs – root damage
White grubs	*Anomala* sp.	White grubs – root damage
Spider mites	*Tetranychus* sp.	Rasping and sucking (mites)
Nematodes	*Radopholus similis*	Nematode – root damage
Nematodes	*Helicotylenchus* sp.	Nematode – root damage
Nematodes	*Meloidogyne* sp.	Nematode – root damage
Nematodes	*Pratylenchus* sp.	Nematode – root damage

These weevils infested up to 100% of the corms, except in April and May 1997, where only 65 and 50% of infested corms were recorded. The severity of the damage varied between 2.4 and 4.6 (in a scale of 1-5), which is equivalent to 15-50% of destruction of the corm (Table 2).

Two larval predators (*Plaesius javanicus* and a dermapteran (Fam. Forficulidae) commonly known as "scissors") and an entomopathogen (*Metarhizium anisopliae*) have been observed as natural enemies of the banana weevil.

Table 2. Percentage of infestation and index of damages caused by banana weevils (*Cosmopolites sordidus* and *Metamasius hemipterus*) and mealybug (*Pseudococcus* sp.) in plátano. Buena Fé, 1997-1998.

Months	Weevils					Mealybugs	
	% of infestation	Damage index[1/]	C. sordidus per trap	M. hemipterus per trap	Total	% of infestation	Level of incidence[2/]
M/97	100	3.6	20.8	2.4	23.2	80	1.6
A	65	2.5	9.3	24.4	33.7	60	1.8
M	50	2.6	--	--	--	70	3.6
J	90	3.4	--	--	--	60	1.3
J	100	2.4	3.9	20.7	24.6	100	2.2
A	90	4.1	--	--	--	90	2.0
S	100	3.4	--	--	--	100	3.2
O	100	4.6	3.5	1.0	4.5	35	1.5
N	100	4.2	2.1	0.8	2.9	20	1.0
D	100	4.1	1.1	0.7	1.8	60	2.2
J/98	100	3.9	5.5	0.8	6.3	65	2.0
F	100	4.1	8.3	0.5	8.8	55	2.4
M	100	4.9	7.1	1.2	8.3	85	1.9
A	100	4.3	8.0	1.7	9.7	67	1.5
M	100	4.1	12.4	2.7	15.1	75	1.2
J	100	3.3	11.0	5.3	16.3	59	1.5
J	100	3.2	9.6	8.6	18.2	60	1.5
A	100	2.3	10.5	4.5	15.0	60	1.3

1/ Scale of damage from 1 to 5, where: 1 = healthy; 2 = slight damage (< 10% damage); 3 = moderate damage (10 to 25% damage); 4 = severe damage (25 to 50% damage), and 5 = very severe damage (> 50% damage).

2/ Scale from 0 to 4; where: 0 = absence of mealybugs; 1 = slight infestation (< 5 mealybugs); 2 = moderate infestation (5 to 10 mealybug); 3 = severe infestation (10 to 25 mealybugs) y 4 = very severe infestation (> 25 mealybugs).

Leaf pests have been of little importance during the time of this study. The larval populations of the caterpillar *Antichloris* (=*Ceramidia*) *viridis*, saddleback caterpillar (*Sibine apicalis*) and owlmoth caterpillars (*Caligo teucer* and *Opsiphanes tamarindi*) have been maintained at low levels usually averaging not more than one larva per leaf (Table 3), attributed to biocontrol by natural enemies.

Table 3. Number of caterpillar larvae *Antichloris* (=*Ceramidia*) *viridis*, owlmoth caterpillars (*Caligo teucer* and *Opsiphanes tamarindi*) and saddleback caterpillars (*Sibine apicalis*), registered on the sixth leaf in plátano. Buena Fé, 1997-1998.

Months	Number of larvae per leaf		
	Caterpillar	Owlmoth caterpillar	Saddleback caterpillar
M/97	0	0	0
A	0	0	0
M	0	0	0
J	0	0	0
J	0.50	0.10	0
A	0	0	0
S	0	0	0
O	0.10	0	0
N	0	0.25	0
D	0	0.25	0
J/98	0	0.05	0
F	0	0.10	0
M	0	0	0
A	0.03	0.03	0
M	0	0	0
J	0	0	0
J	0.05	0	0
A	0.10	0	0.10

Seven parasitoids, three predators and two entomopathogens that affect *A. virindis* have been collected, the most common ones being brachonids, wasps and spiders. In respect to the natural enemies of *S. apicalis*, three parasitoids (two branchonids and a Diptera) have been found. The most common larval parasitsm of this species was caused by *Apanteles* sp. In respect to the natural enemies of *C. teucer* and *O. tamarindi*, three parasitoid species have been collected: *Brachymeria commitator*, *Apanteles* sp. and a tachinid fly. The first one attacks pupae and the two others attack larvae. A pest very commonly found on the leaves of the plátano is the whitefly (*Aleurothrixus floccosus*). The highest population of this pest was observed during July 1998, where populations reached 47 nymphs on a leaf surface area of 50 cm^2, and an average of 2.6 individuals per leaf (Table 4).

Table 4. Infestation percentage and incidence levels of whitefly (*Aleurothrixus floccosus*) observed on the sixth leaf in plátano. Buena Fé, 1997-1998.

Months	Whitefly	
	% infestation	Incidence level[1/]
M/97	50	2.1
A	45	1.8
M	70	1.1
J	50	1.2
J	100	2.0
A	100	1.9
S	100	1.6
O	100	1.5
N	85	1.4
D/97	100	1.6
J/98	100	1.6
F	100	1.8
M	100	1.8
A	100	2.1
M	100	2.5
J	100	2.6
J	100	2.9
A	100	----

1/ Scale of 0 to 3, where: 0 = absence of whitefly; 1 = presence of adults and eggs; 2 = presence of nymphs; and 3 = sooty mould

In the following sampling dates, this population was lower, which is attributed to natural control. Of the causes of natural control, the most important factor was observed to be the action of natural predators, as they eliminated up to 61.8% of the nymphs. Parasitoids were responsible of 19.8% of the control. Hence, in August, natural control of white fly due to predators and parasitoids reached 81.6%. Ten natural enemies for *A. floccosus* have been collected; among these the most common ones are the nymph parasitoids of the genus Encarsia, and the predators like the syrphids, lady beetles, lacewings and spiders.

With respect to the population of plant parasitic nematodes and the root damage they cause, results indicate that *Radopholus similis* is the most important nematode representing 64% of the total nematode population. At the beginning of the study, the root damage caused by *R. similis* was 59.7% in May, 1997. After this date, damage was progressively declined until November, 1997 when it reached 17.5%. Populations then rose to 40.2% in September, 1998. These studies show that the population of *R. similis* can fluctuate over time from between 625 and 21,000 nematodes per 100 grams of root.

With respect to the control of the black sigatoka (second experiment), up to now, the results of this study do not show significant differences among treatments; however, plants that received fungicide applications had a higher number of functional leaves.

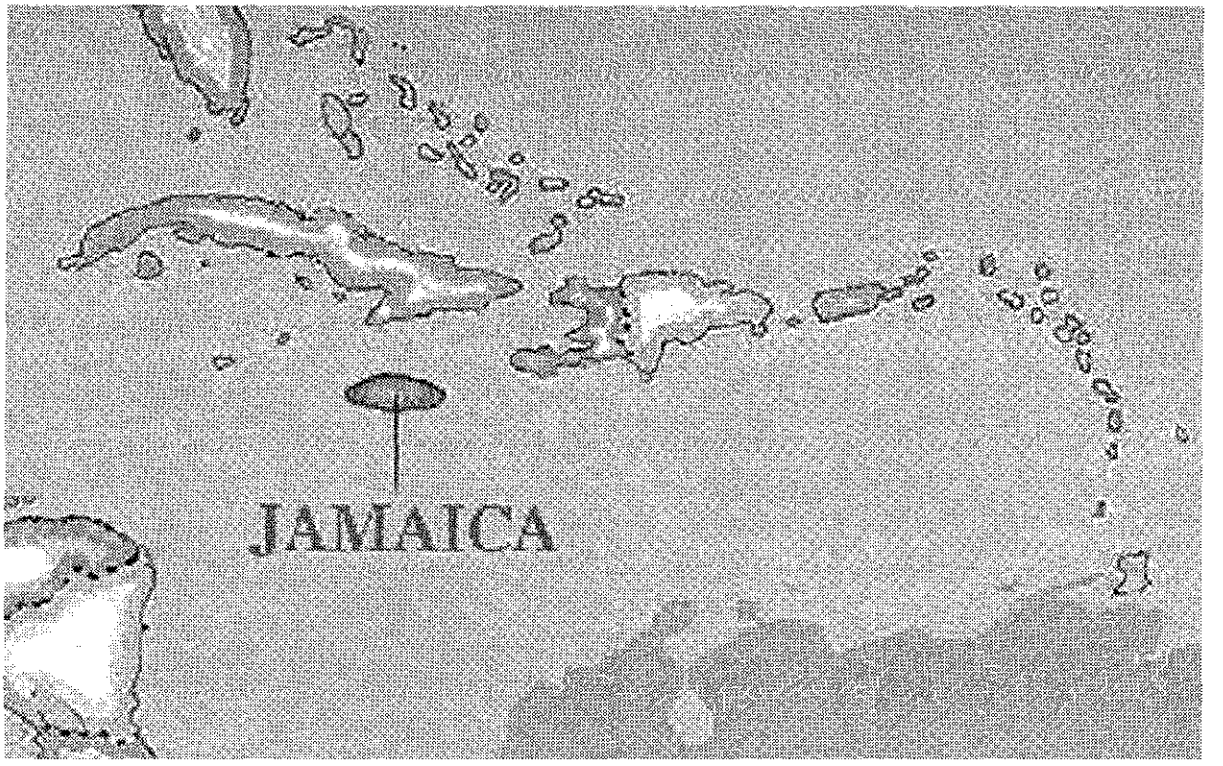
Impact

The results up to now suggest that plátano pests can be controlled with natural enemies and cultural practices such as traps (for banana weevils), the removal of infected leaves (sanitation) and the deschante. Using these methods it may be possible to reduce the use of chemical pesticides to control these pests.

As for the control of the black sigatoka, our results are very preliminary and no definite conclusions can be drawn from the results of this study regarding an efficient ecological and economical control of the disease in plátano plantations.

Workshops

Dra. Carmita Suárez, meeting in Washington, USA.



CARIBBEAN

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IPM System Development: For Pests Affecting Callaloo

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Abstract

Key components have been identified to form the framework of an IPM model for the management of major pests on callaloo. An identification guide for enhancing diagnostic capabilities of extension agents and farmers was published for distribution and use in education programs.

A derived statistical model of lepidopteran populations in the target area and an action threshold of 1 larva/plant per six leaf sample has been used in the development of a sampling plan. From this plan a field chart was designed to guide pest management decisions and reduce the frequency of pesticide application. Validation studies have shown this to be an effective system, with the potential to reduce pesticide inputs by over 40% without significant increase in pest damage. Farmer training has been initiated among 16 farmers within the major callaloo growing parish of St Catherine and farmers were very receptive to information on pest identification and the sampling system.

The importance of the need to identify more effective pesticides for controlling major arthropod pests was underscored by crop loss assessments in all studies and initial pesticide evaluation trials showed the biorational emamectin benzoate to give more effective control of defoliating pests resulting in markedly higher salable yields (62.3%) than the grower standard (44%)

Initial results from the use of exclusion as an alternative pest management procedure was promising, insect damaged rejects from covered plots being only 14.3% compared to 53.8% in uncovered plots.

Efforts to improve and standardize post harvest treatment of callaloo have so far resulted in the design of a callaloo washer basket which should reduce mechanical damage to leaves during washing and increase the efficiency of the manipulation of each wash load.

Objectives

- Determine taxonomic status of the lepidopteran larvae infesting callaloo to the species level.
- Estimate the seasonal dynamics of pests in callaloo, and statistical properties of insect sampling data for the development of sampling programs.
- Initiate the design for integration of a scouting system in control programs for callaloo pests.
- Define the phenological times of pest infestation in callaloo.
- Develop action thresholds for lepidopteran larvae (*Spodoptera exigua, S. eridania, S. frugiperda, Spoladea recurvalis,* and *Herpetogramma bipunctalis*) infesting callaloo when control is based on a grower-standard insecticide (lambda-cyhalothrin).
- Initiate the design for integration of exclusion tactics in control programs in callaloo.
- Select more effective, safer pesticides for controlling major pests of callaloo.
- Evaluate and enhance farmer knowledge of pests and crop management in major callaloo growing areas in St Catherine.
- Develop protocols that would ensure freedom from contamination due to arthropod pests and pesticide residue in callaloo produced in selected areas.
- Develop protocols to assist in returning callaloo to the preclearance list.

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IPM Constraints

- 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.

- Statistical properties of sampling data of pests of callaloo needs to be defined in order to develop sampling programs.

- 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 integrating other management tactics, and creates environmental, health and export constraints. Developing action thresholds would begin to manage these insecticide inputs.

- 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.

- Ideally, IPM seeks to minimise pesticide use in production systems effective non-chemical methods need to be identified and adapted to this cropping system

- Farmer empowerment through education and transfer of technology is paramount to the successful implementation of new methods of crop (pest) management.

- Post-harvest management of the crop needs to be developed to complement pre-harvest efforts towards the supply of produce of high quality.

Taxonomy and Identification Guides

The taxonomies of major arthropod pests of callaloo were identified and from this work, a color indentification guide to identify pests of callaloo was published this year by Pennsylvania State University. Pests described in the guide are *Spodoptera frugiperda* (J. E. Smith); *S. exigua* (Hb.); *S.* eridania; *Herpetogramma bipunctalis* (Fabr.); *Spoladea recurvalis* (F.); *Disonycha* spp; *Diabrotica baleteata* LeC; *Empoasca* spp. and *Tetranychus* spp.

Determination of an Action Threshold for Use of Lambda-cyhalothrin Against Lepidopteran Larvae on Callaloo

Research Methods

Pest frequency and leaf damage assessment. In 1996/97 a field site at CARDI Mona campus was divided into 19 plots (each 6.5m^2) and five treatments were arranged in a randomised block design (5 treatments x 3 blocks plus one incomplete block of four treatments). Five treatments were timed for spray application at 4 action thresholds (1, 2.5, 4 and 6 larvae/plot) and a farmer practice standard (spray application every 8 days). In each plot there were 56 plants (8x7 plants). The 20 central plants were the experimental plants and the surrounding 36 plants formed a border. Five plants were randomly selected from among the experimental plants, tagged, and examined twice weekly to determine pest infestation and damage. Six leaves were examined per plant (three leaves each from the inner and outer whorl). The number of feeding holes; mite, leafhopper, and fungal damaged leaves; and pest frequency (lepidopteran larvae and mites); were recorded. The activity of non-lepidopteran pest species and fungal pathogens was noted to get their relative importance.When the mean number of larvae in any given treatment plot was greater than or equal to the designated action threshold, that plot was sprayed with 0.26ml of lambda cyhalothrin (Karate) in 200ml of water. Farmer practice (control) plots were sprayed once weekly with the same concentration. Plants were irrigated twice weekly depending on rainfall and fertilizer was applied once every three weeks at a rate of 490 g/plot.

A second trial was conducted in 1997/98 using the same procedures. In addition the severity of damage severity within treatment plots was indexed during the last six weeks of the experiment. Each type of pest damage was indexed separately. Indices were described as 0: No damage, 1: < 30% damage, 2: 31-60% damage, 3: > 60% damage. The incidence of a braconid parasite of lepidopteran larvae on callaloo was also recorded.

Crop loss assessment. 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). The data were analysed using Analysis of Variance.

Results

Pest frequency. Lepidopteran larvae of the genera, *Spoladea,*

Herpetogramma and *Spodoptera* were the major pest species observed for the duration of both trials. During Trial I the 2.5 larvae action threshold plots had lower mean populations of lepidoptera larvae (24.1) than in weekly sprayed plots (24.5) but these differences were not significant (P> 0.05). Mean of total larval population other plots ranged from 26.5 to 43.68 with no discernable trend. Highest populations were recorded in the plots sprayed at threshold 1 larva/plot.

In the second trial, treatment effects on pest frequency varied from one species to another. The frequency of *Spoladea* which had the highest incidence, was significantly different when action thresholds were varied. The control plots had the lowest number of larvae, mean cumulative total over time (99.5), while in other treatments mean totals ranged from 186.3 to 247.5 larvae. Populations of other lepidoptera species were not significantly different among treatments.

Incidence of a the braconid wasp, was also found to be significantly (P=0.016) different among treatment plots. Weekly sprayed plots had the lowest numbers, mean total (19.0), while in other treatment plots the mean total ranged from (30.5-38.0). The block effect was also significant (P=0.016). Edge blocks had the highest number of braconids. This may be attributed to the proximity of the plants to surrounding vegetation. Plots closest to weeds had the highest population of braconids per treatment.

Pest damage incidence. In both trials, differences in incidence of damage caused by insect pests (leafhoppers and lepidopteran larvae) were significant among treatments. The grower standard of weekly sprays had the least number of leaves damaged by each arthropod pest. Increasingly higher damage incidence was observed with increased thresholds (Tables 1 and 2).

Table 1: Mean incidence of insect damage in treatment plots sprayed at varying action thresholds - Trial I

Treatment	Number of leaves with damage symptoms	
	Leafhopper	Lepidopteran larvae
1 larva/ plant	12.6	36.9
2.5 larvae/plant	16.5	39.2
4 larvae/plant	16.6	42.5
6 larvae/plant	17.2	42.5
weekly sprays	8.8	30.2
SEM	1.078	0.9602
	(1.28)	(1.143)
P	< 0.001	<<0.001

NB Bracketed SEM corresponds to observations in treatment plots sprayed at action threshold 2.5 larvae/plant which had one less replicate than other treatments.

Table 2: Mean incidence of arthropod damage in treatment plots sprayed at varying action thresholds - Trial II

Treatment	Number of leaves with damage symptoms		
	Leafhopper	Lepidoptera larvae	Mite
1 larva/ plant	467.5	656.5	37.0
2.5 larvae/plant	496.0	722.8	37.8
4 larvae/plant	531.8	708.8	49.0
6 larvae/plant	555.5	768.3	36.8
weekly sprays	433.3	590.5	30.3
SEM	15.62	24.34	10.02
P	<0.001	0.002	<<0.001

Frequency of pesticide applications. Timing spray applications using action thresholds based on larval counts per plant influenced the frequency of spray applications throughout the growing season (P<0.001). Farmer practice (weekly-sprayed) and 1-larva/plant treatments had significantly more applications (7 and 7.25, respectively) than plots sprayed at action thresholds of 2.5, 4, and 6 larvae/plant (2.25, 1.75 and 0.75 spray applications, respectively) (Table 3). Similar trends were observed during the second trial where number of spray applications decreased with higher thresholds.

Table 3: The effect of varying action thresholds on frequency of spray applications

Treatment	MEAN no. of applications	
	Trial I	Trial II
1 larva / plant	7.25	9.25
2.5 larva / plant	2.25	5.25
4 larva / plant	1.75	3.25
6 larva / plant	0.75	2.25
weekly sprays	7.00	13.00

In both trials, treatment effects on crop loss were not significant in any category with the exception of insect damaged rejects in Trial I which was significant at P=0.041. Weekly sprayed plots gave higher proportion marketable yields, however at much higher spray input, and the level of crop protection was still inadequate. Crop loss was very high for all treatments and insect damaged losses from all treatment plots were greater than 15 %. However, in the first trial (Table 4) insect damaged rejects in plots treated at 2.5 larvae/plant were not significantly higher (P <0.05) than weekly sprayed plots. Thus, the additional insecticide input of the weekly sprayed plots (7 sprays) did not provide lower insect damage of statistical significance than the 2.5

larvae/plant treatment (2.25 sprays).

Table 4: Cumulative yields per damage category obtained from plots treated with lambda-cyhalothrin at varying action thresholds - Trial I

Treat -ment	Weight (kg) perYield Category					# of Sprays
	Total	Marketable	Insect	Fungus	Mites	
1 larva / plant	16.29	4.22	5.48	3.86	0.22	7.25
2.5 larva/ plant	12.12	2.84	4.43	2.93	0.09	2.25
4 larva / plant	14.11	2.47	6.28	3.64	0.30	1.75
6 larva / plant	13.16	2.38	7.24	2.73	0.00	0.75
weekly sprays	14.20	5.59	2.12	4.63	0.36	7.00
SEM	2.311 (2.751)	0.965 (1.148)	1.013 (1.206)	0.77 (0.913)	0.091 (0.108)	
P	0.808	0.162	0.041	0.478	0.098	

NB Bracketed SEM corresponds to observations in treatment plots sprayed at action threshold 2.5 larvae/plant which had one less replicate than other treatments

In Trial II, losses were not stemmed by any of the treatment regimes (Table 5).

Table 5: Cumulative yields per damage category obtained from plots treated with lambda-cyhalothrin at varying action thresholds - Trial II

Treatment	Weight (kg) per Yield Category					# of sprays
	Total	Marketable	Insect	Fungus	Mites	
1 larva / plant	29.18	9.99	17.34	0.51	0.68	9.25
2.5 larva / plant	24.11	5.73	16.98	2.42	0.00	5.25
4 larva / plant	26.92	6.66	20.76	1.88	0.00	3.25
6 larva / plant	25.76	6.83	21.93	0.14	0.15	2.25
weekly sprays	26.69	10.94	17.47	0.48	0.00	13.00
SEM	3.59	1.469	3.471	0.54	0.076	
P	0.89	0.106	0.783	0.78	0.568	

Mean spray input requirements ranged from 2.25 sprays in the 6 larvae/plot treatment plots (highest threshold) to 9.25 sprays in the 1larva/ plot treatment plots compared to 13 sprays in the weekly sprayed plots during the growing season. Despite encouraging results obtained with respect to the use of action thresholds in the first trial, results of the second trial emphasise the need for more effective chemicals to be introduced for use against callaloo pests. Crop losses in all categories were high and no statistically significant differences were detected. The development of action thresholds however remains critical to insecticide resistance management of any new chemicals to be introduced.

Developing Sampling Progams for Pests in Callaloo

Research Methods

Monitoring lepidopteran populations. Populations of lepidopteran larvae were monitored twice per week for three cropping seasons in field plots located at Bodles, St. Catherine between April 1997 and March 1998 (during the vegetative to late reproductive phases). The size of experimental plots was 137 m^2 with 1000 plants. Two transects divided the field into four quadrats each containing 250 plants.

Four central plants were selected by systematically walking a zigzag path through central plants in each quadrant and tagging one plant after every ten paces. Similarly four plants were tagged per quadrant among the designated edge plants. Six leaves from the inner and outer whorl of each tagged plant were randomly selected, searched for lepidopteran larvae and records made of number, position and size of larvae found. Size of larvae were recorded as one of four categories: small, < or = 10 mm ; medium, 10.1- 20 mm and large >20 mm.

Lepidopteran adults were monitored by using a sweep net (diameter 24 inches) to catch moths. Two sweeps were done per row per quadrat among the designated centre plants. The number of each species of moth caught was recorded. Four sweeps were also done per quadrat along the designated edge of the field. All sweeps were done before conducting other sampling activities. The variation of lepidopteran populations with phenolgical stage of crop were analysed using Pearsons ranked correlation. The association between adult and larval lepidopteran populations was also analyzed using Pearsons ranked correlation.

Modeling the frequency distribution of larval populations. The variance-to-mean relationship of data collected per twelve leaf sample was examined and a k parameter for a negative binomial distribution was estimated from the data collected in the first two crops. Regression analysis was then used to examine the independence of k with respect to the mean to determine whether a common k (clumping parameter, k_c) could effectively model the population at Bodles. The estimate of k_c was made by regressing mean crowding (*mc*) against the mean (Iwoa 1968) and regressing *y'* on *x'* (Elliot 1977). These parameters are defined by the equations $mc = x + (s^2/x-1)$ [Iwao 1968]; $y' = s^2 - x$ and $x' = x^2 - (s^2/n)$ [Elliot 1977], where the slope of the regression of

y' on x' gives the common k.

Development of sequential sampling plans. Equations in Waters (1955) were used to prepare a computer spreadsheet for calculating sequential sampling plans. We used varying inputs of upper (m_o) and lower (m_1) class limits, which bracketed an action threshold 1 larva per plant (6-leaf sample), the k_c based on the modeled probability density function, and a range of allowable Type I and Type II error rates. Several plans with a maximum of 25 and a minimum of 10 samples were derived to satisfy a range of thresholds around the 2.5 larvae per plant (12-leaf sample) limit implied by results of earlier field studies. The maximum and minimum sample sizes and the 6-leaf sample unit were selected based on the level of accuracy required balanced with the need for the process to be practical to the farmer.

Validation of the sequential sampling plan. A suitable plan was selected based on all the aforementioned criteria and a chart was designed to be used as a field tool to guide decision making based on the sequential sampling plan. Thirty-two callaloo farms within a 28 km^2 radius in St. Catherine were monitored by looking at the maximum twenty-five samples. The pest management decision reached based on the sequential sampling plan was compared to a decision based on a fixed sample of 25 plants using a threshold of 1 larva per plant. This procedure for validation was described by Luna *et al* (1983). Analyses of this data were conducted during a collaborative visit to Penn State University. Results were presented at the Third Annual Symposium of IPM CRSP and the 34th Annual Meeting of the Caribbean Food Crop Society.

On-farm validation/ demonstration. A validation trial was conducted on two farms in Bushy Park.Two plots of four hundred plants each were established on each of two farms.

Treatments. Sampling Plan: Pesticide applications were made based on a decision making tool using a sequential sampling plan. Farmer Practice: Pesticide applications were made once per week on a calendar cycle.

Data collection. 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. The level of lepidoptera feeding damage on each leaf was recorded as one of four indices: 0: No damage, 1: < 30% damage, 2: 31-60% damage, and 3: > 60% damage.

Results and Discussion

Temporal and spatial distribution of lepidopteran pests. Seasonal dynamics was considered to determine generally when to intensify sampling activities. The total number of lepidoptera larvae observed per sampling date ranged from 19 to 238 during crop 1, 0 to 322 during crop 2 and 2 to 193 during crop 3 (Figure 1). Population monitoring data collected for the three cropping seasons substantiated farmer perception of the hot months being the season of highest pest pressure . Although the highest number of lepidoptera larvae was recorded in October, a comparison of the means and medians of individual crop seasons (Table 6) showed consistently higher pest numbers during the May to July crop, followed by August to November, and lowest numbers between December and March.

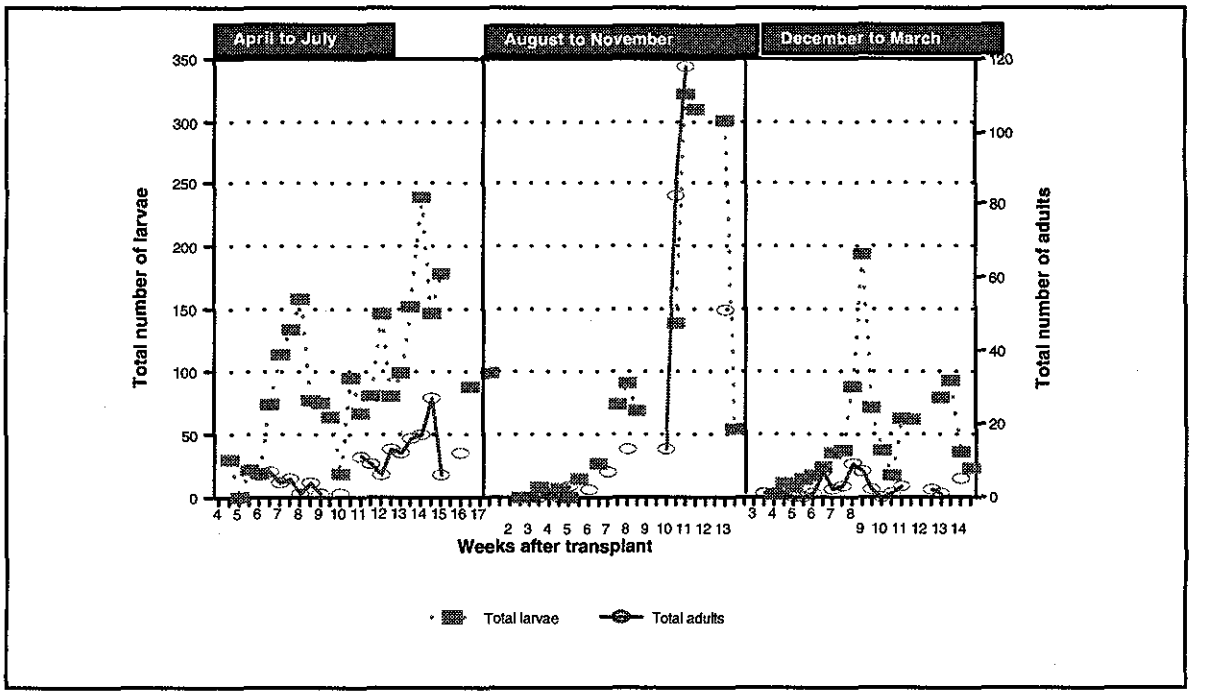

Figure 1. Larval and adult population changes of lepidoptera species during three callaloo seasons between April 1997 and March 1998- Bodles, St Catherine, Jamaica

Table 6: Population levels of lepidopteran larvae observed during three cropping seasons at Bodles, St. Catherine

	Crop 1	Crop 2	Crop 3
Duration	*April to July*	*August to November*	*December to March*
Maximum	238	322	193
Minimum	19	0	2
Median	88	40.5	36
Mean	98.09	88.75	47.89
Standard Deviation	53.59	113.52	43.82

The correlation between total adult and total larval lepidopteran populations over all crop seasons (Table 7) was very significant (P < 0.0001). The more visible sign of increased moth activity can therefore be used as a signal to increase sampling activity for lepidoptera larvae. Proposed studies to assess pheromone and light traps as early warning devices will complement these findings.

Table 7: Correlation of adult and larval (number per 12-leaf sampling units using a visual search) populations of Lepidoptera observed between April 1997 and March 1998 at Bodles, St. Catherine.

Lepidoptera species	Correlation coefficient
Spoladea recurvalis	0.714
	(P< 0.0001)
Herpetogramma bipunctalis	0.724
	(P< 0.0001)
Spodoptera spp.	0.611
	(P<0.0001)
Total All species	0.722
	(P<0.0001)

Crop phenology was also found to significantly correlate with larval population of Lepidoptera. A positive correlation (r = 0.525) between total lepidopteran larvae and number of weeks after planting was highly significant (P=0.0070).

The within-plant distribution of the pest was investigated to define specifics of the sampling unit. Analyses carried out on a partial data set revealed significantly greater (P= 0.001) number of larvae on outer whorl leaves than on the inner whorl. Larval size was also found to affect within plant distribution. More larvae in the small size class were found in the outer whorl, while larger larvae were found more often in the inner whorl (P= 0.002). Within field distribution (edge versus center) was not significant (P= 0.428). These early analyses were the basis of sample allocation (3 inner and three outer whorl leaves per 6-leaf sample) for using sampling plans in field validation activities. To ensure that sampling for decision-making would consider both small and large size classes of larvae , further work was conducted with a six leaf sampling unit comprising 3 inner leaves and 3 outer leaves.

The frequency distribution model. Comparison of the Chi-square values obtained when data collected during crop 1 and crop 2 were fitted to both Poisson and negative binomial models (Table 8) showed that the negative binomial model consistently gave a much better goodness-of fit. Further work will set probability values to the chi-square to confirm that the negative binomial is an appropriate model of both the frequency distribution and probability density function, of data collected under growing conditions in Bodles, St. Catherine using 6-leaf sampling units.

Table 8: Chi-squared for fit of Negative Binomial and Poisson to counts of lepidopteran larvae in callaloo using 6-leaf sampling units (n = 128 per crop and date).

Date	Mean	k	-ve Binomial	Poisson
CROP 1				
14-Apr	0.5	0.7	9.37E+00	2.47E+01
21-Apr	0.38	6.44	1.75E+00	2.00E+00
23-Apr	0.27	0.28	2.40E+00	1.04E+02
05-May	1.2	0.51	1.10E+01	3.03E+04
07-May	2.25	0.81	1.85E+01	4.98E+03
12-May	2.02	1.1	7.52E+00	1.96E+02
14-May	2.48	2.64	1.22E+01	4.26E+01
19-May	1.8	1.07	1.08E+01	5.84E+03
19-May	1.66	1.46	8.00E+00	8.60E+01
21-May	1.16	2.67	7.17E+00	2.21E+01
26-May	1.15	1.08	8.75E+00	3.00E+01
27-May	0.38	2.63	3.80E-01	4.48E+00
02-Jun	1.6	1.29	6.95E+00	1.06E+02
02-Jun	1.5	1.52	7.63E+00	3.99E+01
10-Jun	1.48	0.34	3.30E+01	>33
10-Jun	1.2	0.78	1.12E+01	1.34E+02
12-Jun	2.16	1.45	1.24E+01	1.33E+02
16-Jun	1.47	1.14	1.40E+01	5.06E+02

Table 8 ***continued***

16-Jun	1.27	1.99	9.29E+00	2.34E+01
18-Jun	1.32	1.12	4.28E+00	2.83E+02
18-Jun	1.47	0.77	9.06E+00	3.96E+04
23-Jun	2.38	1.13	8.75E+00	6.79E+02
25-Jun	3.73	1.82	2.32E+01	4.37E+04
26-Jun	3.52	2.4	1.81E+01	1.32E+02
30-Jun	2.31	0.94	1.45E+01	2.70E+03
03-Jul	2.78	0.97	2.41E+01	>33
09-Jul	1.17	0.41	1.11E+01	3.52E+05
14-Jul	1.24	1.1	9.08E+00	4.25E+02
14-Jul	1.34	0.92	1.43E+01	9.28E+02
CROP 2				
27-Aug	0			
29-Aug	0			
01-Sep	0.125	0.11	3.97E+00	6.33E+01
08-Sep	0.11	0.56	2.80E-01	1.54E+00
10-Sep	0			
17-Sep	0.23	0.27	3.34E+00	3.76E+01
22-Sep	0.45	0.05	3.81E+01	6.11E+18
29-Sep	1.05	0.83	1.08E+01	1.27E+03
01-Oct	1.39	2.27	1.78E+01	3.02E+01
08-Oct	1	0.48	1.78E+01	1.70E+06
22-Oct	2.14	0.75	1.22E+01	1.90E+07
28-Oct	4.97	0.28	1.20E+02	4.93E+51
30-Oct	4.8	0.64	4.36E+01	1.32E+19
06-Nov	4.73	0.86	2.74E+01	3.65E+08
12-Nov	0.72	0.3	1.13E+01	1.84E+03
17-Dec	0.09	-1.18	4.70E-01	3.20E-01

The regression of 1/k against the mean showed a trend only reinforced by two outliers, however, this trend was not significant (P=0.1474) (Figure 2). Since the influence of the mean on k was a weak one it was assumed that a common k value which would be applicable to the range of growing conditions encountered in the callaloo growing areas in Jamaica, could be used in developing the model. The common k (k_c) estimated was 0.644.

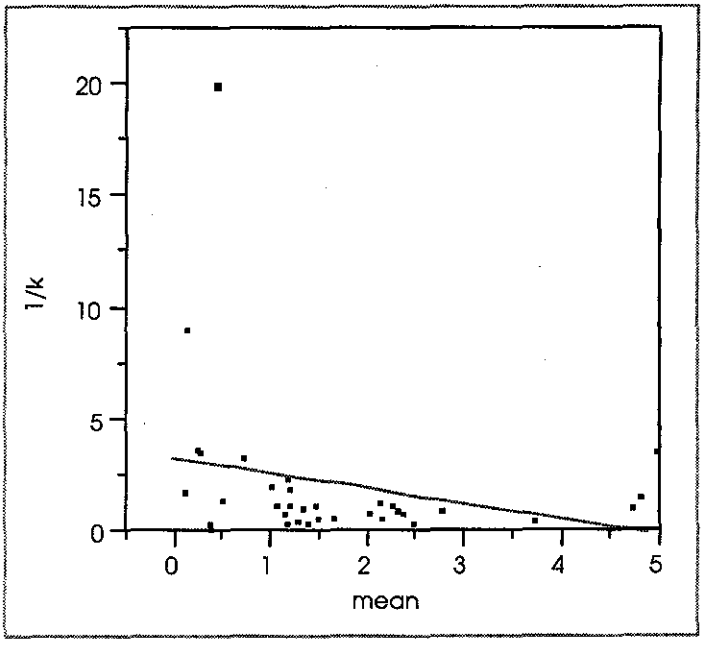

Figure 2. 1/k versus mean larval population per date

The sequential sampling plan. Sequential sampling plans were generated from the developed frequency distribution model. Inputs of an action threshold of 1 larva per plant (6-leaf sample), and varying acceptable Type I and Type II error rates for decision making were assessed using our subjective knowledge of farmer tolerances and potential sampling labor inputs. The sampling plan (Table 9) was selected as the most feasible. The Type I and Type II error rates used was 0.2. A minimum requirement of 10 samples was set to reduce decision errors and the maximum number of samples was fixed at 25 based on the estimated time required (forty-five minutes to an hour) to take these samples. The sampling chart was further modified to be used as a field guide to sampling and decision making in pest management of lepidoptera larvae on callaloo. In the chart predetermined decisions as to whether or not to apply pesticides were listed based on the cumulative number of larvae found after a given number of 6-leaf samples. Additional samples are recommended when counts fall within the range of uncertainty.

Table 9: Sequential sampling plan for lepidopteran larvae on vegetable amaranth

Sample	Cumulative Frequency Of Larvae		
Number	Do Not Spray	Take Another Sample	Spray Now
10	3	4 to15	16
11	4	5 to 16	17
12	5	7 to 16	18
13	6	7 to 18	19
14	7	8 to 19	20
15	8	9 to 20	21
16	9	10 to 21	22
17	10	11 to 22	23
18	11	12 to 23	24
19	12	13 to 24	25
20	13	14 to 25	26
21	14	15 to 26	27
22	14	15 to 27	28
23	15	16 to 28	29
24	16	17 to 29	30
25	17	18 to 30	31

Validation of sequential sampling plan. To date, validation has been done in 32 callaloo fields (Table 10).

Table 10: Pest management decisions based on sequential sampling plan compared to decisions based on a fixed sample size of 25.

Field No.	N using the Sequential Plan	Pest Management Decision	
		Sequential Sampling Plan	Fixed Sample Size (25 samples)
1	10	No Spray	No Spray
2	10	No Spray	No Spray
3	10	No Spray	No Spray
4	12	No Spray	No Spray
5	10	Spray	Spray
6	11	No Spray	No Spray

Table 10 *continued*

7	15	No Spray	No Spray
8	10	No Spray	No Spray
9	10	Spray	Spray
10	10	No Spray	No Spray
11	17	No Spray	No Spray
12	10	No Spray	No Spray
13	10	Spray	No Spray
14	23	No Spray	No Spray
15	10	No Spray	No Spray
16	19	No Spray	No Spray
17	17	Spray	Spray
18	10	Spray	Spray
19	25	No Decision	No Spray
20	10	No Spray	No Spray
21	10	No Spray	No Spray
22	15	Spray	Spray
23	10	Spray	No Spray
24	10	No Spray	No Spray
25	25	No Decision	No Spray
26	21	Spray	Spray
27	25	No Decision	No Spray
28	18	Spray	Spray
29	15	No Spray	No Spray
30	10	Spray	Spray
31	10	No Spray	No Spray
32	10	No Spray	No Spray

Of these fields, 87.5% gave the same management decisions using the sequential sampling plan as a fixed sampling plan of 25 samples (estimated farmer tolerance threshold). Inaccurate decisions were reached in 3.1% of the fields while 9.4% of the fields resulted in no decision (after 25 samples) with the sequential sampling plan. Overall the sequential sampling plan gave 87.5% accurate decision with a mean of 13.5 samples per field compared to 11.5 more samples being required for a fixed sample size of 25 samples per field. This represents a savings of 46% in sampling time.

This effort has helped to identify when to concentrate sampling efforts, and has defined a sampling unit that considers the major defoliating pest species and includes all larval size classes. Expected frequency distributions modeled using these sampling units allowed for the development of a common model developed for the range of conditions and pest densities observed in local agroecosystems. These probability density functions were combined with empirical, expert opinion regarding farmers, and then used to develop a sequential sampling plan that could optimize allocation of sampling labor resources. Trials to validate time saving benefits and accuracy of the sampling plan are confirmatory results which implied that savings of >40% of the sampling resources may be. Follow up on farm work to evaluate the cost benefit of the plan with respect to pesticide use have been initiated. If necessary, additional sampling plans can be generated to improve the efficiency, and validation work will now move into educational and implementation efforts.

Two educational and implementation tools for IPM in callaloo developed: the Identification Guide (Clarke-Harris *et al.* 1998) based on field collection and taxonomic collaborative research, and this sampling plan, based on field research and statistical collaborative research, both formatted for use in educational programs with extensionists and farmers have already been used in training workshop and in the second phase of the IPM-CRSP, impact assessment of audience knowledge of major pests and level of adoption of scouting procedures will be conducted. Select groups in other geographic locations will also be targeted to implement scouting systems.

The initial results obtained from on farm evaluation trials on both farms showed savings in pesticide inputs (Table 11) in pesticide application. Figure 3 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 on low pest populations.

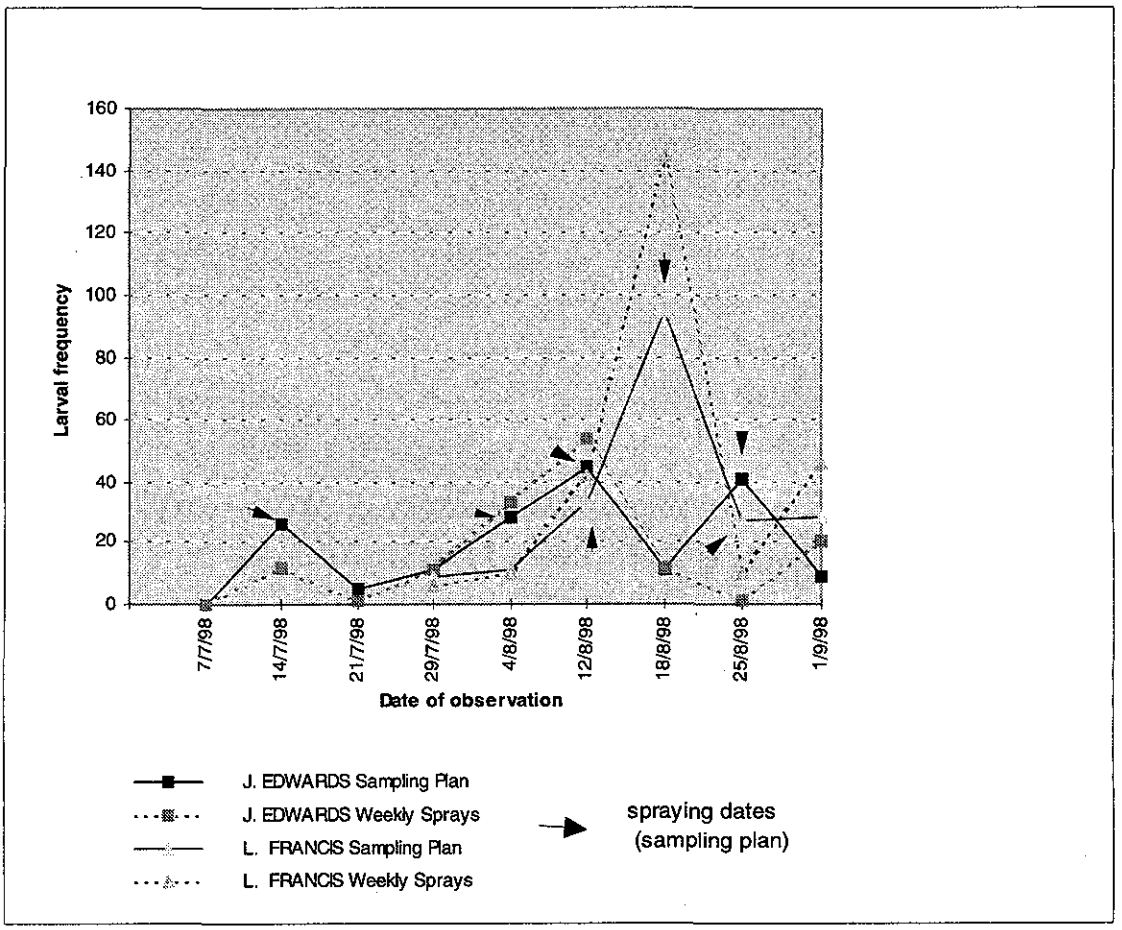

Figure 3: Relative incidence of lepidoptera larvae and spray applications in weekly sprayed plots versus spray timing using a sampling plan.

Table 11: Severity of damage to callaloo leaves treated with timed pesticide applications based on a sampling plan versus calendar spraying.

Farms	Sampling Plan					Calendar Spraying				
	No. of sprays	Mean number of leaves with damage index				No. of sprays	Mean number of leaves with damage index			
		0	1	2	3		0	1	2	3
Francis	3	15.8	44.7	55.7	33.8	6	15.8	44.5	59.2	30.5
Edwards	4	23.1	51.7	56	18.6	9	33	50.8	46.1	19.2

Comparison of degrees of severity of damage to callaloo leaves in both treatment plots showed no appreciable difference in level of damage despite the reduced pesticide input using the sampling plan. The number of spray applications were reduced by greater than 40% on both farms. These trials will be replicated on two additional farms.

There were no significant differences between mean percentage yields obtained from the two treatments on both farms (Figure 4). Insect damaged yields were higher than 35% for both treatments on both farms but were not significantly different between treatments indicating that the same levels of damage control may be obtained with less frequent applications. However again the need for more effective chemistries is evident.

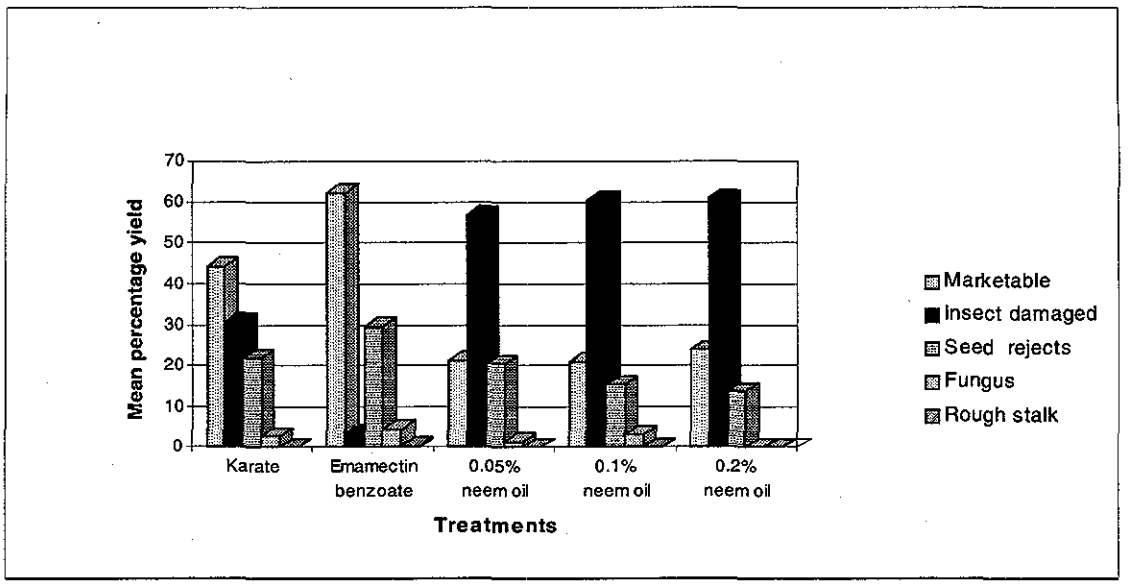

Figure 4: Comparison of percentage yields in different grade categories harvested from weekly sprayed plots versus plots with timed sprays based on sampling plan

Assessment of Exclusion as a Control Tactic for Callaloo Pests

Research Methods

Experimental design. A completely randomised design experiment (2 treatments x 3 replicates) was set up at CARDI, Mona Campus to investigate the effect of exclusion on insect damage levels on callaloo. Each plot consisted of 56 plants (8x7 plants) planted at 30 cm spacing within row and 45 cm spacing between row.

Sampling. The pest frequency and damage were monitored in each plot twice weekly. Ten plants were randomly selected along diagonals and samples taken.

Lepidopteran larvae. Three leaves per plant were randomly selected and examined, with the number of larvae. The larvae found were placed in three size categories (small<or = 10 mm; medium 10.1 to 20 mm and large > 10 mm).

Mites. Mite infestation levels were recorded per leaf. For mite levels greater than 21 adults the actual number of mites per leaf was recorded, a and b represented levels 21-100 and greater than 100 respectively.

Leaf damage assessment. The number of leaves per three

leaves having symptoms of fungus, mite, leafhopper and feeding hole damage was recorded. The level of lepidoptera feeding damage on each leaf was recorded as one of four indices: 0: No damage, 1: < 30% damage, 2: 31-60% damage, and 3: > 60% damage. Crop loss assessments were conducted as described previously.

Results and Discussion

Pest frequency. *Spoladea* and *Herpetogramma* had the highest populations in the field during the study. *Spodoptera* were also present but the numbers were low and no significant difference (P= 0.238) was detected between the treatments. The populations of *Spoladea* (P=0.023) and *Herpetogramma* (P=0.026) were significantly lower in exclusion cage plots than uncovered plots (Table 12). Leafhopper populations were not different between treatments and mites were rare.

Table 12: Relative frequency of arthropods in covered versus uncovered plots

Treatment	*Spoladea*	*Herpetogramma*	*Spodoptera*	Leaf-hopper
Exclusion	72.33	11.00	15.67	43.67
No exclusion	391.67	51.33	9.67	59.67
SEM	35.113	4.696	2.550	20.506
P	0.023	0.026	0.238	0.720

Pest damage incidence. The number of leaves showing symptoms of damage by arthrpod pests was lower in exclusion cage plots than uncovered plots (Table 13). Although these differences were not found to be significant, the number of leaves with feeding hole damage observed in exclusion plots was notably lower than in uncovered plots.

Table 13: Number of leaves showing symptoms of damage by arthropod pests

Treatment	Type of damage		
	Feeding holes	Leafhopper	Mite
Exclusion	244.7	216.3	2.67
No exclusion	406.3	297.00	0.67
SEM	29.85	33.12	1.08
P	0.062	0.23	0.32

Crop loss. The percentage of cumulative yields in the different reject categories was less from exclusion cage plots than from uncovered plots, however, this difference was only significant (P< 0.001) with respect to insect damaged rejects, where losses were 53.8 % in uncovered plots compared to 14.3% in covered plots (Table 14).

Table14: Comparison of yield grades obtained from covered and uncovered callaloo plots

Yield grade	Percentage Yield	
	Exclusion	No Exclusion
Insect	14.46	53.79
Seed	0.53	3.15
Mite	0	0.15
Rough Stalk	0	0.66
Fungus	0	0.98
Marketable	85.01	41.26

Total yield in exclusion cages was significantly (P=0.041) less than in uncovered cages and this was attributed to the shade factor in covered plots. Validation demonstration trials will be conducted on farm with row covers which give lower percent shading.

These results show a definite potential to exclude pests from the crop, but the type of material used to construct covering must be researched for optimum growth and development of the callaloo, and for cost effectiveness. The low level of losses due to insects in the exclusion plots is also noteworthy as this level of control was in the absence of pesticide use. Covering seed beds should further reduce pest infestation and damage caused by insect pests.

The experimental design was developed for follow-up studies to assess three row covers applied at two different phenological stages, at transplant and at first harvest. Selection of row covers was done in consultation with Drs Shelby Fleischser and Irene Mbugua, and Mary Woodecki of Penn State University. Three types of row covers have been identified and will also be used in demonstration plots on farm to sensitise farmers to this mode of production and its benefits in pest control.

Evaluation of the Efficacy of New Chemistries in Controlling Major Pests on Callaloo

Research Methods

A randomized complete block (five treatments and four replicates) experimental trial was laid down to compare the efficacy of manufacturer recommended rate of emmamectin benzoate with that of three concentrations of neem oil. The

farmer standard, manufacturer rate of lambda cyhalothrin (Karate®) was used as control. Treatments were applied once per week beginning two weeks after transplant.

Each treatment plot contains 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 plants per plot were monitored once weekly to determine pest infestation and damage.

Crop loss assessments were carried out as described previously.

Results and discussion

Pest frequency. On comparing incidence of lepidoptera larvae among treatment plots, plots treated with emamectin benzoate had the lowest larval populations (Figure 5). Plots treated with Karate® also had good control of lepidoptera larvae while the three concentrations of neem had the highest larval densities. Subsequent to the first harvest at four weeks after transplant, trends in yields among treatment plots appear to be substantiate that the insect growth regulator and the pyrethroid are the most effective treatments, the former being more effective. Lepidoptera populations in the last three weeks were below detectable levels in all plots.

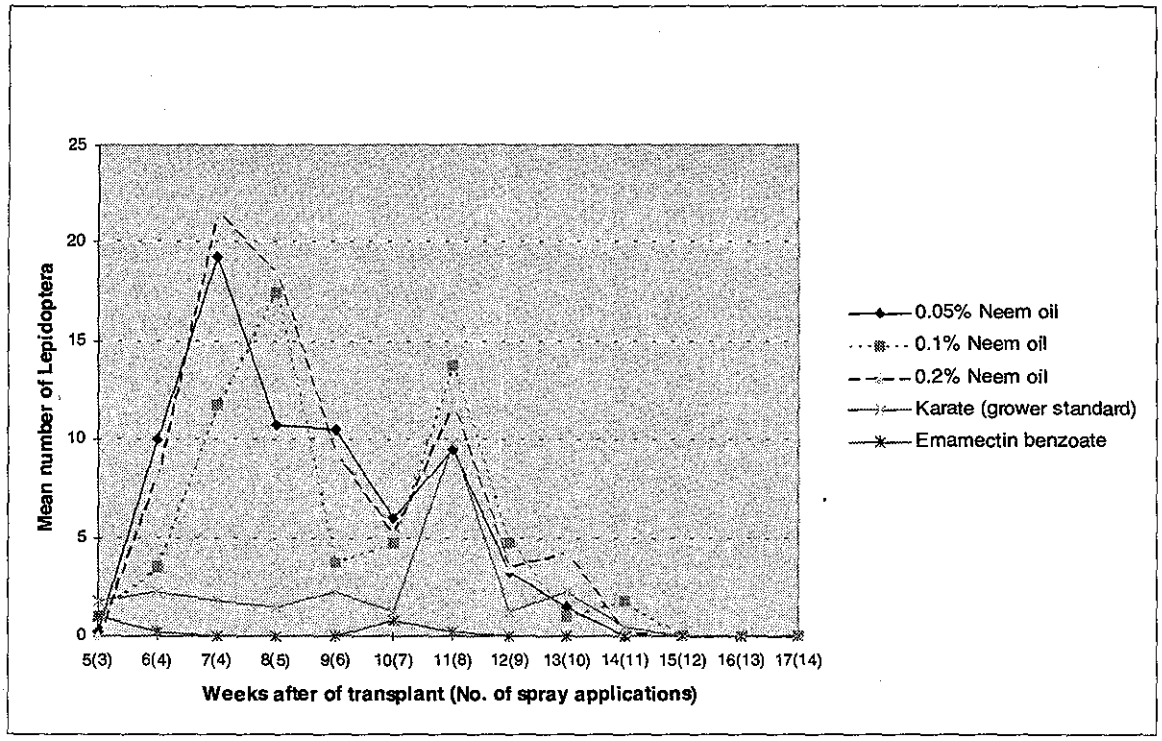

Figure 5: Effects of Karate, emamectin benzoate and three concentrations of neem oil on lepidopteran populations on callaloo

Damage incidence and severity. A comparison of the severity of damage to leaves collected from different treatment plots showed emamectin benzoate giving superior protection to the crop. The mean number of undamaged leaves observed in plots treated with emamectin benzoate was 87.6% compared with 49.2%. The three concentrations of neem did not appear to offer any protection against lepidoptera as over 71.8% had feeding hole damage 15 -20% had > 60% feeding hole damage (Figure 6).

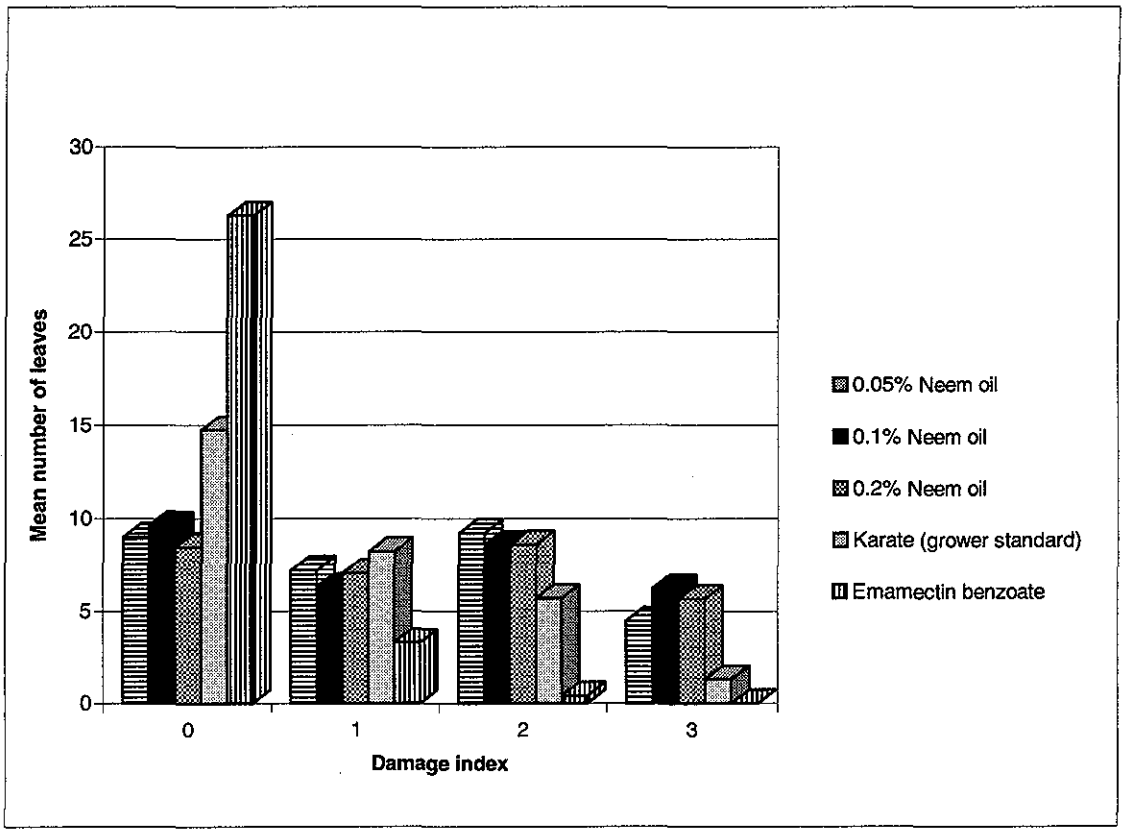

Figure 6: Lepidoptera damage levels on leaves sprayed with different insecticidal treatments

Crop Loss. Levels of crop loss followed the same trends as pest frequency and damage (Figure 7). Emamectin benzoate treated plots gave the highest volume of marketable yields (62.3 %) while showing comparatively less damage levels in insect damaged category (Figures 7 & 8). Marketable yields in other treatments ranged from 44.44% (Karate) to 21.07% (0.1% neem oil). Plots treated with emamectin benzoate had markedly lower insect damaged rejects than the grower standard and neem oil treatments had significantly ($P<0.05$) higher losses (Figure 8).

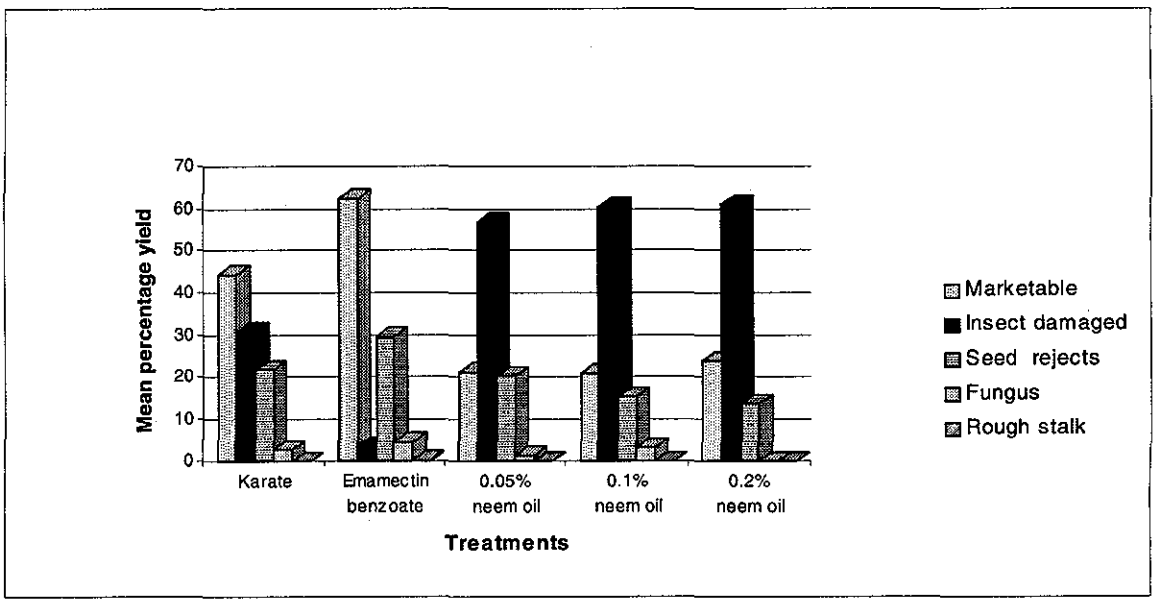

Figure 7: Effects of Karate, emamectin benzoate and three concentrations of neem oil on yield grades of callaloo

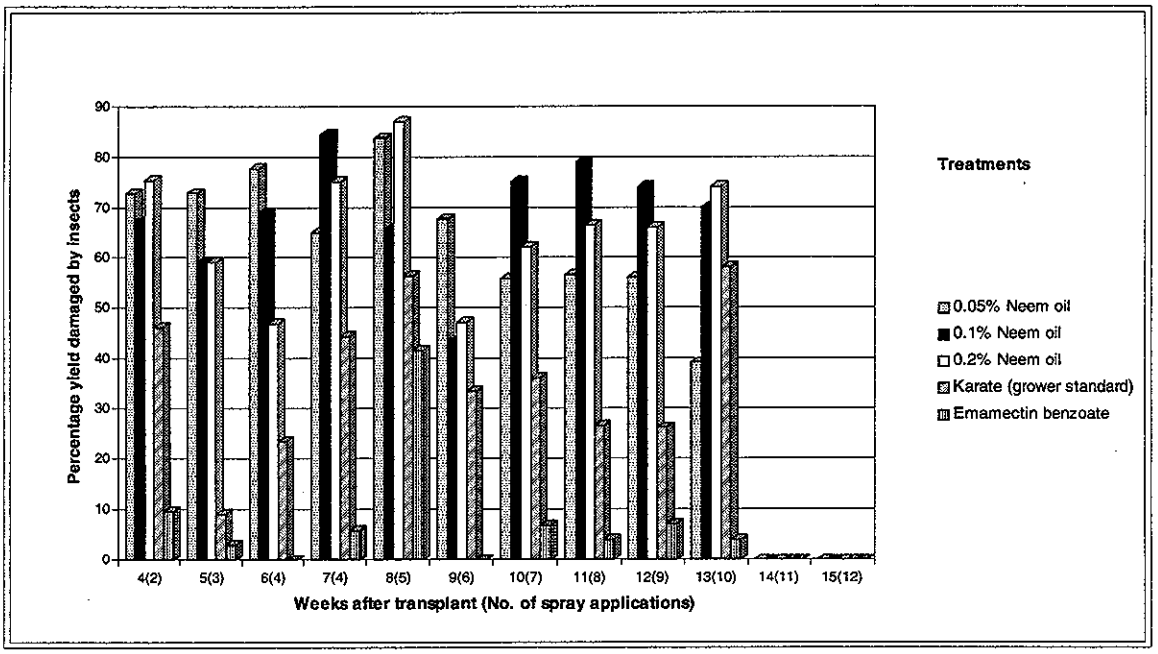

Figure 8: Effects of Karate, emamectin benzoate and three concentrations of neem oil levels of callaloo rejects caused by lepidoptera larvae

The high level of control of lepidopteran pests obtained with emamectin benzoate gives credence to the perception that insectcide resistance is the main contributor to the ineffectiveness of current pesticides. Should this new chemistry (insect metabolite) be introduced for the control of lepidoptera larvae, strict resistance management procedures have to be in place to prevent the erosion of its efficacy

The failure of neem oil treatments could have been due to instability of the active ingredient in its natural state or sublethal doses in applied concentrations. Follow up evaluations will be carried out on commercial formulations of azadiractin and mini trials will be conducted with the neem oil to explore its usefulness.

Farmer Survey Workshops

Research Methods

A farmer training workshop was held for farmers in the old Harbour and Bushy Park communities. The theme of the workshop was "Integrated Pest Management on callaloo- *Pest Identification, Scouting and Timing Pesticide Application*". The objectives were:

- to improve farmer pest and disease diagnostic capabilities
- to provide general information on proper pesticide use and agronomic practices involved in IPM in callaloo systems
- to initiate sensitization of farmers to the concept of regular scouting using a sequential sampling tool for decision making.

Results and Discussion

A total of 16 farmers from the Bushy Park area attended the workshop. IPM CRSP activities were reviewed to give background information on CARDI's research efforts in pest problems on callaloo. The components of IPM of callaloo were outlined and two handouts were distributed (see Appendices 2 and 3). Preserved and live specimens and mounted photographs of pests and diseases of callaloo were used to educate farmers in identification of the major problems. Farmer education pest/ disease diagnosis was identified during the workshop in October 1997 to be a critical need. A sequential sampling tool developed for making pest management decisions against lepidoptera larvae was introduced during an interactive exercise. Farmers showed great enthusiasm for the plan and were very receptive to applying it to their management systems.

Post Harvest Disinfestation of Callaloo

Pre-intervention Assessment of Postharvest Treatment. Visits were made to the Agricultural Marketing Cooperation (AMC) where the majority of callaloo for export are prepared for export. Informal interviews with six exporters were conducted to obtain background information on major problems at this stage of production and marketing. Post harvest treatment was observed and information obtained were used as the basis for developing protocols for disinfestation trials.

Preclearance Survey. A survey of the level of rejection of callaloo was initiated at the two international airports.

Disinfesting Trials. Three concentrations of salt solution (0,

2% and 5%) were assessed at three retention times (1,5 and 8 minutes) to determine effectiveness at removing pest residues from harvested callaloo stalks. 13.64 kg of callaloo stalks were used for each trial. Before treatment, a 1.5 kg sample was randomly taken from among pretreated stalks, all leaves were examined, the number each pest species found was recorded and the sample replaced. Salt was added to forty five gallons of water to make up the desired solution. Callaloo stalks were submerged in solution and agitated for the designated retention time then removed from solution and rinsed twice for five minutes each in forty-five gallons of water. Another 1.5 kg sample was taken after the final rinse and a post treatment assessment conducted.

Monitoring shelf life. The shelf life of the produce after washing was assessed for each treatment. Half a kilogram of callaloo was trimmed of all unhealthy leaves and the remaining healthy leaves counted. They were then placed in plastic bags which were pierced with six holes, 7 cm in diameter and refrigerated. The condition of the leaves on each stalk was examined over the next seven days record was made of leaf abcission and the number of healthy, wilted and decomposed leaves.

Results and Discussion

Informal interviews with six exporters revealed that winter months, November to March, are relatively good months for them as pest populations are relatively low. Consequently, their shipments are seldom rejected during this time. Post harvest treatment was observed and information obtained will form the basis for developing protocols for disinfestation of callaloo for export.

During the preclearance survey of the level of rejection of callaloo at the two international airports was obtained between February 17 and April 4, 1998. Information from Norman Manley International Airport reported that of 2,862 cartons (39, 027 kg) of callaloo submitted by 12 exporters for export to the US during this period 2,582 cartons (90.2%) were accepted. 280 cartons (9.8 %) were rejected because of the presence of lepidoptera pests on them.

Shipment of callaloo from the Sangster's International Airport was very rare for the duration of the survey. Only two batches (two exporters), totaling 80 cartons (1088 kg) were submitted for export to USA (39 cartons) and Canada (41 cartons). The 39 cartons (48.7%) for the US market were rejected due to the presence of lepidoptera. Lepidoptera is not of quarantine importance to the Canadian market therefore the 41 cartons were shipped although larvae were present.

Data obtained from disinfesting trials and monitoring shelf life after treatment are being analysed and the optimal concentration and retention time deduced will be used to conduct evaluation trials on optimal throughput per volume of washing solution. During this experimentation a callaloo washer basket was designed and constructed in order to reduce the level of mechanical damage to leaves during agitation in wash solution, this device is currently being validated. The washer basket will also improve the efficiency with which callaloo is removed from solution.

Impact

This year marked the end of the first five-year phase of the IPM CRSP project. Achievements during this phase greatly contributed to the resource base on this commodity and opened up new avenues along which the management of this crop can be greatly improved.

Networking Activities

- Visited with Dr Shelby Fleischer, Vegetable Entomologist, at Penn State University, January 18-24, 1998 to analyse data collected from field trials conducted at the Jamaica Site
- Networking with IPM researchers from the wider Caribbean during the Second Meeting of the IPM Network, February 4-6, 1998
- Visited the Agricultural Marketing Cooperation, to liaise with Callaloo exporters February 16 and 23
- Collaborative Research planning meeting between CARDI and MINAG, Bodles Staff, February 18
- Conducted Farmer Training Workshop, Integrated Pest Management of Callaloo- *Pest Identification, Scouting and Timing Pesticide Application*, April 30 with an attendance of 16 farmers
- Caribbean Site Meeting, Virginia Polytechnic Institute (VPI), May 13-14
- Networking with IPM researchers from the other CRSP sites during the Third Technical Symposium, IPM CRSP, May 15-16
- Revision of workplan and budgets for IPMCRSP Phase II Year I
- Networking with IPM researchers from the wider Caribbean at the Caribbean Food Crop Society Meeting, Holiday Inn Sunspree Resort, Montego Bay Jamaica, July 13-16, 1998
- Networking with IPM researchers from the wider Caribbean to identify research needs to address food safety issues affecting the Caribbean during the Regional Workshop, *Food Safety Initiatives Influencing Hemispheric Trade*, September 13-16, 1998

Publications and Presentations

Poster presentation, *Networking for Sustainable IPM Solutions*, Second Meeting of Integrated Pest Management Network

- Identification Guide *Major Pests of Callaloo.* Technical Bulletin *D O Clarke-Harris, S J Fleischer and A Fender*
- Development of a sequential sampling plan for the lepidopteran complex in vegetable amaranth in Jamaica, *D O Clarke-Harris and S J Fleischer,* paper presented at the Third Annual Symposium of IPM CRSP, VPI, May 15-16.
- Identification Of Major Pests And A Sampling Plan For Lepidoptera Larvae In *Amaranthus viridis* (Callaloo) In Jamaica, *D O Clarke-Harris*[1], *S J Fleischer*[2] Paper presented at the 34 th Caribbean Food Crop Society Meeting, Holiday Inn Sunspree Resort, Montego Bay Jamaica, July 12-18
- Poster presentation, *"Promoting Sustainable and Competitive Agriculture for the New Millenium"* National Consultation- PROCICARIBE, August 4-5

Highlights

- The lepidopteran pest complex which significantly affects the quality of harvested yields of callaloo was identified at the species level into five taxa
- A identification guide to major pests of callaloo was published.
- A sampling tool to guide the timing of pesticide applications was developed.
- A statistical model of the frequency distribution of sampling units relevant to this agroecosystem, allowing for development and modification of sampling plans
- A promising safer pesticide to control lepidopterous pests on callaloo was identified.
- The potential of the use of row covers as a pest management alternative to contemporary production practice was identified.
- A washer basket to increase the efficiency of post harvest disinfestation of callaloo was designed and constructed.
- 16 callaloo farmers from a major callaloo growing area in pest identification and principles and practice of IPM were trained.

IPM Systems Development of Hot Pepper, *Capsicum chinense*

Investigators: R. Fery[1] , J. Thies[1]; AL. Myers[2]; R. Martin[3], J. Reid[3]; S. McDonald[4], B. Nault[4], and S. Tolin[4], F.W. Ravlin[5]

Collaborating Scientists: D. Hutton[6], D. McGlashan[2], T. P. Mack[4]; F. McDonald[3], B. Lauckner[3], P. Chung [7]

Abstract

Hot pepper farms in the parishes of St Mary, St Catherine and St Elizabeth were surveyed over four periods between February 1997 and March 1998 to determine the incidence of pests as well as production practices. Virus symptoms were observed on 99% of farms with plants over two months old. Tobacco etch virus was the most frequently detected virus, being present on 72% of farms. Aphid vectors such as *Aphis gossypii* and *Myzus persicae* were the most prevalent arthropod pests and were present on 74% of farms.

The population dynamics of these vectors has been monitored, from March 1998, on four farms in South St Catherine using pan traps. *Myzus persicae, Uroleucon ambrosiae* and *A gossypii* have been the most frequently detected species. Highest populations were recorded at the start of the study in February. *Aphis gossypii* is the only species which has been present throughout the entire study period.

1 USDA, ARS 2MINAG 3CARDI 4Virginia Tech 5Ohio State 6UWI 7RADA

The temporal and spatial pattern of virus spread was monitored in South St Catherine. Tobacco etch virus (TEV) was the only virus detected. The rate at which plants became infected with TEV over the study period followed a logistic pattern indicating that the virus is spread mainly by intrafield means (secondary infection).

An experiment assessing the impact of viruses on the yield of Scotch Bonnet and West Indian Red found the yield of virus infected Scotch Bonnet plots to be 50% lower than that of uninfected plots. The yield of virus infected West Indian Red plots was 15% lower than that of uninfected plots.

Laboratory, greenhouse, and field studies were conducted to address pest problems associated with the production of peppers in the Caribbean and the United States. Four manuscripts reporting research conducted, in part, with IPM-CRSP funds were published in refereed journals. A breeding program to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into Habanero pepper was continued; the second backcross was completed and resistant plants were selected from this backcross for use in completing the third backcross. The resistance to the peanut root-knot nematode (*Meloidogyne arenaria* Race 1) exhibited by the *C. chinense* germplasm line PA-353 was found to be conditioned by a single dominant gene; this gene is probably allelic to a gene that conditions the resistance in *C. annuum*.

The results of a field test conducted cooperatively with a CARDI investigator in St. Kitts demonstrated that the recently released *C. chinense* germplasm lines PA-353, PA-398, and PA-426 are resistant to indigenous field populations of *Meloidogyne* spp.; two *C. chinense* cultivars that are commonly grown in the Caribbean were susceptible. The results of growth chamber tests indicated that resistance to southern root-knot nematodes (*M. incognita*) in *C. chinense* is compromised at high temperatures. However, the root galling response and nematode reproduction in the resistant Scotch Bonnet germplasm line PA-426 at high temperatures was significantly lower than in susceptible Habañero-type peppers. Root-knot resistant *C. chinense* cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates.

An experiment designed to compare the labor and expense of using back-pack sprayer applications of the natural herbicide pelargonic acid (Scythe) with hand weeding for controlling weeds in peppers was repeated. Weed control with the herbicide took less labor than hand weeding; however, monetary savings in labor were offset by the cost of the herbicide. An experiment to evaluate four summer legumes (cowpea, soybean, sunnhemp and velvetbean) as cover crop mulches for pepper production is in progress. Preliminary observations indicate that (1.) each of the mulches suppresses weed growth, and (2.) early growth of peppers planted in mulches is more rapid than those planted in bare soil, probably due to nitrogen provided by the legumes.

A district in St Mary has been selected for the transfer of IPM technology. Four training sessions were held in the district. Topics such as "IPM", "Common pests of hot peppers and their control", and "Common question which arise at the start of hot pepper production" were covered. The training days are now being held in farmers' fields where hot pepper crops have been followed since the seedling stage.

Objectives

- Determine the incidence of arthropod pests of hot pepper in various agroecological zones in the parishes of St Mary, St Catherine and St Elizabeth
- Collect information on current hot pepper production practices
- 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.
- Investigate the temporal and spatial patterns of virus (e.g., tobacco etch virus) spread in a *C. chinense* field.
- Determine the impact of viruses and mites on the yield of two varieties of hot pepper (Scotch Bonnet and West Indian Red).
- Evaluate control tactics (USDA resistant clones, mulches, screen cages, acaricides, soaps and oils) to manage pepper pests
- Develop root-knot nematode (*Meloidogyne incognita*) resistant habanero-type peppers (*Capsicum chinense*)
- Determine the inheritance of peanut root-knot nematode (*Meloidogyne arenaria*) resistance in *C. chinense*.
- Evaluate various root-knot nematode resistant Scotch Bonnet (*C. chinense*) lines in Jamaica and/or St. Kitts for adaptability, horticultural traits, and yield.
- Evaluate the stability of root-knot nematode resistance in Scotch Bonnet peppers under high temperatures.
- Develop methodologies for using the newer and safer

herbicides in combination with simple application equipment for controlling weeds in pepper.

- Determine the feasibility of using mulched cover crops to control weeds in pepper plantings.
- Develop and evaluate training packages to extend pepper IPM methods to farmers

IPM Constraints

Viruses, mites, root-knot nematodes and weeds are widely recognized as yield-limiting pests of peppers. However, the relative importance of these pests in Jamaica and the wider Caribbean is largely unknown. This must be determined so that research is directed at key pests and strategies developed which maximise the adoption of IPM. Many weeds are known to be alternate hosts of root-knot nematodes and other plant pathogens, and the alternate host status of weeds must be considered for successful implementation of an IPM program. The major constraints being addressed by this project are, the unavailability of information on pest status, 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 making herbicide recommendations for the pepper cropping systems in Jamaica.

Incidence of Pests of Hot Pepper in Various Agroecological Zones in the Parishes of St Mary, St Catherine and St Elizabeth *(R. Martin, L. Myers, S. McDonald and F.W. Ravlin)*

Research Methods

With the assistance of the local extension service (Rural Agricultural Development Authority) as well as farmer cooperatives, major pepper districts in the parishes of St Mary, St Catherine and St Elizabeth were identified. These were grouped based on elevation and annual rainfall as well as their location in the parishes. Two to 5 farms were surveyed in each section. The number of farms selected was dependent on the number of farms in each district. Farms with plants under one month old were not included in the survey. On each farm 20 plants were selected systematically. The sampling interval between and within rows was dependent on farm size and shape and ranged in number from 2 to 10. Plants were assessed for the presence of viral symptoms and arthropod pests. Viral symptoms were scored from 0-4, 0 being no symptoms and 4 severe leaf deformation and reduction in leaf size, while the incidence of arthropod pests was scored based on presence or absence on four sections of the plant. These sections were selected based on the natural branching of the plant (Table 1).

Table 1: Characteristics of the areas surveyed within the parishes of St Catherine, St Elizabeth and St Mary

Parish	Section	Elevation (m)	Rainfall (mm)[1]	Temperature[2] Min	Max
St Catherine	North (NSC)	160 – 280	1242 [1366]	17.4	30.3
	Central (CSC)	180 – 280	1100 [1616]	18.0	30.9
	South (SSC)	<20	647 [1052]	18.6	31.5
St Elizabeth	North (NSE)	200 – 450	2452 [2496]	17.4	30.4
	South (SSE)	80 – 200	713 [1551]	18.5	31.5
St Mary	North (NSM)	20 – 200	1008 [1774]	18.6	31.6
	South East (SESM)	160 – 200	958 [1838]	17.2	30.1
	South West (SWSM)	300 – 500	1362 [1960]	16.1	29.0

[1] Annual values for 1997 [30 year mean; 1951-1980] ,[2] 30 year means; 1951-1980

The survey was conducted over four seasons between February 1997 and March 1998. During the first season, soil samples were collected from the farms and assessed for nematodes while leaf samples were collected from each farm for confirmation of virus presence by light microscopy.

Chi squared analysis was used to assess differences in incidence among survey periods while Analysis of Variance was used to assess differences in virus severity and arthropod levels among seasons and among districts.

Research Results

Virus symptoms were observed on 97% of farms surveyed (Table 2).

Table 2: Virus incidence (%), and mean severity score (range: 0-4) on farms surveyed in St Mary, St Elizabeth and St Catherine; February 1997 to March 1998.

Period	No. of farms	Virus incidence (%)	Mean Virus score	SE
Feb to Apr 97	46	98	2.36	0.132
Jun to Aug 97	29	93	2.28	0.166
Oct to Nov 97	23	96	2.37	0.187
Jan to Mar 98	25	100	2.66	0.179
Overall	123	97	2.41	0.0807

All farms with plants over six months old and 99% of farms with plants over two months old were infected indicating that the viruses infected the crop early. This has implications for yield as several reports indicate that the

younger the plants are infected the less yield is obtained. TEV was detected in samples from 72% of the farms assessed while PVY was detected on 31% of farms and TMV on 19% of farms. There were no significant differences in virus severity or incidence among seasons. For all seasons about 75% of plants had severity scores of 2 or 3 with the mean severity score being 2.41 overall. Rootknot nematodes, *Meloidogyne* sp. were present on 26% of farms assessed: 33% of farms in St Mary, 10% of farms in St Catherine and 29% of farms in St Elizabeth.

Aphids were present on a significantly higher number of farms (74%) than other arthropod pests (P<0.001; Table 3). However, the incidence was significantly lower than that of virus infection (P<0.001). On 92% of farms, 50% or more of the plants assessed were infected with a virus while on only 12% of farms, 50% or more of the plants assessed had aphids. This indicates that the aphid transmitted viruses were being spread by transient aphids. The farmer practice of planting a new crop close to an old crop will therefore aid in virus spread. Locating the nursery in or close to an old field also increases the chance of plants being infected.

The broad mite (*Polyphagotarsonemus latus*) was the next most common arthropod pest and was present on 37% of farms while whiteflies, thrips and stink bugs were present on 34%, 27% and 26% of farms respectively. There were no significant differences among seasons in the incidence of any arthropod pest (Table 3).

Table 3: Incidence (%) of aphids, thrips, mites, whiteflies and stink bugs on farms surveyed in St Mary, St Elizabeth and St Catherine; Feb 1997 to Mar 1998.

Period	No. of farms	Aphids	Mites	Whiteflies	Thrips	Stink bugs
Feb to Apr 97	46	80	35	24	26	17
Jun to Aug 97	29	72	31	31	45	28
Oct to Nov 97	23	83	44	39	17	35
Jan to Mar 98	25	56	44	52	16	32
Overall	123	74	37	34	27	26

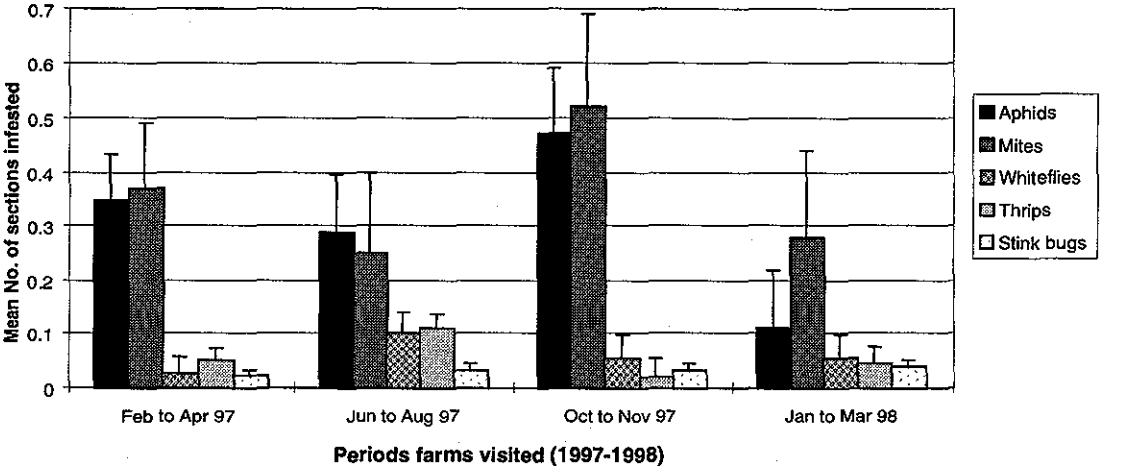

Figure 1. Infestation levels of arthropods on farms surveyed

Aphids and mites had similar infestation levels and were present on significantly more sections than other pests (Figure 1; P<0.001). Farmers attach more importance to mites because the effect on the plant is relatively fast and very noticeable. In severe cases, the growth of the plant is restricted due to defoliation of the growing parts and the fruits are hardened making them unmarketable. Very few farmers are aware that aphids transmit viruses and see them as harmless requiring no control.

Although present in smaller numbers the importance of whiteflies should not be underestimated as they are transient vectors of the tomato yellow leaf curl geminivirus. The status of these viruses is currently being investigated by a group of scientists from the University of the West Indies.

Pests of quarantine significance such as thrips do not have to be present in large numbers to generate concern. Also, pests which affect the fruit such as stink bugs and fruitworms, need not be present in large numbers to be economically important. Their high mobility enables a few to damage a significant portion of the crop.

No significant differences were found over seasons in the number of plant sections with the various arthropod pests.

This can be attributed to high variability, within each season, in infestation levels among the areas surveyed. Significant seasonal differences in aphid infestation levels were detected in South St Catherine only, where the highest level was observed in the October to November period (Figure 2).

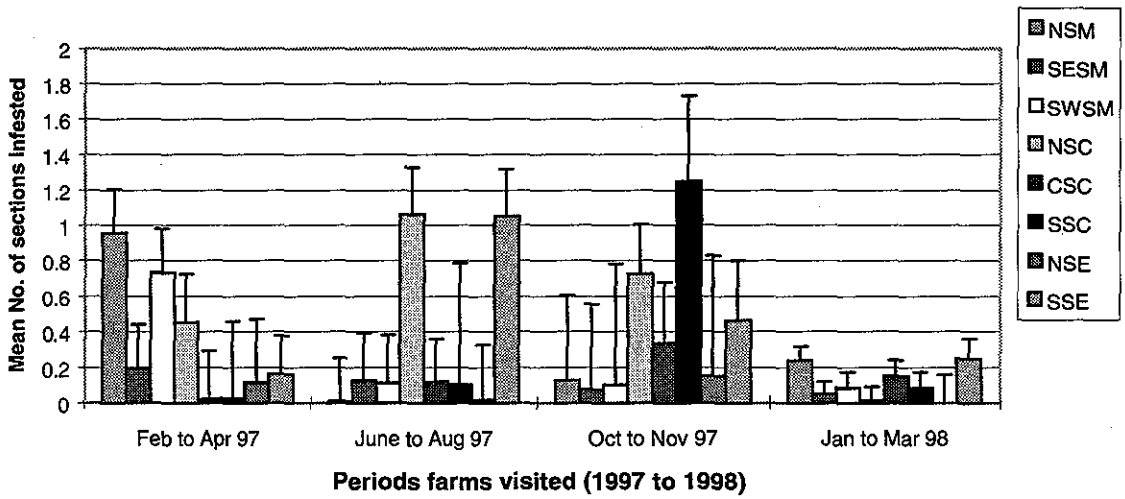

Figure 2. Infestation levels of aphids in areas surveyed

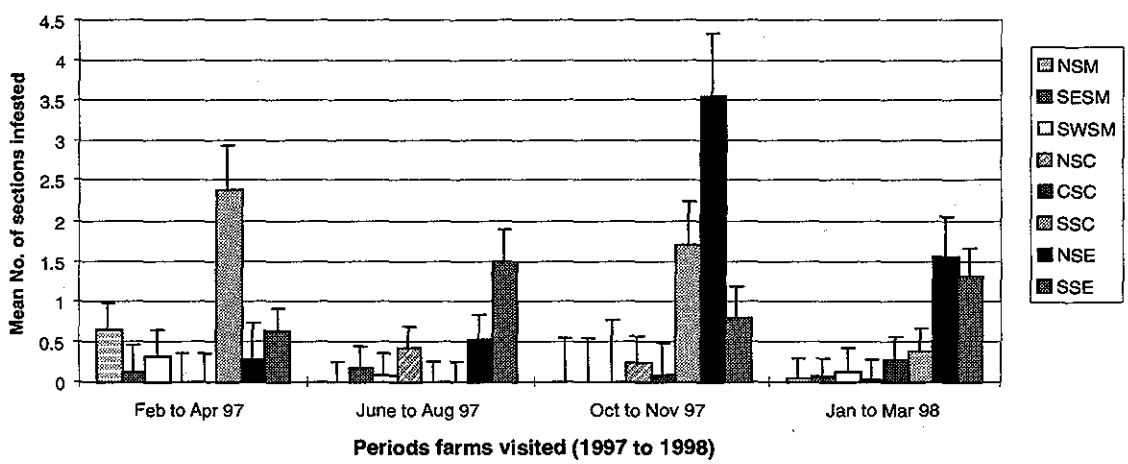

Figure 3. Infestation levels of broad mites in areas surveyed

This area had the highest rainfall; however, the broad mite is able to survive in areas with high rainfall as it lives under the leaves where it is sheltered (Messiaen 1992, Parker *et al* 1995). Across locations, higher levels of mites and aphids were detected in wetter periods than drier periods. This does not necessarily imply a direct relationship with rainfall but may be a response to new growth as the plants would have been water stressed due to lower than average rainfall during the period of study. The variability among locations in infestation levels is expected because factors which influence pest populations, such as fertilizer use pattern, presence or absence of irrigation as well as shade management were also highly variable. This provides a challenge to the IPM practitioner who, therefore, has to tailor interventions to address specific conditions present on farms. Therefore, training in IPM should be principle based.

Production Practices on Farms Monitored for Seasonal Pest Incidence

Research Methods

Farms surveyed in this section are those previously selected. A questionnaire was used to assess current agronomic practices as well as farmer perception of the impact of pests

on yield.

Research Results and Discussion

The area of hot pepper cultivated on farms surveyed ranged in size from approximately 0.04 ha (200 plants) to 4 ha (10,800 plants). The median area cultivated was 0.12 ha. The maximum age of plants (after transplanting) was 26 months while the median age of plants was seven months. None of the farms visited in St Mary were over one year old while 77% and 88% of farms in St Elizabeth and St Catherine were one year and older. The length of time that farmers were growing peppers ranged from five months to approximately 20 years. Median years of experience was three years. St Mary (35%) had the highest number of farmers growing peppers for less than one year while St Elizabeth was the only parish with farmers with over 20 years experience (Table 1). Both were from South St Elizabeth.

Table 1: Experience of farmers in hot pepper production in the parishes surveyed.

		% Farmers planting hot peppers for less than 1, 3, 10 and 20 yrs			
Parish	**#**	**< 1year**	**< 3 yrs**	**< 10 yrs**	**< 20 yrs**
St Mary	29	35	55	86	100
St Catherine	20	15	50	90	100
St Elizabeth	15	13	33	80	87
Overall	64	23	48	86	97

The majority of farmers in St Mary (92%) and St Catherine (95%) grew a yellow variety of hot pepper (mainly Scotch Bonnet) to be sold as fresh produce on the export and local markets while 62% of those in St Elizabeth grew red varieties to be sold to processors. This difference is also evident within St Elizabeth as all farmers surveyed in North St Elizabeth (3/3) grew a yellow variety while 82% (9 of 11) of those in South St Elizabeth grew a red variety. Eighty three percent of farmers in St Mary, 68% percent of farmers in St Catherine and 52% of farmers in St Elizabeth plant between June and November each year.

In the first season (February to April 1997), thirty percent of farmers were growing hot peppers for the first time. Of those who were replanting, 10% had planted hot pepper at the same location in the farm the year before. Another 13% had planted tomatoes at the same location while 47% intended to replace the current pepper crop with another pepper crop at the same location. Fifty percent had more than one plot. Of these, 70% had the plots at the same site. Seventy percent of the farmers sourced seeds off the farm such as from other farmers and farm stores while 90% produced their own seedlings. Thirty four percent planted with spacing of 1m x 1m, 36% planted at a wider spacing, 20% at a narrower spacing while 10% didn't plant at a set spacing.

Fifty three percent of farmers applied foliar fertilizer (20-20-20 NPK) to their plants weekly or fortnightly. Of these, 28% applied other fertilizers to the soil at planting, after first harvest and monthly thereafter. The other 25% applied at planting and every three months after. Use of organic manure was dependent on availability. Only 10% of farmers reported using it. Average weekly yield was approximately 500 kg/ha while average weekly yield per thousand plants was approximately 200 kg. This was well below farmer expectation as the average yield expectancy was 1700 kg/ha.

Thirty three percent of farmers surveyed considered viruses to be their major pest. Among the parishes, St Elizabeth had the most farmers (64%) with this perception while St Catherine had the least (12%; Table 2). Mites were considered to be the major pest by 20% of farmers while 23% of farmers did not think that they had a major pest problem. Seventy eight percent of the farmers surveyed used pesticides. The most frequently used insecticides were diafenthiuron and profenophos which were each used by six farmers in mite control. In all, a total of 21 pesticides were used; 14 insecticides and 7 fungicides (Table 3). One farmer used a mixture of diafenthiuron, profenophos and lambda cyhalothrin to control mites after they failed to give adequate control singly or two at a time.

Table 2: Farmer perception of major pest on farms surveyed in St Mary, St Elizabeth and St Catherine.

		Percent farmers indicating pest as major pest					
Parish	**No. of farmers**	**Virus**	**Aphids**	**Mites**	**Fungi**	**Other**	**No major pest**
St Mary	29	35	6.9	24	3.5	14	21
St Elizabeth	14	64	0	21	7.1	0	7.1
St Catherine	17	12	0	18	18	12	41
All farmers	60	33	3.3	20	8.3	10	23

Note: Other pests include stink bugs, hornworms, whiteflies, crickets and slugs

Table 3: List of insecticides/acaricides and fungicides used by hot pepper farmers

Trade Name	Common Name	Trade Name	Common Name
Agrimek	avermectin-b	Neoron	bromopropylate
Basudin	diazinon	Pegasus	diafenthiuron
Belmark	fenvalerate	Ridomil	metalaxyl
Bravo/Daconil	chlorothalonil	Selecron	profenofos
Champion	copper hydroxide	Sevin	carbaryl
Decis	deltamethrin	Shell white oil	petroleum oil
Dithane	mancozeb	Perfekthion	dimethoate
Karate	lambda-cyhalothrin	Thiodan	endosulfan
Kocide	copper	Top-Cop	basic copper sulfate
Lannate	methomyl	Topsin	thiophanate
Malathion	malathion		

Hot pepper is now grown as an annual crop rather than a perennial due to viruses and market prices. Several farmers abandon their crop during the summer months when prices are low. The practice has implications for pest incidence as the abandoned crop may serve as a reservoir for pests.

The survey has identified three distinct groups of farmers; those linked to a cooperative or exporter and who mainly produce for export, those with contracts with processors and those who sell to the local markets mainly. Recently, farmers producing for export have been hard hit by the detection of a new Dipteran pest of the family Cecidomyiidae. The pest, which develops in the pedicel of the fruit, is of quarantine significance to the United States and several shipments have been rejected. There is now mandatory fumigation at the ports. CARDI is a member of the task force formed to develop strategies to manage the pest.

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, B. A. Nault, S. A. Tolin, T. P. Mack, L. R. Nault, and J.C. Reid)

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 the species recorded or described. Samples of each species of aphid were sent to an aphid taxonomist for confirmation or identification.

Farm 1 is located on the Ministry of Agriculture Research Station in Bodles and was an area of approximately 1 ha. Other crops grown on this piece of land included, *Allium cepa* (onion), *Zea mays L.*(corn), *Hibiscus* sp., and *Ipomoea batatas* (L) Lamarck (sweet potato). Farms 2, 3 and 4 are located in Bushy Park. Farm 2 was a 0.6 ha plot of pepper, bordered on one side by a plot of *Abelmoschus esculentus* (okra), and an abandoned Scotch Bonnet plot on the other side. This farm was abandoned in the middle of the season. The 0.8 ha plot which comprised Farm 3, only had 0.04 ha of land under pepper at the beginning of the season and then a new pepper plot occupying about 0.2 ha of land at the end of the period under investigation. Other crops grown were *Lycopersicon esculentum* Miller (tomato), *Amaranthus dubius* Mart. (callaloo) and *Cajanus cajan* (pigeon peas). Farm 4 is 4 ha in size but had only 0.4 ha of peppers. Other crops grown included *Solanum melongena* L. (egg plant), *Brassica* spp., *Cucumis* spp., and *Momordica* spp.

All farms had heavy weed pressure during some periods of the study. Farms 2 and 3 had the heaviest weed pressure, lasting throughout most of the investigation. The other two farms tended to become weedy during rainy periods. The weed species were common to all farms and included,

Amaranthus spp. (Amaranthaceae), *Parthenium hysterophorus* L. (Asteraceae), *Cleome viscosa* L. (Capardiaceae), *Commelina elegans* Hbk. (Commelinaceae), *Chamaesyce* spp. and *Phyllantus amarus* Schum. & Thonn. (Euphorbiaceae), *Cyperus rotundus* L. (Cyperaceae), *Cenchrus echinatus* L. and *Sorghum halepense* (L.) Pers. (Poaceae).

The effect of time on the abundance of aphids was analysed for each farm using regression analysis (JMP, SAS Statistical Institute Inc. 1995)

Research Results and Discussion

About seven species of aphids have been found in the water pan traps. Their identification have not yet been confirmed. These include *Myzus persicae, Uroleucon ambrosiae, Aphis gossypii, A. craccivora, A. fabae, Tetraneura nigriabdominalis, and Pentalonia nigronervosa.*

Mean aphid flights varied significantly ($p < 0.001$) with time on farms 1, 3, and 4 but was consistently low ($p > 0.1$) on Farm 4 (Fig. 1). Aphid flights were highest during mid February to mid March with moderate counts during mid March to mid May and the last two weeks of July. Very few aphids were found during the rest of the study period.

The aphid species complex varied throughout the season with *Myzus persicae, Uroleucon ambrosiae* and *A gossypii* being the most abundant. *M. persicae* were absent after April, while *U. ambrosiae* were present until May and *A. gossypii* were found throughout the entire study period. Other aphid species found included *A. craccivora, A. fabae, T. nigriabdominalis,* and *P. nigronervosa. A. craccivora* was seen on one occasion only, during Mid April. *A. fabae,* and *P. nigronervosa* were observed during April to June. *T. nigriabdominalis* was found throughout the study period, especially during periods when field plots became infested with grasses.

Investigating the Temporal and Spatial Patterns of virus (e.g., Tobacco Etch Virus - TEV) Spread in a *C. chinese* Field *(S. McDonald, B. A. Nault, S. A. Tolin, T. P. Mack, L. R. Nault, and J.C. Reid)*

Research Method

Scotch Bonnet seeds were sown and the seedlings grown under a screen cage that excluded aphids. On June 26, 1998 about 900 plants were transplanted at the field station of the Ministry of Agriculture, in Bodles, St. Catherine. Seedlings were planted in 26 rows containing 35 plants, 0.9 x 0.9 m apart, respectively. Each week thereafter, Scotch Bonnet plants were observed individually for symptoms of virus infection. Symptomatic Scotch Bonnet pepper plants were tagged with a different colour flag each week. Tissue blots were taken from each symptomatic plant as well as from 20 randomly selected pepper plants each week. Virus infection was confirmed by serological assay of the tissue blots. Four virus antisera, tobacco etch, potato virus Y, cucumber mosaic and tobacco mosaic, were used.

Research Results and Discussion

Only tobacco etch virus (TEV) was confirmed in the Scotch Bonnet plants. The first symptomatic Scotch Bonnet pepper plant confirmed as having TEV was observed four weeks after transplanting. The rate at which plants became infected with TEV seems to follow a logistic pattern (Fig 2.) which indicates that the virus is spread mainly by intrafield means (secondary infections).

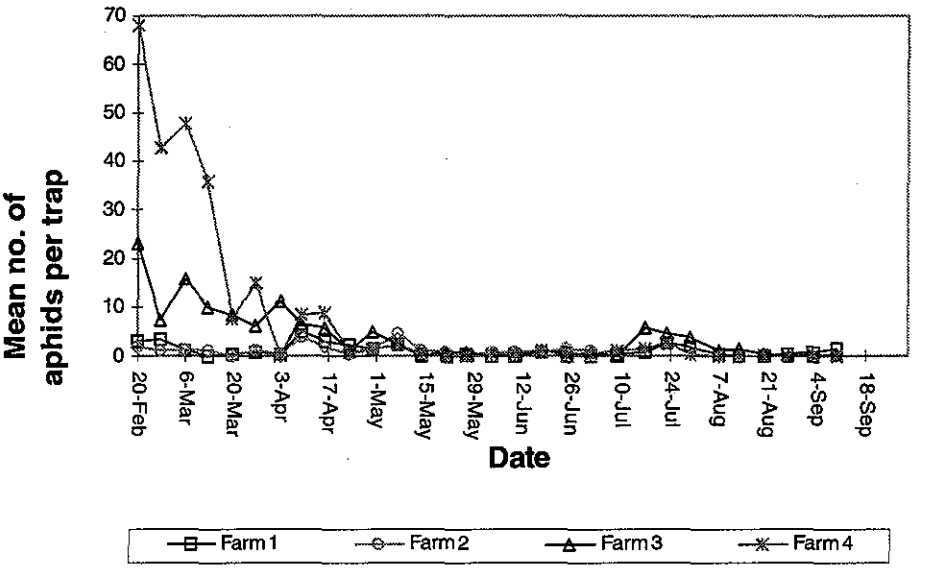

Figure 1. Aphid abundance in St. Catherine, Jamaica, February to September 1998

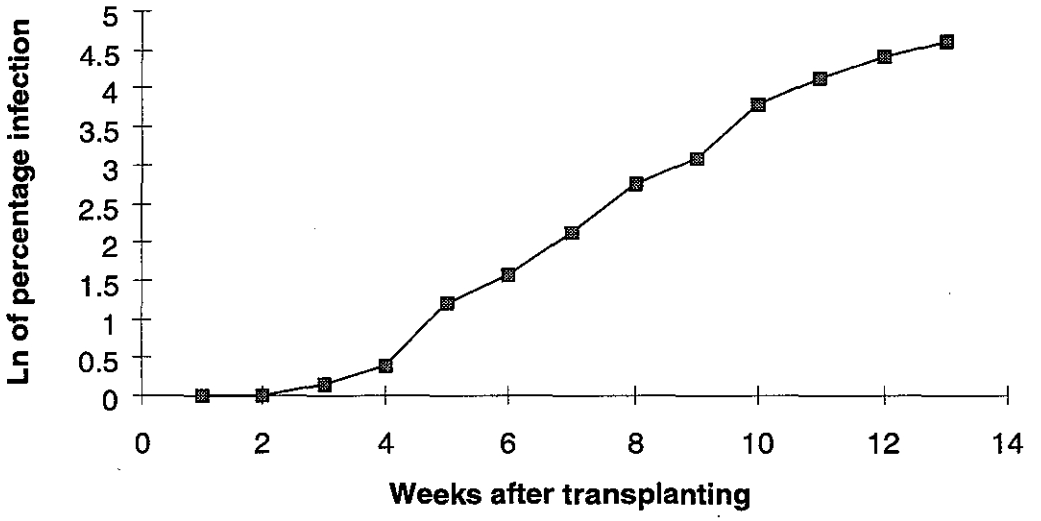

Figure 2. Disease progress curve for tobacco etch virus in Scotch Bonnet pepper plot in St. Catherine, Jamaica

Impact of Viruses on the Growth and Yield of Scotch Bonnet and West Indian Red Hot Peppers *(L. Myers, R. Martin and S. McDonald)*

Research Methods

The experiment was conducted at the Bodles Research Station in St Catherine. Scotch Bonnet and West Indian Red pepper seeds were sown in a steam sterilized potting mixture of 2 soil:1 sand in potting bags. The seedlings were fertilized with weekly applications of 20:20:20 NPK soluble fertilizer. Peat was added four weeks after germination to recondition the soil. The seedlings were kept in a glass house for eight weeks and then hardened off for another 2 weeks after which they were transplanted to the experimental plots on July 8, 1997. The plots were watered by overhead sprinkler irrigation once to twice weekly while one ounce of 15-5-35 fertilizer was applied to each plant on July 28 and August 26, 1997. One ounce of sulfate of ammonia was applied on October 13, 1997.

The experiment was a 2x2 factorial arranged in a randomised block design. The factors were variety (West Indian Red and Scotch Bonnet) and cover (presence or absence). The covering was made of Typar® fabric supported by a wooden framework 8m long x 5m wide x 1.7m high and the plots were covered two weeks after transplanting. The varieties were arranged in six blocks, each block containing two plots per variety while cover was arranged in three blocks with one plot covered and three plots uncovered for each variety. Each plot consisted of 28 pepper plants, of a single variety, planted four rows wide with seven plants per row. The inter-row spacing was 1m, while the intra-row spacing was 0.9m. Plots were 3m x 6m spaced 3.0 m apart.

The plots were visited weekly and the ten inner plants assessed for symptoms of virus disease. Virus severity was ranked from 0-4, 0 being no symptoms and 4 severe leaf deformation and reduction in leaf size. Virus presence was confirmed by dot blot immunobinding assay (DIBA). Five of the ten plants were assessed for the presence of pests and their natural enemies. These plants were divided into four sections based on the natural branching pattern of the plant and incidence scored based on presence or absence on these sections of the plant. Plant height, spread (length by width), and number of fruits borne, were recorded at different stages of the growth period from the ten inner plants. Fruits were harvested when there were initial signs of ripening, sorted into marketable and unmarketable fruits and weighed. Marketable fruits were assessed as those greater than 3cm in diameter with no aberrations due to fungal, bacterial or mechanical sources. Temperature, relative humidity and rainfall were monitored throughout the experiment. Data were collected up to the eight harvest on November 4, 1997.

Data were analysed using GENSTAT and JMP statistical software. Overall treatment effects were assessed using analysis of variance.

Research Results and Discussion

Relative humidity in the covered plots ranged from a low of 42% in the day to 100% at night while in the uncovered plots it ranged from 22% in the day to 98% at night. Temperatures in the covered plots ranged from 21^{0}C at night to 43^{0}C during the day while temperatures in the uncovered plots ranged from 19^{0}C at night to 38^{0}C during the day. The conditions in the covered plots were more favourable for vegetative growth as plants of both varieties grew significantly taller under these conditions than those uncovered ($P<0.001$; Fig 1). The West Indian Red variety grew significantly taller than Scotch Bonnet during the vegetative stage both in covered and uncovered plots ($P=0.013$). However, Scotch Bonnet plants attained similar height by first harvest. Similar results were obtained for plant spread.

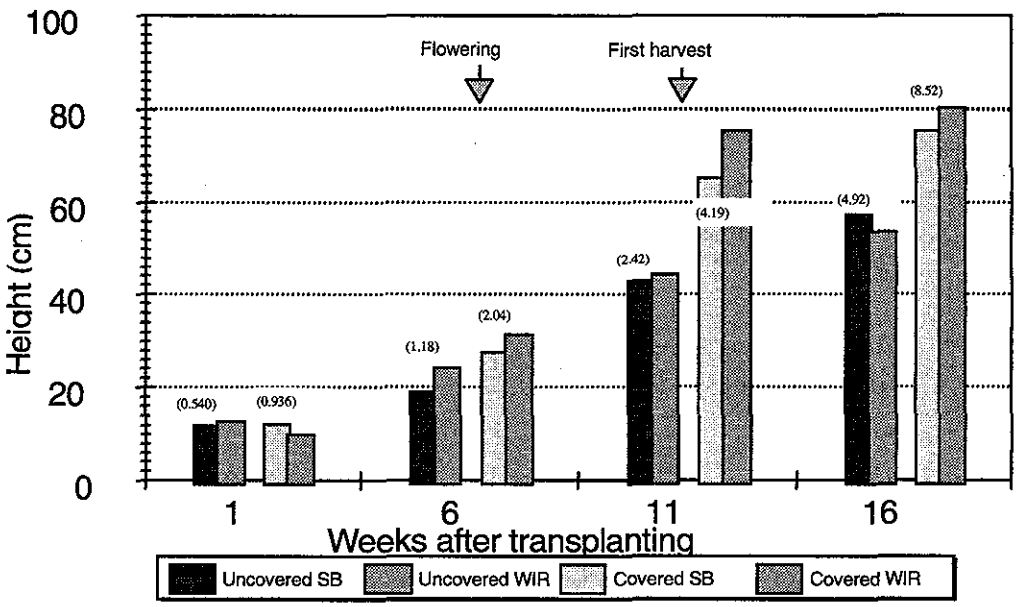

Figure 1. Height and (SEM) of covered and uncovered Scotch Bonnet and West Indian Red pepper plants 1, 6, 11 and 16 weeks after transplanting

The faster vegetative growth of West Indian Red translated into faster flowering (Fig 2) and fruit set. However, flowering and fruit set were retarded by covering. Uncovered West Indian Red plants reached 50% flowering during the 6th week after transplanting compared to the 8th week for uncovered Scotch Bonnet plants and the 10th week for covered West Indian Red plants. Fifty percent flowering was not observed in covered Scotch Bonnet plots.

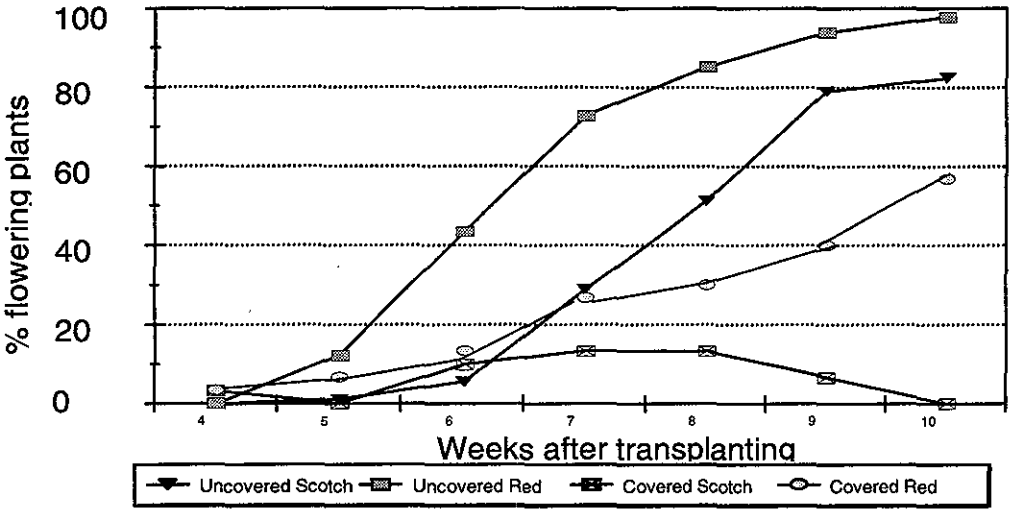

Figure 2: Percentage of Scotch Bonnet and West Indian Red plants flowering in covered and uncovered plots

The differences in flowering were reflected in yield (Table 1), as plants in uncovered plots bore significantly higher number of fruit (325.8) than plants in covered plots (94.67) while plots with West Indian Red plants had significantly higher number of fruit (291.8) than plots with Scotch Bonnet plants (128.7; P<0.001 and P=0.005 respectively). Uncovered West Indian Red plants bore the highest number of fruit while covered Scotch Bonnet plants bore the lowest number of fruit (Table 1).

Table 1: Mean marketable number of fruits per plot of covered and uncovered Scotch Bonnet and West Indian Red plots after eight harvests

	Covered	Uncovered	Overall variety means
Scotch Bonnet	6.67	250.8	128.7
West Indian Red	182.7	400.9	291.8
Overall cover means	94.67	325.8	
Standard error of means (18df)	62.30	35.97	

Significance levels: Cover P<0.001, Variety P=0.005, Cover x variety P=0.8

Similar results were obtained for fruit weight (Table 2). There was no significant difference between varieties in weight per fruit.

Table 2: Mean marketable weight of fruits per plot (g) of covered and uncovered Scotch Bonnet and West Indian Red plots after eight harvests

	Covered	Uncovered	Overall variety means
Scotch Bonnet	66.15	2173.25	1119.7
West Indian Red	1498.4	3380.94	2439.7
Overall cover means	782.28	2777.1	
Standard error of means (18df)	551.22	318.25	

Significance levels: Cover P<0.001, Variety P=0.009, Cover x variety P=0.8

Virus disease was detected seven weeks after transplanting in West Indian Red plots and eight weeks after transplanting in Scotch Bonnet plots. No viruses were detected in Blocks 1-3. Only uncovered plots in Blocks 4-6 were infected with virus during the course of the experiment. The disease incidence in these Blocks increased rapidly moving from below 20% to 100% in four weeks.

Tobacco etch virus was confirmed by DIBA in plants manifesting virus-like symptoms. Virus spread occurred by natural means. Aphids were present within one week after transplanting (Figure 3). *Aphis gossypii* was the predominant and only colonising aphid species. The pattern of infestation was similar in both varieties. At peak infestation, on September 19, 1998 apterae were present on an average of two sections per plant. Peak infestation was followed by a rapid increase in virus incidence.

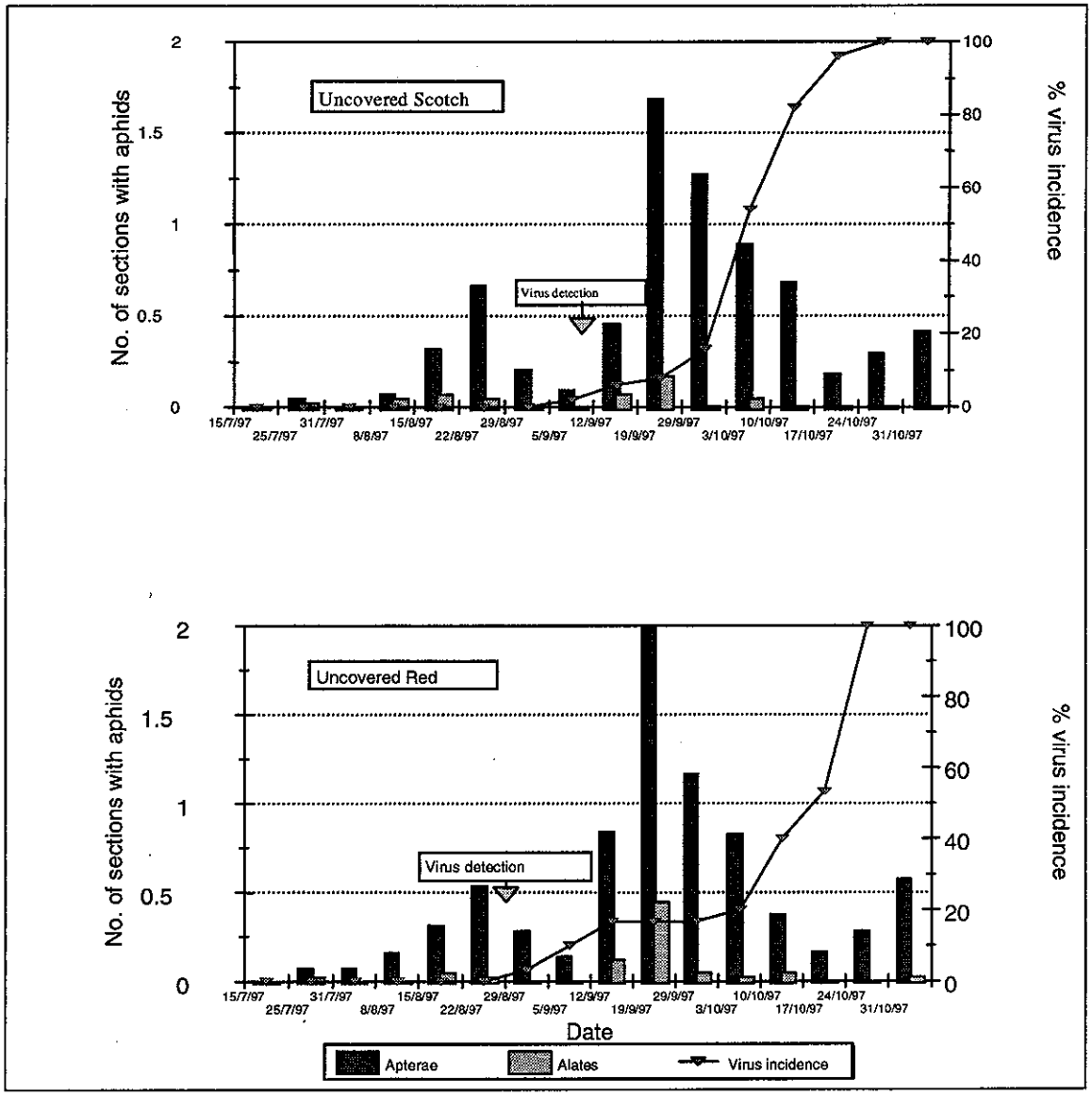

Figure 3: Variation of aphid population and virus incidence over time in uncovered Scotch Bonnet and West Indian Red plots

A comparison of cumulative marketable weight over time, of both varieties in uncovered plots without virus, reveal similar productivity although Scotch Bonnet yield lagged behind that of West Indian Red (Figure 4). At the end of the experiment cumulative Scotch Bonnet yield was 15% lower than that of West Indian Red.

A comparison of plots with virus show the productivity of Scotch Bonnet to be lower than that of West Indian Red (Figure 5). At the end of the experiment the cumulative yield of Scotch Bonnet was 50% lower than that of West Indian Red. Cumulative yield of Scotch Bonnet in virus infected plots was approximately 50% lower than that in uninfected plots while that of West Indian Red in virus infected plots was approximately 15% lower than that in uninfected plots.

From the survey of farms in St Mary, St Elizabeth and St Catherine it was reported that 80% of farmers grew yellow varieties of hot pepper of which Scotch Bonnet was the main one. It was also reported that 99% of farms over two months old were infected with virus disease. In this experiment, virus symptoms were detected seven weeks after transplanting and virus infected Scotch Bonnet plots yielded 50% lower than uninfected plots. It is therefore probable that the majority of hot pepper farmers are experiencing 50% or more reduction in yield due to viruses. West Indian Red, being a higher yielding variety in addition to being more tolerant, may be a viable option for hot pepper farmers at this time.

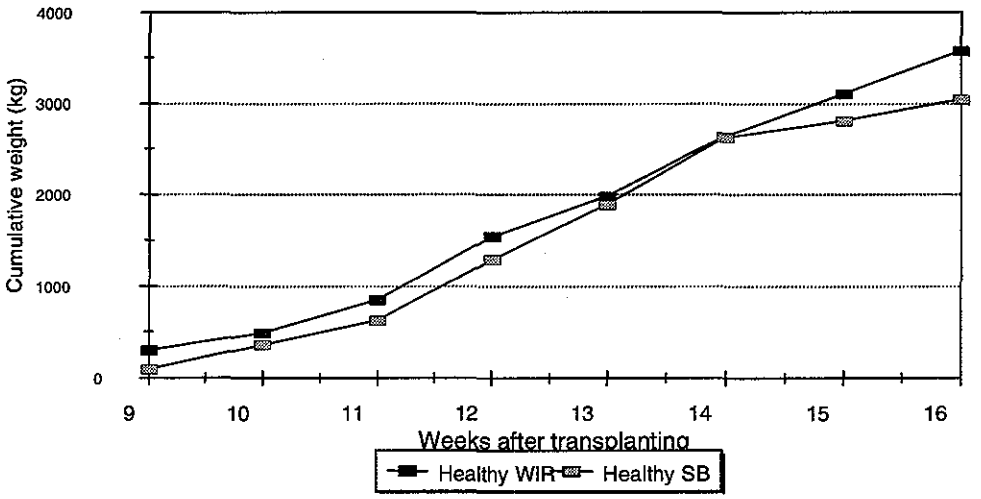

Figure 4: **Mean cumulative marketable weight of uncovered healthy Scotch Bonnet and West Indian Red treatments over time**

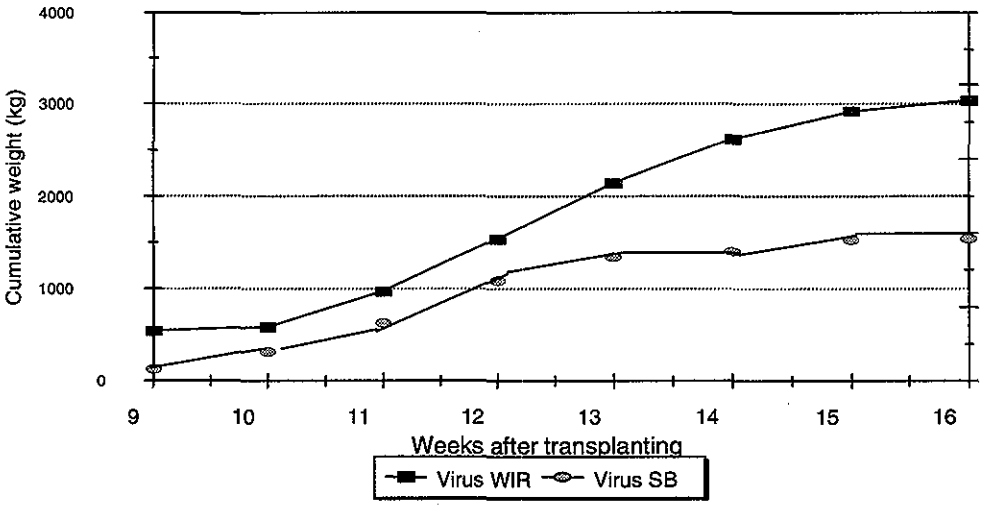

Figure 5: **Mean cumulative marketable yield of uncovered virus infected Scotch Bonnet and West Indian Red treatments over**

Integrated Pest Management Components for Vegetable Crops *(R. L. Fery, H. F. Harrison, Jr. and J. A. Thies)*

Develop Root-knot Nematode (*Meloidogyne incognita*) Resistant Habañero-type Peppers (*Capsicum chinense*)

Research Methods

Two major activities were undertaken during the past year to further efforts to incorporate a southern root-knot nematode resistance gene into Habanero-type peppers. The first activity was the execution of a crossing block to complete all hand pollinations needed to develop F_1 populations of the second backcross. The second activity was the execution of a greenhouse test to evaluate the new backcross populations for reaction to the southern root-knot nematode.

All hybridizations were made in a greenhouse using greenhouse-grown plants. The donor parent of the dominant resistance gene is the germplasm line PA-426, and the recurrent parent is the germplasm line PA-350. PA-426, a Scotch Bonnet-type pepper released by the USDA in 1997, is highly resistant to the southern root-knot nematode. PA-350, a Habañero-type pepper, is susceptible to the southern root-knot nematode. The crossing block was set up to allow efficient hand-crossing of 30 resistant F_1 plants selected from a segregating backcross (first backcross) population to

susceptible PA-350 plants.

The parental lines (PA-350 and PA-426) and F_1 populations of the second backcross were evaluated for reaction to the southern root-knot nematode. The test was conducted in a greenhouse bench containing a steam-pasteurized mixture of soil and sand. Ten plants of each population were evaluated. Seedlings were started in flats containing a sterilized artificial growth medium, and transplanted into the bench after true leaves had expanded. After the plants were established and growing, each plant was inoculated with .3,000 *M. incognita* race 3 eggs. All plants were evaluated 24 weeks after inoculation. Each plant received a subjective score for the prevalence of root galling. A 1 to 5 scale was used to score the severity of galling: 1 = no galling and 5 = severe galling. All plants with a gall index of 1 to 2+ were classified as root knot resistant; plants rated 3 to 5 were classified as susceptible.

Research Results and Discussion

A sufficient quantity of seed was harvested from the hand pollinations to allow testing of both parental lines and 25 backcross-two populations for reaction to *M. incognita*. Each of the parental populations reacted as expected. All of the PA-426 plants were resistant to the southern root-knot nematode. All of the PA-350 plants were susceptible. All of the backcross-two population segregated for resistance. A total of 25 resistant plants were selected from the backcross-two populations and these plants were subsequently replanted in a new greenhouse crossing block to develop backcross-three populations.

It should be noted that the backcross-two populations were also segregating for both fruit size and type. An effort was made to select plants with Habanero-type fruits. We now anticipate that it will be necessary to make at least four backcrosses before a pedigree breeding procedure can be initiated to select a homogeneous Habanero-type pepper that is highly resistant to the southern root-knot nematode.

Determine the Inheritance of Peanut Root-knot Nematode (*Meloidogyne arenaria*) Resistance in *C. chinense*

Research Methods

The data reported under this objective are from two greenhouse experiments conducted at Charleston, South Carolina. 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 24EC and 32EC and all plants were evaluated 14 weeks after inoculation. 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 and egg mass indices of 1 to 2+ were classified as root knot resistant; plants rated 3 to 5 for either galls or egg masses 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-353 x PA-350 were tested for resistance to *M. arenaria*. PA-353, a Scotch Bonnet-type pepper, is resistant to *M. arenaria*. PA-350, a Habañero-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-353 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-353 backcross plants, and eight plots of F_1 x PA-350 backcross plants. Each replicate also contained one plot each of the *C. annum* cultivars Carolina Cayenne (resistant control) and California Wonder (susceptible control). The seeds were planted on 14 January 1998, the seedlings were transplanted on 3 February 1998, established plants were inoculated on 3 March 1998, and the roots of each plant were evaluated on 10 June 1998. The 1.05% NaOCl procedure was used to extract eggs from fibrous root samples harvested from the PA-353, PA-350, and F_1 hybrid plots.

Experiment II. Plants of the parental and F_2 generations of the cross PA-353 x "Carolina Cayenne" were tested for resistance to *M. arenaria*. The experimental design was a randomized complete block. Each plot contained five plants. Each replicate contained two plots of PA-353 plants, two plots of "Carolina Cayenne" plants, and eight plots of the F_2 plants. Additionally, each replicate contained two plots of the susceptible cultivar "California Wonder" (susceptible control). The seeds for this test were planted on 14 January 1998, the seedlings were transplanted on 3 February 1998, established plants were inoculated on 3

March 1998, and the roots of each plant were evaluated on 10 June 1998.

Research Results and Discussion

The procedures used to infest the established plants in the growing medium with *M. arenaria* eggs were effective and reliable. Except for "California Wonder", all homozygous lines with known reactions to the parasite reacted as expected. The "California Wonder" seed were obtained from a commercial seed company, and the cultivar was heterozygous for reaction to *M. arenaria*.

Experiment I. PA-353 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-353 is conditioned by a single dominant gene (Table 2). All 20 F_1 plants were resistant and all of the 149 F_1 x PA-353 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.

Experiment II. All of the plants of the parental lines of the PA-353 x "Carolina Cayenne" cross were resistant (Table 3). The lack of segregation in the F_2 generation of this cross suggests that the dominant resistance gene in the *C. chinense* germplasm line PA-353 is allelic to a gene conditioning resistance to *M. arenaria* in the *C. annum* cultivar Carolina Cayenne.

Evaluate Various Root-knot Nematode Resistant Scotch Bonnet Pepper (*C. chinense*) Lines in Jamaica and/or St. Kitts for Adaptability, Horticultural Traits, and Yield

The purpose of this study was to evaluate the performance of *Capsicum chinense* (Scotch Bonnet-type pepper) accessions in a Caribbean environment. A field study was conducted in a root-knot nematode (*Meloidogyne* spp.) infested field in the Fountain region of St. Kitts. Six *Capsicum chinense* cultigens were used in this experiment. The genotypes evaluated in the test were three *M. incognita*-resistant Scotch Bonnet-type lines (PA-353, PA-398, and PA-426) released by USDA (HortScience 33:760-761. 1998), a *M. incognita*-susceptible Habanero-type line (PA-350), and two West Indies local cultigens. The experimental design was a randomized complete block with seven replications. The experiment was planted on 22 Sept. 1997. Three-row plots were established on 1-m centers with 51-cm in-row plant spacing and 7 plants per row. Plots were fertilized with 61 and 66 kg 15-15-15 N-P-K on 25 Sept. 1997 and 7 Nov. 1997, respectively. Mature red or yellow (depending on genotype) fruits were harvested and weighed on 4 Dec. and 17 Dec. 1997, and 7 Jan. and 19 Jan. 1998. On 9 Feb. 1998, six cores of soil were collected in the root zones of the middle row of each plot. Heights of the five plants in the middle row of each plot were recorded, the stems were clipped at the crown and the fresh shoot weight of each plant was recorded. 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-knot nematode eggs were extracted from the fibrous roots using 1% NaOCl. Second-stage juveniles (J2) were extracted from a 50 cm^3 subsample of each soil sample using the sugar flotation method. Eggs and J2 were counted using a stereomicroscope. Egg and J2 count data were $\log_{10}(x+1)$ 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 and very low nematode reproduction (Table 1). The local West Indies cultigens (West Indies Red and West Indies Yellow) and the susceptible Habanero check (PA-350) exhibited low to moderate root galling and 12 to 29 x greater numbers of total eggs per root system than the resistant *C. chinense* lines. Numbers of second stage juveniles (J2) were ≤ 10 per 50 cm^3 soil (data not shown), indicating that nematode population levels were relatively low in this field. West Indies Red and West Indies Yellow had heavier shoot weights ($P<0.05$) and the plants were taller ($P<0.05$) than the Scotch Bonnet and Habanero-type lines. Differences in fruit weight among genotypes were not detected. Results of this study demonstrate that PA-353, PA-398, and PA-426 were resistant to the indigenous field population of *Meloidogyne* sp. in the Fountain region of St. Kitts. The reactions of West Indies Red and West Indies Yellow were similar to that of PA-350 (susceptible check), suggesting that they were susceptible to the indigenous root-knot nematode population. These results support our previous observation that West Indies Red is susceptible to *M. incognita* (1996-1997 IPM CRSP Annual Report). Additional tests at other field sites in will be necessary to further evaluate performance of these *C. chinense* genotypes in the St. Kitts environment.

Evaluate the Stability of Root-knot Nematode Resistance in Scotch Bonnet Peppers Under High Temperatures

Research Methods

The purpose of this study was to determine the heat stability of resistance to *M. incognita* in Scotch Bonnet-type pepper (*C. Chinese*). Two *C. Chinese* germplasm lines, PA-426 and PA-350, and two *C. annum* cultivars, Charleston Belle and

Keystone Resistant Giant, were used in this experiment. PA-426 is a Scotch Bonnet-type germplasm line 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 two replications in time. Whole plots were three temperatures (24, 28, and 32 EC). Sub-plots were the four pepper genotypes with 18 blocks per chamber. Results of the first replication are presented in this report.

Seedlings of each genotype were started in the greenhouse in a commercial potting medium. Twenty-one days later, single seedlings were transplanted into individual pots and each plant was inoculated with 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 EC, with a 16 h/8 h (light/dark) cycle. Sixty-eight days 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 $R = P_f / P_i$, where P_i = initial inoculum level and P_f = final inoculum level. Egg count data were $\log_{10}(x+1)$ 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 EC (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 0.5 at 24 EC to 19.8 at 32 EC. Nevertheless, the root gall index for PA-426 was only 1.92 at 32 EC, which is still within the resistant range (≤ 2.0). The root galling response and nematode reproduction for the resistant check Charleston Belle were similar to those for PA-426. Both PA-350 and Keystone Resistant Giant exhibited highly susceptible reactions at both 28 and 32 EC. Although the resistance of PA-426 was compromised at high temperatures, cultivars possessing this resistance may be a useful component of integrated systems designed to manage soilborne pests in hot climates.

Develop Methodologies for Using the Newer and Safer Herbicides in Combination with Simple Application Equipment for Controlling Weeds in Pepper

Research Methods

A randomized complete block design was utilized to compare hand weeding with manual herbicide application for weed control in peppers. Peppers were transplanted, and maintained relatively weed free. Data collected included time required for weeding and amount of herbicide used. Expense of weeding was calculated based on Jamaican wage and the local cost of Scythe. This experiment was destroyed by heavy rainfall which caused flooding of the field and prevented pepper fruit set. In the previous year yields were similar in hand weeded and pelargonic acid weeded plots.

Research Results and Discussion

Weed control back-pack sprayer applications of pelargonic acid required less than 10% of the labor required for hand weeding; however, monetary savings in labor were offset by the cost of the herbicide. This technique appears to have good potential for offsetting the labor shortage experienced by small scale Jamaican farmers. Pelargonic acid is much safer to handle than paraquat; however it is not as effective.

Determine the Feasibility of Using Mulched Cover Crops to Control Weeds in Pepper Plantings

Research Methods

An experiment to evaluate summer legumes as mulched cover crops for pepper production was arranged in a randomized complete block. Treatments included four summer legume mulches (cowpea, soybean, sunnhemp, and velvetbean) and a bare soil control. Nitrogen fertilizer was applied at 2 the normal rate in order to detect the effect of nitrogen fixed by the legumes.

Research Results and Discussion

This study is still in progress. Preliminary observations indicate that each of the mulches suppress weed growth and early pepper growth is more rapid, probably due to nitrogen provided by the legumes. Use of cover crops could be of benefit to small scale farmers, because they offer the benefits of providing nitrogen, suppressing weeds, reducing soil erosion and improving tilth.

Dissemination of Information *(R. Martin and P. Chung)*

Research Methods

A hot pepper growing district in St Mary was selected for the study. The district is comprised of approximately 30 households and all are engaged in pepper production at varying levels. Knowledge of hot pepper pests is limited. The training was conducted in two phases. In the first phase training was conducted in a classroom setting while in the second phase which is ongoing training is being conducted in farmers' fields where the crop is being followed from seedling stage.

Research Results and Discussion

Four training sessions have been held to date. Topics covered have been; common pests of hot pepper and their control, IPM, and common questions which arise at the start of hot pepper production. Officers from the local extension service (RADA) have been in attendance at all the training days and have provided valuable input.

The trainings have been interactive and farmer knowledge was assessed based on questions posed. What was highlighted is that farmers were not able to distinguish between mite damaged plants and virus infected plants. This resulted in the use of pesticides on virus infected plants in an attempt to control it. Mites were the main problem which farmers encountered. Current pesticides were said not to work.

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. or 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. Although these new releases have the potential for providing an immediate solution to the root knot problem facing the Jamaican hot pepper industry (the Scotch Bonnet is widely grown in Jamaica), they do little for the U.S. industry because the main cultivar class of *C. chinense* grown in this country is the Habanero. 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 Habanero peppers.

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 indicates 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-353. 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.

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.

The southern root-knot nematode, *M. incognita*, is a major pest in pepper growing areas of the world. The loss of many nematicides from the market due to environmental concerns and the prohibitive costs of reregistration has centered attention on the use of host plant resistance for managing plant parasitic nematodes in vegetable crops, including pepper. However, expression of resistance to root-knot nematodes is heat sensitive in tomato, cotton, alfalfa, sweetpotato, and bean. Since a large portion of global pepper production occurs in hot climates where root-knot nematodes are a severe pest, knowledge about the expression of root-knot nematode resistance in pepper is essential for pepper resistance breeding programs and for recommending cultivars for high temperature production regimes. Our results indicate that although resistance to root-knot nematodes is compromised at high temperatures (32 EC), the root galling response and nematode reproduction in the resistant Scotch Bonnet PA-426 is significantly lower than in the susceptible habanero. Thus, root-knot resistant *C. Chinese* cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates.

A major complaint of the small scale Jamaican farmer is the inability to control weeds in pepper fields. Weeds reduce crop yields directly by competing with crops for light, water and nutrients and indirectly by harboring insects and diseases that reduce yields. Hiring labor to manually weed crops is very expensive, and in many instances labor is unavailable. The results of the study reported here indicate that simple, inexpensive equipment can be used to effectively apply herbicides to small plantings of peppers and there are low toxicity alternatives to the toxic herbicide paraquat.

The potential impact of using cover crop mulches to control

the weed pests of pepper will not be clear until ongoing research by U.S. and Caribbean scientists has been completed.

Networking Activities

- R. L. Fery served as a member of the Advisory Committee for a Clemson University M.S. student funded by the Bean/Cowpea CRSP.
- R. L. Fery served as a member of the Pepper Germplasm Committee.
- R. L. Fery participated in the USAID Administrative Management Review of IPM CRSP Caribbean Site Activities, Lincoln University, Jefferson City, MO, October 8-9, 1997.
- R. L. Fery and H. F. Harrison, Jr. participated in an IPM-CRSP Caribbean Site Planning Conference, Blacksburg, VA, May 13-14, 1998.
- H. F. Harrison provided a backpack sprayer, herbicides, and technical advice to cooperators in Jamaica.
- J. A. Thies traveled to St. Kitts in February 1998 to cooperate with Mr. 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 resistance to root-knot nematodes. Plans were made with Mr. Weekes for additional field testing of Scotch Bonnet pepper germplasm in St. Kitts. An additional research site where soil was heavily infested with root-knot nematodes was identified for further pepper field tests. Arrangements were made to ship additional Scotch Bonnet seed from USDA, Charleston, SC to, CARDI, St. Kitts, for further testing.
- J. A. Thies participated as member in Annual Meeting of S-253 Technical Committee (Managing Plant-parasitic Nematodes in Sustainable Agriculture with Emphasis on Crop Resistance) and presented a research progress report. October 29-30, 1997. Haines City, FL.

Publications and Presentations

Presentations

- R. Martin presented a paper entitled "Seasonal incidence of hot pepper pests in major hot pepper (*Capsicum* spp.) producing areas in Jamaica" at the IPM CRSP Symposium, Blacksburg, VA, May 15-16, 1998.
- L. Myers presented a paper entitled The effect of tobacco etch virus on the growth and yield of two *Capsicum chinense* pepper varieties at the JSAS/34th Annual conference of the CFCS, Montego Bay Jamaica, July 12-18, 1998.
- R. L. Fery presented a paper entitled "Southern root-knot nematode resistance in hot pepper (*Capsicum Chinese*): Potential for the development of resistant cultivars for the US and Caribbean markets" at the IPM CRSP Symposium, Blacksburg, VA, May 15-16, 1998.
- R. L. Fery presented a poster entitled "Resistance in bell pepper to southern root-knot nematodes: Characterization of resistance and development of resistant cultivars" at the XXV International Horticultural Congress, Brussels, Belgium, August 2-7, 1998.
- R. L. Fery presented a poster entitled "Inheritance of resistance to the southern root-knot nematode in *Capsicum Chinese* Jacq." at the Annual Conference of the American Society for Horticultural Science, Charlotte, NC, July 12-15, 1998.
- H. F. Harrison, Jr. presented a paper entitled "Alternative methods for weed management by small-scale vegetable growers" at the IPM CRSP Symposium, Blacksburg, VA, May 15-16, 1998.
- J. A. Thies presented a paper entitled "Potential for using resistant peppers (*Capsicum* spp.) to manage root-knot nematodes in vegetable crops" at the IPM CRSP Symposium, Blacksburg, VA, May 15-16, 1998.
- J. A. Thies presented a paper entitled "Heat stability of root-knot nematodes in bell pepper" at the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, CA, November 2-5, 1997.

Abstracts

Fery, R. L., J. A. Thies, and S. C. Weekes. 1998. Southern root-knot nematode resistance in hot pepper (*Capsicum Chinese*): Potential for the development of resistant cultivars for the US and Caribbean markets. pp. 1-2. Abstracts of the Third IPM CRSP Symposium, Virginia Polytechnic Institute and State University, Blacksburg, VA. May 15-16, 1998.

Fery, R. L., and J. A. Thies. 1998. Inheritance of resistance to the southern root-knot nematode in *Capsicum Chinese* Jacq. HortScience 33:500.

Fery, R. L., and J. A. Thies, and P. D. Dukes. 1998. Resistance in bell pepper to southern root-knot nematodes: Characterization of resistance and development of resistant cultivars. p. 216. Abstracts of the XXV International Horticultural Congress, Brussels, Belgium, August 2-7, 1998.

Harrison, H. F., R. L. Fery, and J. Lawrence. 1998.

Alternative methods for weed management by small-scale vegetable growers. pp. 3-4. Abstracts of the Third IPM CRSP Symposium, Virginia Polytechnic Institute and State University, Blacksburg, VA. May 15-16, 1998.

Thies, J. A., R. L. Fery, and S. C. Weekes. 1998. Potential for using resistant peppers (*Capsicum* spp.) to manage root-knot nematodes in vegetable crops. p. 2. Abstracts of the Third IPM CRSP Symposium, Virginia Polytechnic Institute and State University, Blacksburg, VA. May 15-16, 1998.

Thies, J. A., R. L. Fery, and J. D. Mueller. 1998. Resistance in pepper to southern root-knot nematodes (*Meloidogyne incognita*). Russian J. Nematol. 6:83.

Refereed Manuscripts

Fery, R. L., and J. A. Thies. 1998. PA-353, PA-398, and PA-426: Southern root-knot nematode-resistant *Capsicum Chinese* Jacq. germplasm lines. HortScience 33:760-761.

Fery, R. L., P. D. Dukes, Sr., and J. A. Thies. 1998. 'Carolina Wonder' and 'Charleston Belle': Southern root-knot nematode-resistant bell peppers. HortScience 33:900-902.

Harrison, H. F., and R. L. Fery. 1998. Response of leading bell pepper varieties to bentazon herbicide. HortScience 33:318-320.

Thies, J. A., J. D. Mueller, and R. L. Fery. 1998. Use of a resistant pepper as a rotational crop to manage southern root-knot nematode. HortScience 33:716-718.

Thies, J. A., P. D. Dukes, J. D. Mueller, and J. R. Bohac. 1998. Evaluation of regional and standard entries for reaction to southern root-knot nematode. pp. 34-35. In: W. J. McLaurin (ed.). National Sweetpotato Collaborators Group Progress Report. The State Expt. Stns., the Coop. Ext. Serv., and the USDA.

Manuscripts Prepared for Publication in Refereed Journals

Fery, R. L., and J. A. Thies. Genetic analysis of resistance to the southern root-knot nematode in *Capsicum Chinese* Jacq. (Prepared for the J. Amer. Soc. Hort. Sci.)

Training Output

Graduate student training

- Sharon McDonald: PhD student at Virginia Tech conducting research on hot pepper.

Conference Proceedings/Technical Reports

- Thies, J. A., and R. L. Fery. 1997. Heat stability of root-knot nematode resistance in bell pepper. Annual Intl. Conf. on Methyl Bromide Emmissions Reductions. November 3-5, 1997. San Diego, CA, p. 32/1-32/2.

Project Highlights

- Viruses have been detected on 99% of farms with plants over 2 months old.
- TEV spread in a field followed a logistic pattern indicating spread mainly by intrafield means.
- Virus infected Scotch Bonnet plots gave 50% lower yield than uninfected plots.
- Four manuscripts reporting research conducted, in part, with IPM CRSP funds were published in refereed journals.
- Two manuscripts reporting research conducted, in part, with IPM CRSP funds were prepared for publication in refereed in journals.
- A breeding program to transfer southern root-knot nematode resistance from Scotch Bonnet pepper into Habanero pepper was continued; resistant plants were selected from the second backcross and these selections are being used to complete the third backcross.
- The resistance to the peanut root-knot nematode (*M. arenaria* Race 1) exhibited by the *C. Chinese* germplasm line PA-353 was found to be conditioned by a single dominant gene.
- The single dominant gene conditioning resistance in *C. Chinese* germplasm line PA-353 to the peanut root-knot nematode is likely allelic to a gene that conditions the resistance in the *C. annum* cv. Carolina Cayenne.
- The results of a field test conducted in St. Kitts demonstrated that the recently released *C. Chinese* germplasm lines PA-353, PA-398, and PA-426 are resistant to indigenous field populations of *Meloidogyne* spp. Two *C. Chinese* cultivars that are commonly grown in the Caribbean (West Indies Red and West Indies Yellow) were susceptible. (Note: The detailed results of this test are reported in CARDI's annual report.)
- The results of a growth chamber test indicated that resistance to southern root-knot nematodes (*M. incognita*) in *C. Chinese* is compromised at high temperatures. However, the root galling response and nematode reproduction in the resistant Scotch Bonnet germplasm line PA-426 was significantly lower than in susceptible Habanero-type peppers. Root-knot resistant

C. Chinese cultivars should be a useful component of cropping systems designed to manage *M. incognita* in hot climates.

- Significant progress was made in the development of insect rating indexes for use under Jamaican condition

IPM Systems Development of Sweetpotato, *Ipomoea batatas*

Investigators: Janet Lawrence[1], Mike Jackson[2], and Janice Bohac[2]

Collaborating Scientists: Phillip Chung[3] and Trevor Martin[3]

Abstract

Over the past year, the focus of sweetpotato IPM research has been to evaluate the potential of USDA multiple pest resistant sweetpotato breeding lines and selective low toxic compounds for managing the two major pests, the sweetpotato weevil and the newly emergent soil grub. In relation to the USDA breeding lines, significant strides were made in the development of a rating scale to measure levels of resistance. The scale greatly assisted in identifying variation in the levels of insect resistance among USDA lines and local varieities in replicated field studies. Under Jamaican growing conditions, USDA breeding lines produced yields comparable to local lines, exhibited varying levels of resistance to sweetpotato weevil and the soil grub, and met market and consumer criteria. One of the most promising lines identified was "Picadito".

As a short term strategy, the potential of the low toxic compound Fipronil was evaluated for management of the soil grub. Results indicate that this compound was able to reduce sweetpotato root damage by soil grubs 50% more than the current farmer practice, Ethoprop.

In an effort to disseminate the current sweetpotato weevil IPM technology of mass trapping male weevils with high doses of female sweetpotato weevil sex pheromone in combination with cultural practices to farmers/agricultural students and extension in major growing areas, interactive technology transfer sessions were conducted. Over the past seven months over 200 persons have been exposed to the technology.

Objectives

- Develop high yielding, cream fleshed sweetpotato lines with resistances to rootknot nematodes, diseases and insects.
- Develop improved methodologies to evaluate host plant resistance to white grubs in field plots in USA and Jamaica
- Compare yield, culinary quality, and insect and disease resistance traits of select USDA cream-flesh sweetpotato breeding lines to standard Jamaican sweetpotato varieties
- Determine the potential of USDA cream fleshed sweetpotato lines and chemical insecticides to reduce root damage due to soil grubs
- Disseminate sweetpotato weevil IPM technology

IPM Constraints

- Sweetpotato weevils and sweetpotato leaf beetle significantly constrain sweetpotato production. The ultimate incorporation of tactics such as resistant breeding lines and low toxic chemicals into the present IPM technology will greatly assist in improving the quantity and quantity of marketable yields being produced not only by Jamaican farmers but those in the wider Caribbean who experience similar pest problems.

[1] CARDI [2]USDA [3]RADA

- Dissemination of IPM technology to farmers in major sweetpotato growing areas will also facilitate the goal of reducing pest damage and improving the sweetpotato production.

Development of High Yielding, Cream-fleshed Sweetpotato Lines with Resistances to Root-knot Nematodes, Diseases, and Insects. *Janice Bohac (USDA), Judy Theis (USDA), Michael Jackson (USDA)*

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 *Fusarium* wilt pathogen. The 1998 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 1997 field season, various tests were conducted in the winter of 1997-1998 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. Twenty-eight advanced lines, two cultivars, 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 July 1997 and the soil surrounding each cutting was infested with ca. 3,000 *M. incognita* eggs in 5 ml H_2O. The greenhouse conditions were maintained for favorable growth of sweetpotato and nematode development. On 24 September 1997, 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 79%, and 5 = >80% of root system galled or covered with egg masses.

Research Results and Discussion

Sweetpotato breeding program. Over 3000 seedlings from the 1997 polycross nursery were planted in the greenhouse and screened for southern root knot nematodes, and other horticultural traits (such as skin and flesh color of storage roots). Of these, approximately 870 were selected and transplanted for the 1998 field trials. The data on yield, quality, and insect resistance from the 1997 field trials in South Carolina were used to determine which lines would be kept for testing in the 1998 field trials (data not shown).

Of all the lines kept for testing in the 1998 South Carolina trials, those with the highest resistance to soil insects and that combine high yield, appropriate culinary quality, and appearance were selected for a joint experiment in South Carolina and Jamaica. The final list of the lines that were put into the 1998 South Carolina trial are presented in Table 1. The same lines will be placed into the Jamaican test in the fall and winter of 1998-1999.

Table 1. Dry fleshed, multiple resistant sweetpotato breeding lines selected for entry into the Charleston and Blackville, South Carolina, and Jamaican trials, 1998 growing season.

Entry	1997-98 (Jamaica)	Skin color	Flesh color	WDS complex	Flea beetle	Grub	Weevil (Jamaica)	Weevil (Mississippi)
94-127	Exp 2	Rose	Yellow	R	R	VHR	-	--
94-145	No	Rose	Lt. Yellow	R-HR	VHR	VHR	-	-
94-207	No	Red	White	I-R	HR	I	-	-
94-37	Exp 1	Rose	Cream	R	R or S	R	-	-
94-39	Exp 1	Rose	Cream	I-R	I-R	S	R	-
95-102	No	Red	V. Lt. Orange	VHR	R	R	-	-
95-175	No	Red	Yellow	I	R	I-R	-	-
95-190	No	Rose	Lt. Yellow	HR	HR	S-I	-	-
96-47	No	Red	Yellow	-	-	-	-	-
96-51	No	Rose	Lt. Yellow	-	-	-	-	-
PI399163	No	?	?	R	-	-	R	HR
PI508523	No	?	?	R	-	-	-	HR
PI531116	No	Tan	Cream	R	-	-	-	HR
PI538288	No	Purple	White	R	-	-	-	R
PI538354	No	?	?	R	-	-	-	HR
PI564149	No	Purple	Purple	R	-	-	-	HR
High Dry	No	Tan	Cream					

Table 1 ***continued***

Picadito	Exp 2	Scarlet	White	-	-	-	R	HR
Regal	No	Red	White	R	R	R	-	
SC-1149-19	Exp 1	Lt. Cu	Lt. Orange	S	S	S	HS	S
Sidges	Exp 1& 2	Red	Cream	-	-	-	-	-
Sumor	Exp 1	Tan	Cream	HR	R	R	MR	R
Tanzania	No							
White-Regal	Exp 1	Scarlet	Cream	R	R	R	R	MR
W-326	Exp 1	Rose	Yellow	HR	HR	HR	MR	-
W-332	No	Red	Yellow/Cream	-	-	-	-	-
W-341	No	Red	Cream	R	I-R	R	-	-

Evaluation for nematode resistance. The standard resistant and susceptible check cultivars performed as expected (Table 2). Twenty-three entries were highly resistant (HR), similar in reaction to PI 399163 and Nemagold (HR-Checks). Four entries were resistant (R), similar in reaction to Jewel (R-Check). One entry was intermediate-susceptible (I-S), similar in reaction to Porto Rico (I-S Check). Two entries were susceptible (S), similar in reaction to Beauregard (S-Check).

Table 2. Reaction of advanced lines, plant introductions, cultivars, and check cultivars to southern root-knot nematode (*Meloidgyne incognita* race 3) in a greenhouse test at the U.S. Vegetable Laboratory, USDA, ARS, Charleston, SC, 1997. [1]

Entry	GI[2]	EMI[3]	Rating[4]
Advanced Lines and Plant Introductions			
W-334	1.0	1.0	HR
W-347	1.0	1.0	HR
W-328	1.0	1.0	HR
94-57	1.0	1.0	HR
95-87	1.0	1.0	HR
94-116	1.0	1.0	HR
W-336	1.0	1.0	HR
95-61	1.0	1.0	HR
95-238	1.0	1.0	HR
W-311	1.0	1.0	HR
W-302	1.0	1.0	HR
PI564149	1.0	1.1	HR
94-69	1.1	1.1	HR
94-184	1.1	1.1	HR
PI539141	1.1	1.1	HR
W-337	1.1	1.1	HR
W-348	1.1	1.1	HR
95-271	1.1	1.2	HR
PI538354	1.2	1.2	HR

Table 2 ***continued***

W-331	1.2	1.2	HR
PI538284	1.2	1.2	HR
PI538534	1.2	1.2	HR
W-238	1.3	1.1	R
W-316	1.3	1.2	R
95-98	1.6	1.7	R
PI531116	2.2	2.1	R
PI538286	2.9	2.8	I-S
PI538288	4.1	4.0	S
Other Cultivars			
Blackie	1.1	1.1	HR
Picadito	4.2	3.9	S
Check Cultivars			
PI399163	1.0	1.0	HR
Nemagold	1.1	1.1	HR
Tinian	1.4	1.4	R
Jewel	1.7	1.7	R
Porto Rico	2.8	2.8	I-S
Beauregard	4.1	3.8	S
LSD (0.05)	0.6	0.6	--

[1]Planted in sand benches and inoculated with approximately 3,000 *Meloidogyne incognita* race 3 eggs/plant on 24 July 1997. Roots lifted and scored for galling and egg mass production 24 September 1997. [2]GI = gall index (1 = none to 5 = severe). [3]EMI = egg mass index (1 = none to 5 = severe).[4]HR = highly resistant; R = resistant; I = intermediate; S = susceptible.

Development of Methodologies to Evaluate Grub Resistance in Sweetpotato

D. Michael Jackson (USDA - Vegetable Laboratory), Janet Lawrence (CARDI), Janice Bohac (USDA - Vegetable Laboratory). (Special Grant)

During the 1996 sweetpotato cropping season, it was observed that farmers within the target area of Ebony Park were experiencing severe losses in the quality of marketable yields due to a soil grub. During the past year efforts were therefore made to determine the taxaonmy of the pest as well as to identify potential management tactics which would the economic losses being incurred. USDA multiple pest resistant lines of sweetpotato have been shown to have moderate to high levels of resistance to soil grubs in the USA. As such, in order to accelerate the process of identifying potential sweetpotato breeding lines which can be incorporated into the present IPM system to manage the soil grub and the sweetpotato weevil, the development of methodologies to rapidly screen germplasm is critical. Below describes preliminary activities which were conducted during the 1997 - 1998 season to assist in the development of these methodologies.

Research Activities/Approach and Observations

Taxanomic Identification. During the past 2 years, marketable yields of sweetpotato have been severely affected by a soil pest, the genus of which was not known. Roots damaged by these pests closely resembled the scaring resulting from the white grubs *Phyllophaga* and *Plectris* (Coleoptera: Scarabaeidae) and thus in earlier reports the pest was refereed to as "white/soil grubs". During the past season, soil grub samples were collected from the Bodles Research Station - MINAG (St Catherine) and farms located in Ebony Park (Clarendon) and successfully reared in the laboratory. With the aid of keys, grubs and the emerging adult beetles were tentatively identified as the Sweetpotato Leaf Beetle, *Typhorous* sp. (Coleoptera: Chrysomelidae).

Nine pinned adult specimens (3 from Ebony Park, 2 from Bodles, and 4 from Yoakum, Texas) and 4 larvae (from Bodles) were sent to Dr. Steve Lingafelter (Coleopteran Specialist) at the Communications and Taxonomic Services Unit, USDA Systematic Entomology Laboratory, Beltsville, MD for confirmation. These results are pending. Two large colonies of the beetles were successfully established under fabric row covers. Data on the life cycle of the beetle is presently being collected.

Performance of USDA Varieties under Row Covers. The performance of sweetpotato cultivars under fabric row covers was evaluated at the USVL, Clemson University - Edisto Research and Education Center (Blackville, SC) during 1996-1998 and the CARDI field station (1997 - 1998). The data from US studies from 1998 experiments are pending. The CARDI plot in which covered (fabric row covers) and uncovered plots of three USDA varieties (Piccadito, SC19-4919, Sumor) and a two local lines (quarter million and Sidges) were established no differences in vegetative growth between covered and uncovered plots was observed. Very poor root enlargement occurred and this prevented the executions of no-choice evaluations proposed. These tests could not be conducted in the USA because of a lack of the insect pests (Chrysomelid grubs).

Damage Rating Scale. The soil pest tentatively identified as immatures of the Sweetpotato Leaf Beetle, *Typophorus* sp. gouge shallow areas on the surface of sweetpotato roots. A four level damage rating scale which is based on the length of feeding channels was developed to assist in measuring resistance in breeding lines. Scale: 0: no injury, 1: >0 - 8 cm channel, 2: >8 - 15.0 cm channel, 3: >15 - 23cm channel, and 4: >23 cm channel. This rating scale was used in all seasonal germplasm evaluation studies.

Evaluation of Yield, Culinary Quality, and Insect and Disease Resistance Traits of Select USDA Cream-flesh Sweetpotato Clones to Standard Jamaican Sweetpotato Clones

Janet Lawrence (CARDI), Janice Bohac (USDA), Mike Jackson (USDA).

The USDA - US Vegetable Laboratory (USVL) through a population breeding programme has developed many breeding lines and cultivars with multiple pest resistance. Utilisation of these breeding lines in sweetpotato production systems is being tested 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 were evaluated in Jamaica and there performance compared to local export varieties.

Objectives

- Evaluate yield and appearance of 28 USDA breeding lines in the Caribbean and the USA.
- Compare insect resistance in commercial US and Jamaican cultivars with USDA breeding lines.

Research Approach

Twenty-eight (28) USDA breeding lines and two commercial cultivars were evaluated at two locations in the USA (USDA - US Vegetable Laboratory Research Farm, Charleston and the Clemson University Research and Education Center, Blackville SC) and one location in Jamaica (Bodles Research Station, St Catherine Parish). The breeding lines for these experiments were selected on the basis of their performance in tests of prior years in South Carolina for insect resistance, yield and quality. Planting material for all breeding lines were grown in plant beds in Charleston, SC, and in Mona, Jamaica.

Each breeding line was planted on beds 23 - 30 cm high, 1m wide and spaced at 30 cm intervals. With the exception of the study conducted in Charleston in which 10 plant plots were established, all other plots consisted of 25 plants/plot. Treatments were allocated in a randomized complete block design with four replicates.

Yield and Horticultural Traits. 120 and 150 days after planting, roots were harvested in the USA and Jamaica, respectively. Roots were graded into 3 size categories relating to local and export market standards (culls, marketable I and II). The number of roots within each category was counted and weighed (kg). Observations on shape, skin and flesh colour, fibre, low sweetness and flavour were recorded. Percentage dry matter was also determined.

Insect Resistance. Roots were scored for pest damage resulting from sweetpotato leaf beetle larvae, sweetpotato weevils, white grubs, 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

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[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 > 2 cm deep and >48% internal tissue injury.*

[2] *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.*

[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.*

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:

$$[(a \times Score\ 0) + \ldots\ldots + (a \times Score\ 5)] / Total\ Number\ of\ Roots$$

Where a= number of roots with the particular score

Statistical Analysis. Data were analysed by Analysis of Variance (ANOVA) and means separated with Duncans Multiple Range Test using SAS statistical software.

Research Results and Discussion

Yield and Horticultural Traits. No significant differences were observed between locations in total yields (P> 0.05). In Jamaica, USDA breeding lines produced significantly higher yields than the commercial variety "Sidges" (P< 0.05). Several of the high yielding USDA breeding lines had flesh colours and textures suitable for both US and Jamaican markets. In an informal culinary evaluation Sumor, Picadito and White Regal were the most favoured varieties in the Jamaican experiment (Tables 1a and b).

Table 1a. Yield, culinary quality and appearance of selected USVL sweetpotato clones and check clones in the USA and Jamaica

Sweetpotato Clone	Appearance		Dry Wt.	Culinary Score	Mean Total Yield (Kg/plot)		Mean Marketable Yield (Kg/plot)	
	Skin	Flesh			Jamaica	USA	Jamaica	USA
W-244	M. Copper	M. Orange	21.5	na°	27.8	40.7	22.0	40.7
W-250	Red	M. Orange	---	na	21.8	34.6	17.5	34.4
W-305	Tan	Yellow	24.5	2.0	29.4	12.0	24.1	12.0
W-325	Tan	Lt. Yellow	25.0	1.5	19.1	20.0	16.2	20.0
W-326	Rose	Yellow	26.0	2.0	19.1	13.6	16.7	13.5
93-238	Tan	Cream	27.3	1.5	25.7	17.9	15.2	17.9
94-37	Rose	Cream	---	2.5	30.7	22.9	24.7	22.9
94-39	Rose	Cream	---	2.5	14.5	18.6	9.9	18.6
94-191	Red	Cream	---	2.5	27.8	32.9	20.6	32.8
94-206	Red	Mot Yellow	---	2.0	23.7	19.9	21.4	19.9
Picadito	Scarlet	White	---	1.5	23.9	---	21.0	
Sumor	Tan	Cream	28.0	2.5	27.3	24.7	24.8	23.6
W.Regal	Scarlet	Cream	---	2.5	16.9	19.7	13.3	19.4
Susceptible Check Line								
SC1149-19	Lt Copper	Lt. Orange	29.0	na	31.9	21.9	22.3	21.2
Jamaican Standard								
Sidges	Red	Cream	---	---	6.9	---	5.9	---
US Standard								
Beauregard	DkCuRose	M. Orange	19.2	na	2.0	9.0	---	28.9

na = not applicable for sweet orange flesh breeding lines

Table 1b. Yield, culinary quality and appearance of selected USVL sweetpotato clones and check clones in the USA and Jamaica

Sweetpotato Clone	Appearance		Dry weight	Culinary Score	Mean Total Yield (Kg/plot)		Mean Marketable Yield (Kg/plot)	
	Skin	Flesh			Jamaica	USA	Jamaica	USA
W-263	M. Copper	M. Orange	----	1.5	20.2	28.9	12.8	39.0
W-308		Yellow	----	1.5	10.6	27.1	8.5	27.1
W-315	Tan	Lt. Yellow	28.6	1.5	19.1	17.9	15.6	17.8
W-329	Tan	Yellow	22.1	2.0	14.2	12.8	9.0	12.8
W-330	Rose	Yellow	29.0	1.5	13.7	28.9	8.5	----
93-250	Tan	Cream	---	2.0	21.7	25.9	7.5	24.8
94-103	Rose	Lt. Yellow	26.5	1.5	8.8	21.3	5.3	21.2
94-127	Rose		29.8	1.5	17.7	---	13.7	----
94-190	Lt Copper	Cream	24.3	1.0	17.2	24.9	12.4	24.2
94-196	Tan	Yellow	29.8	1.5	12.5	26.7	5.8	26.2
94-204		Yellow	30.3	2.5	13.4	---	9.9	----
94-206	Red	MO Yellow	---	2.0	15.0	19.9	3.0	19.9
Resisto	Scarlet	White	---	2.5	4.6	26.9	1.1	----
Susceptible Check Line								
SC1149-19	Lt Copper	Lt. Orange	29.0	na	31.9	21.9	22.3	21.2
Jamaican Standard								
Sidges	Red	Cream	---	---	6.9	--	5.9	----
US Standard								
Beauregard	DkCuRose	M. Orange	19.5	na	Na	29.0	---	28.9

na not applicable for sweet orange flesh breeding lines

Insect Resistance. When compared to the insect - susceptible check, SC1149-19, high levels of resistance to WDS, SFB and grub damage were demonstrated among breeding lines in the USA. Multiple pest resistance was also observed (Tables 2a and b). The US commercial cultivar, *Beauregard,* was significantly more susceptible to WDS, flea beetles and soil grubs than the test lines (P< 0.05).

Table 2a. Resistance ratings of USVL and check sweetpotato clones to soil insects and sweetpotato weevil in the USA and Jamaica

Sweetpotato Clone	WDS % Damage Damage Indices		Flea Beetle: (% Damaged Roots)		White Grub (% Damaged Roots)	SFB Larvae (Damage indices)	SPW (Damage Indices)	
	Jamaica	USA	Jamaica	USA			Crown	Root
W-244	4.0	0.4	0.5	0.0	1.5	1.43	1.2	0.65
W-250	6.1	0.4	1.1	4.0	0.5	1.70	2.8	0.70
W-305	11.4	0.2	3.3	0.1	20.5	1.29	2.5	1.06
W-325	1.2	0.18	0.0	0.6	1.5	1.21	1.9	1.54
W-326	0.5	0.11	0.4	0.1	2.7	1.11	1.1	0.42
93-238	2.9	0.33	0.1	0.1	10.5	1.19	0.9	0.43
94-37	1.6	0.42	1.6	8.8	1.5	0.98	1.2	0.71
94-39	7.7	0.46	1.2	4.1	9.3	1.75	2.7	0.54
94-191	1.1	0.34	1.0	0.1	13.3	1.53	1.1	0.44
94-206	4.6	0.28	0.7	2.7	2.5	1.73	2.1	0.72
Picadito	4.2	--	4.0	4.0	--	0.81	0.6	0.06
Sumor	5.1	0.16	1.7	0.3	6.8	1.61	0.8	0.76
W.Regal	3.9	0.16	1.9	0.6	4.1	1.17	0.7	0.97
Susceptible Check line								
SC1149-19	8.0	1.18	5.0	11.2	20.5	0.87	2.2	0.96
Jamaican Standard								
Sidges	0.9	----	0.6	---	----	1.74	1.0	0.19
LSD	4.4		2.0			0.29	0.94	0.32

White grub damage evaluated in USA only, Sweetpotato weevil (**SPW**) and Sweetpotato Leaf Beetle (**SPLB**) larvae damage evaluated in Jamaica only. *Diabrotica-Systena complex* ***(WDS)*** *– Jamaica and the USA..* **Severity Index** based on the formula ***(a x Score 0) + ...+ (a x Score 5)/Total Number of Roots.*** *Where a= number of roots with the particular score.* ***Rating Scale: 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..* ***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.*

Table 2b. Resistance ratings of USVL and check sweetpotato clones to soil insects and sweetpotato weevil in the USA and Jamaica

Sweetpotato Clone	WDS % Damage Damage Indices		Flea Beetle: (% Damaged Roots)		White Grub (%Damaged Roots)	SLB Larvae (Damage indices)	SPW (Damage Indices)	
	Jamaica	USA	Jamaica	USA			Crown	Root
W-263	4.6	0.85	1.5	3.0	4.3	0.82	0.83	0.65
W-308	2.8	0.58	0.6	3.4	10.7	0.95	141	1.27
W-315	1.8	0.37	0.3	5.9	1.4	0.95	2.16	0.68
W-329	7.2	0.56	6.6	6.2	18.6	0.78	1.26	0.47
W-330	3.4	0.39	2.6	0.43	14.4	0.45	0.89	0.45
93-250	5.0	0.50	1.0	5.9	4.3	1.04	0.93	1.10
94-103	3.1	0.23	3.5	0.8	6.9	0.69	1.88	0.59
94-127	4.0	0.26	1.6	1.4	0.06	0.71	1.55	0.31
94-190	5.0	0.39	1.0	2.1	4.5	0.82	0.76	0.38
94-196	3.5	0.42	1.0	4.1	4.0	0.33	1.50	0.15
94-204	2.6	0.06	0.5	0.2	10.5	0.41	0.1	0.16
94-206	9.5	0.28	0.5	2.6	2.5	0.82	1.9	0.40
Resisto	0	0.2	0	0.6	4.1	1.03	0.27	0.14
Susceptible Check line								
SC1149-19	8.0	1.18	5.0	11.2	20.5	0.87	2.2	0.96
Jamaican standard								
Sidges	0.9	----	0.6	----	----	1.74	1.0	0.19
LSD	4.4		2.0			0.29	0.94	0.32

White grub damage evaluated in USA only, Sweetpotato weevil (SPW) and Sweetpotato Leaf Beetle (SPLB) larvae damage evaluated in Jamaica only. Diabrotica-Systena complex ***(WDS)*** *– Jamaica and the USA.***Severity Index** based on the formula ***(a x Score 0) + ...+ (a x Score 5)/Total Number of Roots.*** *Where a= number of roots with the particular score.* ***Rating Scale: 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..* ***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.*

Significant differences (P< 0.05) were observed among breeding lines for crown and root damage due to the sweetpotato weevil were observed (P< 0.05). Some lines exhibited tolerance to both root and crown attack. No clear trends were observed in the damage resulting from immatures of the sweetpotato leaf beetle; this may have been due to high populations.

Due to either differences in pest composition and/or populations, comparisons of pest damage ratings between locales was not possible. However, the line SC1149-19 demonstrated its value as a susceptible check clone in the USA and Jamaica, and thus will be a good indicator for measuring resistance at both sites. Overall, useful levels of resistance to major pests were observed among USDA breeding lines. Inheritance of insect resistance is quantitative, and prior work has documented that with reliable selection methods it is possible to greatly increase the level of insect resistance in individuals within breeding populations (Jones et al). Several lines, which met market criteria and/or demonstrated potential for high yields and resistance to pest attack were identified (White Regal, Picadito) and will be used as parents in the 1998 season.

The 1998 – 1999 trials are in progress in the USA. The first trial contains 19 sweetpotato breeding lines and cultivars from the USDA program, six Plant Introductions and the insect susceptible check line, SC1149-19. The best lines identified in field experiments in Jamaica were also included in this study. We plan to harvest and collect the yield and insect damage data from the two South Carolina trials in late October or November of 1998. The second replicated field trial was initiated in field trial in Blackville and Charleston SC. Prior ratings of these lines are presented in Table 6. We also included a set of Plant Introductions that had been identified to have weevil resistance in the field by Paul Thompson of Mississippi State University. The same experiment will be planted in Jamaica in the late fall of 1998.

Evaluation of Resistant Varieties and Chemical Insecticide for the Management of the Sweetpotato Soil Grub.

Janet Lawrence (CARDI), Mike Jackson (USDA - Vegetable Laboratory), Janice Bohac (USDA - Vegetable Laboratory)

Over the past 2 years within the parish of Clarendon, sweetpotato farmers have been experiencing severe losses in sweetpotato yields due to the larvae of the sweetpotato leaf beetle, *Typhorous* sp (identification to be confirmed). In some cases, these losses in yields have exceeded 30% of harvested roots. Over the past two seasons (1996 -1998), attempts have been made to identify and evaluate potential tactics to reduce the economic losses being incurred. The study below describes the evaluation of two chemical insecticides and 3 USDA breeding lines which have demonstrated varying levels of grub resistance in the USA.

Objective

- Determine the effectiveness of two chemical insecticides and 3 USDA sweetpotato breeding lines with varying levels of insect resistance
- Determine yields and adaptability of USDA varieties under current farmer production practices.

Research Approach

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 treatments plots and surrounding the field were treated with the herbicide Gramoxone. Sweetpotato weevil infestations were managed with the current recommended IPM practices of mass trapping of male weevils with female sweetpotato weevil sex pheromone and cultural practices.

Experimental Design. Three (3) USDA breeding lines were included in the study *White Regal, Sumor* and *SC1149-19* – a susceptible check line. The local line included Sidges. Chemical pesticides evalauted were Ethoprop (Mocap 10G) and Fipronil [BSI] (Regent) and applied at the rates of 7000g ai. and 100g ai. per hectare respectively. Applications were made prior to planting using a granular applicator. All plots treated with the insecticides were planted with Sidges. Treatments were allocated in a random complete block design with 4 replicates. Each treatment plot consisted of 50 plants (n= 200 per treatment). Plots were surrounded by guard rows of the local variety - Sidges.

Parameters measured: Pest Incidence. At planting and harvest (120 days after 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 form each section was sieved and the number of larvae and adult beetles present was recorded.

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. Weevil populations were also assessed as previously described.

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

Pest Incidence. No soil grubs were found in soil samples at planting, however at harvest a total of 88 grubs and 20 adult beetles of the Sweetpotato Leaf Beetle, *Typhorous* sp. were found in the plot. No significant differences between grub infestation levels were observed among treatments.

Root Damage. Overall roots damaged by sweetpotato leaf beetle averaged 35.4% of total harvested yields. Significant differences were observed among treatments (P= 0.01) (Table 1). In relation to USDA breeding lines, significant differences were observed, *White Regal* had the lowest level of grub damage and as expected SC1149 -19, the susceptible check line had the highest level of damage; mean root damage was 20.0% and 46.3% respectively.

In relation to the chemical insecticides, plots treated with Fipronil had significantly lower levels of damaged roots when compared to the current farmer practice of Ethoprop, mean damage levels were 15.9% and 32.3% respectively. For all treatments, similar trends were also observed in the severity of damage of roots.

Table 1. Efficacy of two chemical insecticides and 3 USDA breeding lines on root damage resulting from the sweetpotato leaf beetle, *Typophorous* sp. in Ebony Park , Clarendon.

Treatment		Sweetpotato Leaf Beetle		Sweetpotato Weevil	
		% Root Damage (±SE)	Severity Damage Index (±SE)	% Root Damage (±SE)	Severity Damage Index (±SE)
Chemical insecticides					
	Ethoprop (farmer practice)	32.3 (2.7)	0.39 (0.02)	8.33 (2.8)	0.15 (0.06)
	Fiponil	18.0 (0.99)	0.22 (0.03)	4.6 (1.4)	0.04 (0.02)
	Control (Sidges variety)	35.9 (3.1)	0.52 (0.03)	4.76 (2.2)	0.05 (0.04)
USDA Breeding Lines	White Regal	20.0 (6.6)	0.20 (0.07)	10.5 (5.9)	0.17 (0.10)
	Sumor	31.8 (7.7)	0.41 (0.10)	7.7 (4.0)	0.09 (0.11)
	SC1149-9 (susceptible check line)	46.3 (7.3)	0.64 (0.03)	43.2 (8.8)	0.7 (0.24)

(P= 0.02 F= 3.57, df= 23)

Performance. Yield per treatment plot averaged 8.4 kg (Table 2). No significant differences in yields were observed among sweetpotato lines (P= 0.72), however the highest yields were produced by that local line - Sidges, mean yield per plot was 11.0 Kg (Table 2). White Regal and Sidges produced the largest number of roots which met domestic and export market size criteria, average root size was 0.34 Kg and 0.46 Kg respectively.

Table 2. Performance of USDA lines under farmer production practices.

	Sweetpotato Lines	Total Yield (kg/50 plant plot) (SEM)	Avg. Root Size (Kg) (SEM)
USDA Line	White Regal	9.6 (3.3)	0.34 (0.23)
	Sumor	10.1 (0.2)	0.08 (0.0005)
	SC1149-19	7.3 (1.1)	0.09 (0.01)
Local Variety	Sidges	11.1 (3.3)	0.46 (0.09)

Overall, Sidges treated with Fiponyl and the USDA line, White Regal had the lowest levels of damage due to soil grubs and appear to be promising adjuncts to the present IPM recommendations. It should be noted that many farmers within the area were very interested in the culinary attributes, shape and skin and flesh colour of the lines which were evaluated and expressed willingness to try these varieties if they were acceptable by the exporters.

Working with Participating Groups to Disseminate Sweetpotato Weevil IPM Technology

Janet Lawrence (CARDI), Phillip Chung (RADA), Trevor Martin (RADA)

During the first 3 years of the sweetpotato research programme, significant progress was made in relation to the validation of an IPM technology for the sweetpotato weevil on select farmers fields in South Central Jamaica. These studies demonstrated that farmers utilising the technology of mass trapping male weevils with high doses of female sweetpotato weevil sex pheromne in combination with cultural practices were experiencing a three fold reduction in sweetpotato roots damaged by the pest when comapared to Non-IPM farmers. Over the past 2 years. efforts have therefore been made to disseminate the technology to farmers in other major growing areas in the parishes of Clarendon and Manchester. As outlined in the Annual Report for 1996 – 1997, the process involves a 4 step approach including: (a) baseline survey, (b) technology transfer and (c) impact assessment/extension training (Figure 1). The baseline survey was conducted and the results reported in the IPM CRSP Annual report (1996 – 1997). The activities during the past year (1997 - 1998), focused on the transfer of the IPM technology. Below describes the approach used to introduce farmers to the technology and highlights some of the observations and experiences gained

from the exercise.

Objective

- Develop and evaluate training packages to sweetpotato farmers in Jamaica
- Disseminate IPM technology to sweetpotato farmers

Research Approach

Based on economic loss data gathered during the baseline survey conducted in Clarendon and Manchester, districts were prioritized and the technology introduced to farmers with the greatest need i.e. experienced high losses in marketable yields due to the sweetpotato weevil.

A two step interactive approach was utilised to transfer the technology. The first step involved introductory seminars consisting of 40 - 60 agricultural students/farmers. During these sessions, the results of the baseline survey were validated and topics such as sweetpotato weevil biology, principles of IPM and sweetpotato weevil IPM technology discussed (Table 1). The rationale of the technology in relation to the life cycle of the pest was emphasised A field demonstration of the weevil IPM technology was also conducted. Pest management guides were distributed at he end of the session.

Figure 1: Model of a stepwise approach to disseminate sweetpotato weevil IPM technology

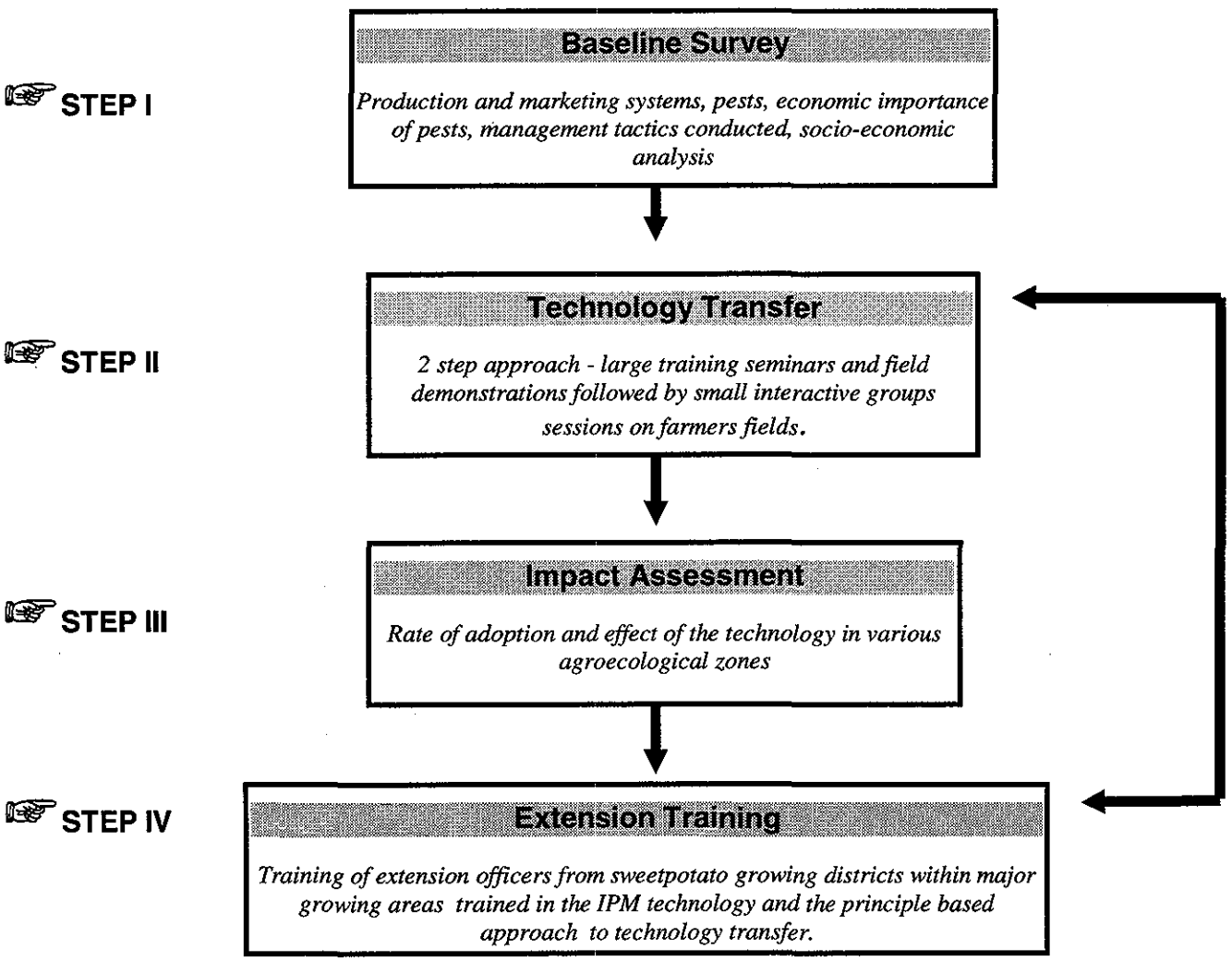

Table 1 : Topics covered in technology transfer sessions

Subject	Topics Covered
Pest biology	• Sweetpotato weevil life cycle • Damage symtomology
Integrated Pest Management (IPM)	• What is IPM (biological, cultural, mechanical, chemical - judiciously) • Reason for IPM (effects of excessive pesticide use resulting in pollution, residues, health, input costs) • Benefits of IPM
Pheromones	• What is a pheromone • Types of pheromone • Role of pheromones in pest management • Trap construction from recyclable materials • Use of traps with sweetpotato cropping systems • Importance of trap maintenance • Sources of pheromones • Cost of pheromones
Sweetpotato weevil IPM	• Cultural practices importance of cultural practices - relationship between biology and cultural practices recommended • Biological – sex pheromone • Trap efficiency as it related to design and maintenance • Importance of integration of the tactics

Subsequent to the large seminars, farmers were organised into small groups (5 - 7 persons) and interactive sessions held on farmer's fields. For these sessions, farmers were requested to bring the materials for making pheromone traps and encouraged to apply the knowledge gained from the seminar to construct traps. Farmers were encouraged participate in the placement of traps within the field and trap efficiency in relation to design, placement and maintenance discussed. Demonstrations of the cultural practices being recommended was also conducted. At the end of the session, a group leader was selected whose primary role would be to provide feedback to extension officers of difficulties they may experience with the technology.

Results and Discussion

To date, 202 farmers/agricultural students have been trained in the technology in 6 extension areas of the parishes of Clarendon and Manchester (Table 2).

Table 2: Farmers/agricultural students in the parish of Clarendon and Manchester exposed to sweetpotato weevil IPM technology

Extension Areas/ District	Number of Farmers/Students Introduced to the Technology
Providence	75
Rose Hill	55
Longside	17
Lottery	5
Christiana	20
North Clarendon	30
TOTAL	**202**

It should be noted that in order to facilitate the process, pheromone lures which are not presently available at farm stores were imported from a Pest Management Supplier in the USA by CARDI. Fifteen hundred (1500) lures were imported and they are being are being sold to farmers though RADA at the cost price of US$3.00 per lure.

Several interesting observations were noted during sessions which relate to farmer perception of the pest and their ability to identify appropriate pest management tactics as well as the approach which was used to transfer the technology. Below highlights comments of farmers and observations by researchers who facilitated the process.

- All the farmers had previously observed the pest (larvae and adults) within the field, however the majority (approximately 90%) had no knowledge of the pest biology i.e. relationship between immature and adult weevil and/or the related damage was not known.
- None of the farmers had heard of IPM.
- At the end of the sessions, participants appeared to have a better understanding of the principle of the technology. This was reflected in the questions which were asked. These preliminary observations will be evaluated during the impact assessment activities (Year 6).
- Trap Design. RADA extension officers reported that that subsequent to training seminars many farmers modified traps.
- Technology Transfer Approach. Many farmers expressed that the small group sessions were enjoyable as they felt more comfortable expressing themselves among friends and neighbors. In addition, the participation assisted in the learning process.

- Trainers noted that some of the aids being used in the sessions were not effective in assessing farmer knowledge and/or demonstrating certain aspects of the technology. For example, photographs which were enlarged proved difficult for several farmers to relate to the actual size of the pest. Special attention should therefore be given to ensure that the aids being used actually facilitate the process.

In the coming season, the focus of the research activities will be to monitor and measure the adoption and the impact of the introduced technology, efforts will also be made to also measure the effects of the approach utilised to transfer the technology.

Impact - *related to all previously related studies*

During the past year (1997 – 1998), significant strides were made in relation to developing, evaluating/screening potential sweetpotato breeding lines for introduction into Jamaica. The US variety line Picadito was one of the most promising lines as it demonstrated the characteristics of good yields, high levels of insect resistance and suitable market requirements of red skin and cream flesh. Extensive on-farm trials will have to be conducted in the coming season to further evaluate this line under farmer production practices. In addition, the identification of the soil grub has assisted greatly in identifying appropriate management strategies for the pest. As a short term strategy, Fiponil, a selective chemical insecticide showed great potential in reducing damage to harvested roots by the sweetpotato leaf beetle. The strategies which were evaluated may prove to be promising adjuncts to the current IPM technology which is being disseminated to farmers in major growing areas. In addition, the technology will be useful for farmers in the wider Caribbean who share a similar pest complex.

Networking Activities

- D. M. Jackson and J. R. Bohac served as members of the Sweetpotato Crop Germplasm Committee.

- M. Jackson traveled to Jamaica in February 1998 to assist J. Lawrence (CARDI) in evaluating two sweetpotato field trials. Rating systems for damage from the new grub species were developed. Growers fields in Ebony Park were also visited.

- R. Bohac traveled to Jamaica in April 1998 to assist J. Lawrence (CARDI) in evaluating two sweetpotato field trials. They also worked together to summarize and analyse data from prior trails and develop future research plans.

- R. Bohac shipped several USDA-developed, dry-fleshed sweetpotato clones to J. Lawrence to evaluate their potential in Jamaica.

- J, Lawrence. Appointed chairperson to the Collaborative Research Planning committee between CARDI and MINAG

- Lawrence, J. attended the 2nd Caribbean IPM Network Meeting (February 4 – 6, 1998). Kingston, Jamaica. – able to network with other IPM researchers for the Caribbean, USA and Europe.

- M, Jackson and Janet Lawrence participated in the IPM CRSP Caribbean Site Planning Conference. Blacksburg, VA. May 13 - 14, 1998.

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Highlights

- Significant strides were made in the identification of the soil grub which has significantly reduced marketable yields of sweetpotato.
- The development of a rating scale to measure levels of resistance in sweetpotato breeding lines has assisted in developing methodologies for screening USDA and local breeding lines.
- USDA breeding lines proved to be a potential tactic for Jamaican sweetpoato growers to integrate into the current IPM technology. Lines were able to produce yields comparable to local lines, exhibited varying levels of resistance to sweetpotato weevil and the sweetpotato leaf beetle and several met market and consumer criteria, "Picadito" is the first line identified as the most promising.
- The selective chemical Fipronil was able to reduce damage due to soil grubs 50% more than the farmer practice of MOCAP.
- Sweetpotato weevil IPM technology was disseminated to 202 farmers and agricultural students in major growing districts in Clarendon and Manchester though a series of interactive technology transfer sessions.

The Role of Soil Fertility Management on Growth, Yield, Nutrient Content and Pest Incidence in Hot Pepper (*Capsicum chinense*) and Callaloo (*Amaranthus viridis*) Cropping Systems

Investigators: F. Eivazi[1], J. Lindsay [2], and R. Martin[2]

Collaborating Scientists: M. Smith[3] and D. McGlashan[3]

Abstract

An experiment was conducted to compare three levels of soil applied fertilizer, foliar applied soluble fertilizer and a control, on Scotch Bonnet pepper (*Capsicum chinense*). Growth and yield were significantly higher on plots with soil applied nutrients compared to control and foliar applied fertilizer. Aphid and broad mite (*Polyphagotarsonemus latus*) incidence were significantly higher in plots with higher leaf nitrogen.

Objectives

- Test the effect of fertilizer rates on growth, yield and nutrient content of hot pepper and callaloo
- Quantify insect incidence as a function of added nutrients

IPM Constraints

Farmers in Jamaica have the tendency to spend scarce resources on pesticide application at the expense of fertilizers. There is also the belief that foliar application is required for optimum crop production. Further, pest incidence is linked to fertility management. Hence, this should be factored in the development of IPM programmes.

The Role of Soil Fertility Management on Growth, Yield, Nutrient Content and Pest Incidence in Hot Pepper (*Capsicum chinense*)

Research Methods

Scotch Bonnet pepper seedlings were grown at the CARDI greenhouse facilities and then transplanted to the experimental plots at Bodles. The seedlings were planted 60 cm within rows and 90 cm between rows with a total of 30 plants per plot. Plots were watered by overhead sprinkler irrigation once to twice weekly.

A randomised complete block design was used with 4 replications and 5 treatments. The fertilizer treatments were as follows: T1 (control, no fertilizer); T2 (187 kg N/ha, 31 kg P/ha, 75 kg K/ha); T3 (374 kg N/ha, 62 kg P/ha, 150 kg K/ha); T4 (747 kg N/ha, 62 kg P/ha, 300 kg K/ha); T5 (foliar application of NPK). The sources of fertilizers were ammonium sulphate, triple superphosphate and muriate of potash. The total amount of phosphorus in each treatment was applied five days after transplanting while nitrogen and potassium were divided into three equal portions and applied one week after transplanting, seven weeks after transplanting and after flowering (12 weeks after transplanting). The fertilizers were applied in bands (ring) and incorporated into the soil. The fertilizer used in the foliar treatment was 15-30-30 soluble fertilizer which was applied every two weeks.

Before planting, composite soil samples were collected from the experimental plots. These were assessed for N, P, K, Ca, Mg, organic matter (OM) and pH. Additional samples were collected from each plot; 6 weeks after transplanting during vegetative growth of the crop; after flowering (12 weeks after transplanting) and at the end of the experiment (19 weeks after transplanting). These additional samples consisted of four cores taken 15 cm from each of four plants. The cores were taken from the top 15 cm of soil. Fifteen recently expanded leaves were also collected from each plot and assessed for N, P, K, Ca and Mg.

The plots were visited weekly and six inner plants were assessed for virus diseases, arthropod pests, plant height and spread and yield. Virus severity was ranked from 0 to 4, 0 being absent and 4 present with severe leaf deformation and reduction in leaf size. Arthropod incidence was measured by dividing the plants into four sections based on the natural

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branching pattern and assigning a score from 0 to 4 based on

was assessed as number and weight of fruit.

Data were analysed using GENSTAT statistical software. Overall treatment effects, on nutrient levels in soil and leaf samples as well as on pest incidence, were assessed using analysis of variance.

Research Results and Discussion

The mean values for selected soil nutrients, 6, 12, and 19 days after transplanting, shown in Table 1 (a-c) indicate a difference only in pH value which was lowest for Treatment 4 which had the highest level of nitrogen (747 kg/N). The source used, ammonium sulfate, has an acidifying effect on the soil. This is probably short lived and localised. In general, however, the N levels in the soil were adequate to supply nutrients to the plant. Organic matter, P, K, Ca and Mg contained in the soil were adequate for average growth and production of pepper. The control treatment showed no deficiency levels of nutrient for the production of pepper.

presence or absence on each of these four sections. Yield

Table 1a: Levels of pH, organic matter, nitrogen, phosphorus, potassium, calcium and magnesium detected in soil samples collected from Scotch Bonnet pepper six weeks after transplanting.

Treatment	pH	OM (%)	N (%)	P_2O_5 (mg/kg)	K_2O (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
T1	7.4	2.36	0.14	139	490	5925	1681
T2	7.0	2.67	0.15	315	609	5725	1594
T3	6.9	3.06	0.18	351	810	6050	1531
T4	6.6	2.40	0.17	350	679	5270	1641
T5	7.5	2.69	0.16	220	577	6563	1606
SE (11 df)	0.254	0.371	0.0267	124	153	598.4	177.7
P	0.029	0.387	0.634	0.394	0.355	0.349	0.934

Table 1b: Levels of pH, organic matter, nitrogen, phosphorus, potassium, calcium and magnesium detected in soil samples collected from Scotch Bonnet pepper 12 weeks after transplanting

Treatment	pH	OM (%)	N (%)	P_2O_5 (mg/kg)	K_2O (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
T1	7.4	2.13	0.13	93	471	4625	1600
T2	7.2	2.38	0.13	166	556	5088	1528
T3	7.2	2.74	0.16	211	748	5063	1494
T4	7.2	2.02	0.14	81	459	4970	1659
T5	7.6	2.24	0.14	167	612	4738	1500
SE (11 df)	0.302	0.279	0.0189	78.0	131	602.0	103.5
P	0.603	0.167	0.635	0.450	0.237	0.914	0.473

Table 1c: Levels of pH, organic matter, nitrogen, phosphorus, potassium, calcium and magnesium detected in soil samples collected from Scotch Bonnet pepper 19 weeks after transplanting

Treatment	pH	OM (%)	N (%)	P_2O_5 (mg/kg)	K_2O (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
T1	8.3	1.79	0.14	72	305	4725	1265
T2	7.4	2.26	0.15	124	535	4575	1197
T3	7.0	2.43	0.16	131	718	4425	1153
T4	6.5	2.06	0.16	67	678	4185	1173
T5	8.4	2.25	0.14	176	480	5050	1190
SE (11 df)	0.383	0.238	0.0101	76.4	134	472.3	148.1
P	0.002	0.151	0.159	0.605	0.064	0.475	0.952

Table 2a: Nutrient levels in leaf samples collected from Scotch Bonnet pepper plots six weeks after transplanting

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	4.02	1.29	4.58	0.56	0.48
T2	3.74	1.48	4.06	0.50	0.38
T3	4.17	1.34	4.22	0.62	0.38
T4	4.36	1.30	4.57	0.70	0.39
T5	3.67	1.32	4.24	0.59	0.45
SE (11 df)	0.317	0.119	0.401	0.0717	0.049
P	0.225	0.515	0.631	0.162	0.168

Table 2b: Nutrient levels in leaf samples collected from Scotch Bonnet pepper plots 12 weeks after transplanting

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	3.86	0.78	4.80	0.52	0.48
T2	4.56	0.77	4.48	0.50	0.44
T3	4.50	0.72	4.30	0.55	0.40
T4	5.12	0.56	4.22	0.48	0.43
T5	3.88	0.95	4.22	0.60	0.46
SE (11 df)	0.345	0.075	0.271	0.0919	0.0358
P	0.012	0.036	0.221	0.831	0.252

Table 2c: Nutrient levels in leaf samples collected from Scotch Bonnet pepper plots 19 weeks after transplanting

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	4.00	1.48	3.50	0.62	0.60
T2	4.35	1.18	4.05	0.54	0.52
T3	5.05	1.07	3.88	0.48	0.41
T4	4.76	1.33	3.96	0.51	0.46
T5	4.89	1.73	4.38	0.59	0.49
SE (11 df)	0.462	0.248	0.226	0.0979	0.069
P	0.216	0.136	0.033	0.570	0.151

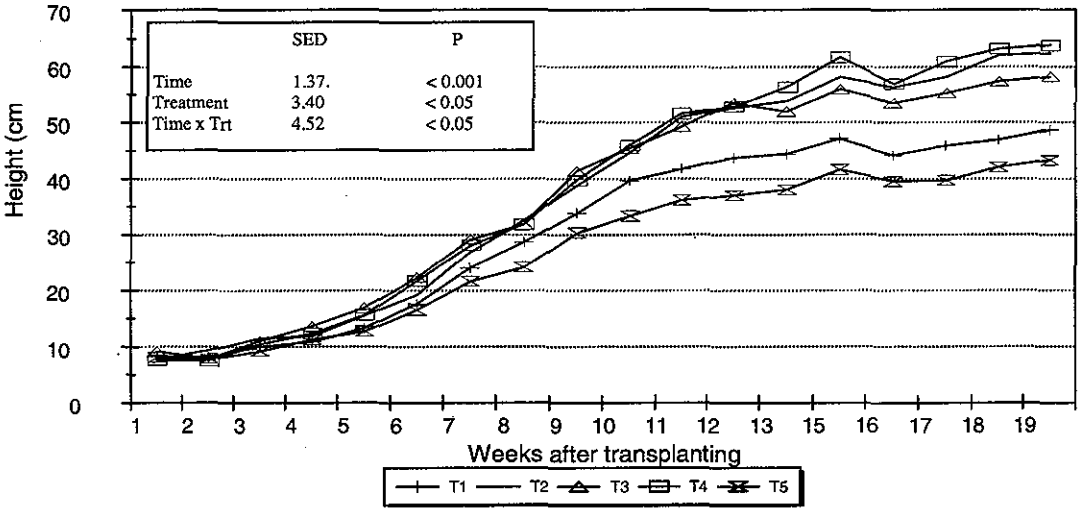

Figure 1: Variation in height of pepper plants in response to fertilizer rates

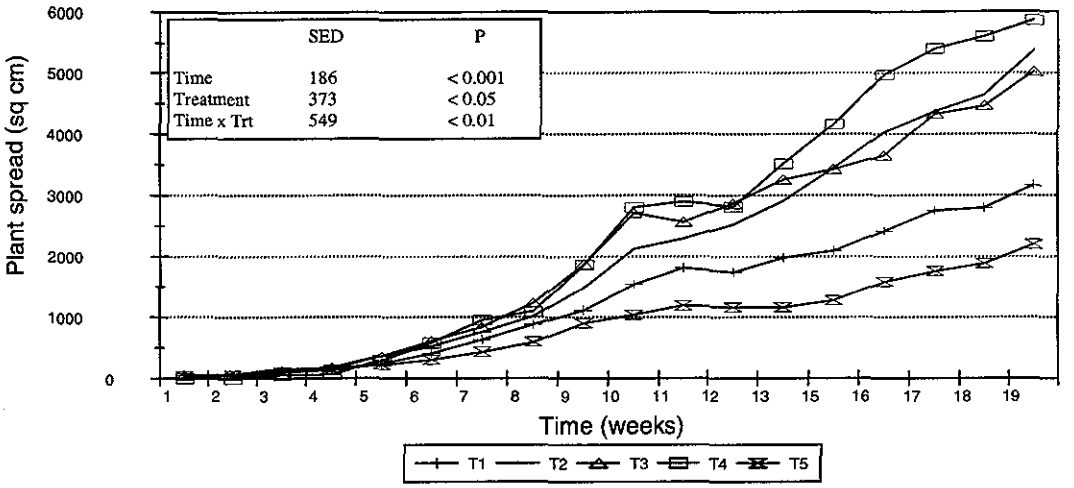

Figure 2: Variation in pepper plant spread (length x width) with time under various fertilizer regimes

Table 3: Weigth (g) and total number of fruits per plot from eight harvests

Treatment	Total weight	SEM (11d.f)	Total weight (g)	Total number of fruits	Total number of fruits	SEM (11 d.f)
T1	5.22	0.443	185	3.03	20.7	0.376
T2	6.26	0.443	523	4.14	62.8	0.376
T3	6.37	0.443	584	4.25	70.1	0.376
T4	6.10	0.527	446	4.06	58.0	0.448
T5	4.59	0.443	98.5	2.62	13.7	0.376
P	0.069			0.036		

There were significant differences among treatments in aphid and mite incidence (P<0.001 and P<0.05 respectively; Figs 3 and 4). For both aphids and mites, plots to which the highest amount of nutrients were applied (T4), and which had significantly higher leaf nitrogen over time, had significantly higher incidence than the control. Although higher levels of pests were present, pest impact on yield did not appear to be significant. The higher pest levels may, however, result in farmers applying higher levels of pesticides.

Symptoms of virus disease were detected 6 weeks after transplanting in Treatment 2. By week 6 virus disease was in all treatments. One hundred percent infection was reached in week 16 in Treatment 4. There were no significant differences in virus disease incidence or severity among treatments (Fig 5).

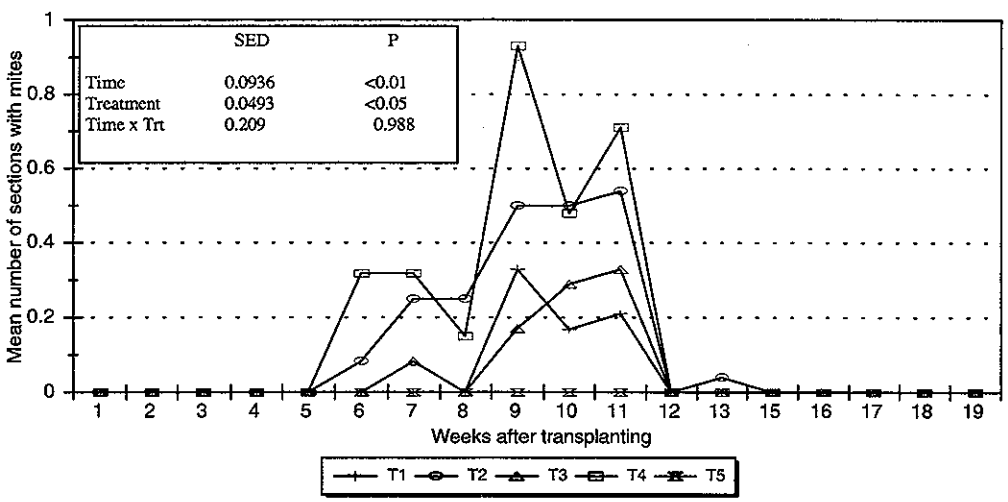

Fig 4: Fluctuation in mite count on pepper branches amongst various fertilizer nutrient levels

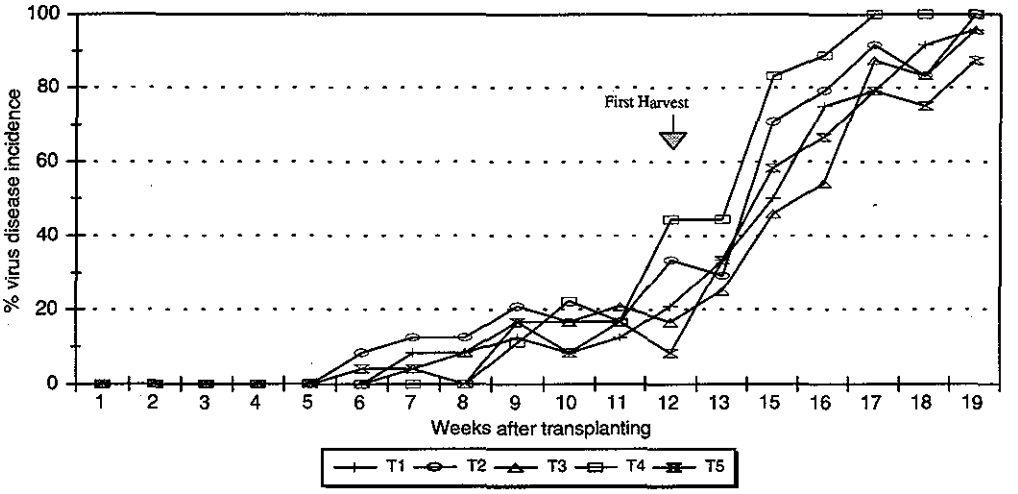

Fig 5: Virus disease incidence under various fertilizer nutrient levels

The Role of Soil Fertility Management on Growth, Yield, Nutrient Content and Pest Incidence in Callaloo (*Amaranthus viridis*) Cropping Systems

Research Methods

The study was carried out at the CARDI field station on the University campus at Mona. The soil type is Maverley loam in which N, P, K and organic matter are at medium levels and the pH is mildly alkaline. The land had been in fallow for at least three months. Weeds were cut with a machete followed by the application of paraquat. The land was refined using a hand tractor and raised beds 300cm x 200cm were built. Seeds of callaloo variety "cow tongue" were sown in a nursery bed. At about six weeks they were transplanted in the field beds at a spacing of 30cm between plants and 50cm between rows. There were six rows with 10 plants per bed . Fertilizer at the appropriate rate was applied in band along the rows and covered. Supplemental irrigation was applied as needed at least twice per week. Plants were kept weed free by hand weeding as necessary. No pesticide was applied for the first 3 weeks at which time a 0.02% neem oil suspended in isopropyl alcohol was applied at two occasions. Due to heavy pest damage the insecticide karate (1ml/litre) was also applied; by that time the plants were damaged beyond recovery, and the trial was stopped. The treatments used were as listed below. They were arranged in a randomised complete block design with four replications: T1: N0P0K0, T2: N1P1K1, T3: N2P1K1, T4: N3P1K1, T5: N4P1K1, T6: N5P1K1, T7: N0P0K0+OM, T8: N0P1K1. The sources of nutrients were ammonium sulphate. triple super-phosphate and muriate of potash for N,P and K respectively. The rates of P and K were 50 and 33 kg/ha respectively. The N rates were as follows0, 17, 34, 50, 68 and 100 kg/ha for N1, N2,N3, N4 and N5 respectively. The source of organic matter was commercial bioganic. It was applied at the rate of 6000kg/ha. All of the P was applied at 10 days after transplanting at which 50% of the organic matter, N and K were also applied. The second application was done 5 weeks later. The fertilizer and manure were applied in small furrows 10cm from the plants and then covered. Five plants in the centre of the two inner rows were monitored to determine plant height and vegetative yield.

Research results and discussion

The variation in the height of callaloo at various sampling dates is shown in Table 2.

Table 2: Variation in callaloo height (cm) under varying N levels

Treatments	Harvests				
	1	2	3	4	5
N0P0K0	48.2	46.9	45.3	48.2	53.2
N1P1K1	39.9	45.2	42.1	51.0	52.1
N2P1K1	38.8	51.1	42.6	49.6	49.4
N3P1K1	44.4	55.6	41.7	54.7	49.8
N4P1K1	38.2	52.7	45.1	52.5	52.2
N5P1K1	45.8	57.7	39.7	45.3	52.6
N0P0K0 OM	38.8	43.8	40.7	48.4	46.9
N0P1K1	41.9	45.8	42.1	47.0	49.3
SEM	3.99	4.55	2.15	3.62	2.49

At first harvest there were no significant differences in the plant heights in response to varying nutrient levels. During

harvests plants are cut back to an average height depending on the size of the branches suitable for marketing or use. Plants were cut back to uniform height and treated but in the re-growth no significant difference was noted. Height of stem is of importance in marketing and neither stems which are too long or too short are desirable.

Callaloo yield in terms of fresh weight is summarised in Tables 3 and 4. Yields were significantly different (P>0.05) at fourth harvest where Treatment 5 showed the highest yield. Marketable yield is based on visual appearance.

Table 3. Variation in marketable yield (kg) of callaloo

Treatments	Harvests			
	1	2	3	4
T1	0.89	0.09	0.44	0.41
T2	0.76	0.15	0.41	0.60
T3	0.76	0.45	0.43	0.83
T4	0.98	0.39	0.43	1.30
T5	0.64	0.16	0.68	0.96
T6	1.04	0.45	0.40	0.69
T7	0.64	0.20	0.38	0.68
T8	0.82	0.26	0.43	0.45
Sig Level	ns	ns	ns	0.02
SEM	0.168	0.112	0.083	0.166

Table 4. Variation in total yield (kg) of callaloo per plot at 5 sampling dates

Treatments	Harvests				
	1	2	3	4	5
T1	1.16	0.96	0.44	0.41	0.23
T2	0.88	1.28	0.41	0.60	0.48
T3	0.80	1.35	0.43	0.83	0.26
T4	1.10	1.82	0.43	1.30	0.34
T5	0.71	1.53	0.68	0.96	0.36
T6	1.14	1.81	0.40	0.69	0.33
T7	0.75	1.09	0.38	0.68	0.28
T8	0.95	0.95	0.43	0.48	0.26
Sig Level	ns	ns	0.021	ns	ns
SEM	0.184	0.272	0.077	0.166	0.053

Pest damage, presence of flowers and hardiness of stems can affect the marketability of the crop. A range of common pests of callaloo reported by Clarke-Harris, Fleischer and Fender 1998) including armyworms (*Spodoptera* spp), banded cucumber beetle (*Diabrotica balleata*) and leaf hoppers (Homoptera) were noted on the crop but pest damage was assessed mainly in terms of the leaves which had been affected by pests.

As the primary aim of the study was to see the effect of the varying N levels on growth and response to pest, neem oil (0.2%) was applied. This did not prevent pest attack.

Later the use of Karate did not prevent attack as all leaves had been damaged at the 5th harvest. There was no recovery of the plants as the photosynthetic area had been lost and the study was stopped.

This study was limited by the absence of soil and leaf nutrient levels. The Maverley loam has medium levels of N, P and K. It drains readily in the upper layers of the profile and with low level of organic matter the soil is drought prone. Irrigation was used to keep the soil moist but the windy and dry conditions would not have facilitated optimum growth conditions.

Impact

The information generated will supplement existing IPM technology in integrated crop management.

Networking Activities

Lindsay and R. Martin participated in a seminar put on jointly by CARDI and UWI entitled "Enhanced pepper production", at the University of the West Indies, Jamaica, May 26 and 28, 1998.

F. Eivazi visited the Jamaica research site, September 1998. During this visit she presented a seminar.

Publications and Presentations

J. Lindsay presented a paper entitled "Preliminary study into nutrient effect on plant growth, production and selected pests and disease incidence in Scotch Bonnet" at the Joint JSAS/CFCS Annual conference, Montego Bay, Jamaica, July 12-18, 1998.

Project Highlight

Application of fertilizer increased yield in pepper. However, this was accompanied by increases in pest and disease incidence. The lowest level of fertilizer produced the most economic yield. Nitrogen fertilizer increased callaloo economic yield. Marketable loss was similar at all levels.

Pesticide Use, Residues and Resistance

Investigators: Clive A. Edwards[1], Frank McDonald[1], D. Clarke-Harris[2], Raymond Martin[2], S. Fleischer[3]

Collaborating Scientists: Gene Barlett[4] and Phillip Chung[5]

Abstract

The goal of this topic is to assess the extent to which pesticides are used on pepper, callaloo, and sweet potato. 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.

Summary

Samples of callaloo and hot peppers collected in market basket surveys in August 1997 and February 1998 were contaminated with the insecticides diazinon, malathion and profenphos at environmentally unacceptable levels. These insecticides, which were present in seven of twenty-one callaloo samples and six of seventeen hot pepper samples, ranged from 0.48 to 2.2 ppm diazinon, 0.62 to 0.90 ppm of malathion and 0.94 to 1.10 ppm of profenphos. An extensive survey demonstrated that twenty-seven pesticides are in common use and many others are used occasionally. There is good evidence that pesticides are being used too often and too close to harvest.

There continues to be dramatic lack of lepidopteran larval control in grower's fields in the presence of 5 to 8 day scheduled applications of pyrethroids, carbamates, organophosphates, microbials (*B. thuringiensis*), and organochlorines applied individually and in tank-mixes. Pesticide resistance is suspected as contributing to this lack of control. Taxonomic work (a related part of this work documented elsewhere in this report) has determined that the lepidopteran larvae complex consist of 5 species (*Spodoptera frugiptera, S. eridania, S. exigua, Herpetogramma bipunctalis,* or *Spoladea recurvalis*). This taxonomic work now allows us to focus on determining what, if any, resistance in present. This project is developing a Caribbean infrastructural capability to assay for resistance, preparing for a transition to biorational management options within a resistance management program. This work is building on resistance management training completed in earlier years, and on development of new biorational control options. We changed methods from a topical bioassay to a leaf dip bioassay, which we determined to be a more appropriate technology for Caribbean applied studies while maintaining scientific rigor. A glass vial bioassay was also tried, but found less useful. We experimented with several methods for colony rearing of field collected larvae, and are currently working out problems with importation of virus with the field collected larvae. Using the leaf dip bioassay, and bracketing recommended field application rates, we determined *that S. eridania* was not resistant to formulated lambda-cyhalothrin (Karate®). However, data using *S. exigua* suggests sufficient levels of resistance to Karate® to cause field failures (data showed no mortality of neonates at twice the recommended field rate). Current efforts are focused on colony development and define dose-mortality curves for *S. exigua* against Karate®.

Objectives

- Identify pesticides used most commonly on callaloo (*Amaranthus viridis*), hot peppers (*Capsicum chinense*) and sweet potatoes (*Ipomoea batatus*) and to monitor their residues on these crops at harvest time. As IPM becomes adopted for these crops it is anticipated that residues will decrease.

- Periodic surveys of the kinds, rates and frequency of

[1] The Ohio State University [2] CARDI [3] Penn State [4] University of Delaware [5] RADA

application of pesticides used on callaloo, hot peppers and sweet potatoes.

- Continuation and extension of long-term program for regular monitoring of pesticide residues in market basket samples of callaloo and hot peppers that are consumed in Jamaica.
- Regular assessment of residues of pesticides on field crops of callaloo and hot peppers that are consumed in Jamaica.
- Regular assessment of residues of pesticides on Preclearance/Export samples of callaloo and hot peppers destined for the USA.
- Quantify levels of insecticide resistance in selected pests of callaloo.

IPM Constraints

The IPM constraints addressed in this project are to use IPM to progressively decrease pesticide residues on callaloo and hot peppers as IPM becomes adopted increasingly, and less pesticides are used on these crops. The pesticide use surveys will establish changes in the kinds, frequency and amounts of pesticides used on callaloo and hot peppers with the target of decreasing overall pesticide use on these crops significantly. a. Quantify levels of insecticide resistance in selected pests of callaloo.

Pesticide resistance is suspected of contributing to field control failures. New biorations options being developed as part of the IPM CRSP must be integrated within a resistance management philosophy. This project is developing the Caribbean infrastructural capability to assay for resistance, preparing for a transition to biorational management options within a resistance management program, while solving a current real-world problem in callaloo. Taxonomic constraints have been addressed, and training constraints completed for a small group of Caribbean scientists. Current constraints deal with establishment and maintenance of field-collected colonies suspected of exhibiting resistance.

Pesticide Use on Callaloo (*Amaranthus viridis*), Hot Pepper (*Capsicum chinense*) and Sweet Potato (*Ipomoea batatas*) in Jamaica

Research Method

1. Baseline Survey on Pesticide Use

All of the pesticides identified as in common use on the three crops were reviewed in terms of their trade names, nammalian toxicities, persistence, solubility and amount of use (Table 1). A survey was made of which pesticides were used on the three crops. The relative uses are summarized in Tables 2 & 3.

2. Pesticide Residue Research on Callaloo, Hot Pepper and Sweet Potato

a) Sampling

(i) Market Basket Sampling: Samples of callaloo and hot peppers were obtained from local markets in August 1997. Three callaloo and three hot pepper samples were purchased from each market and their sites of origin was determined from the vendor. They were stored in portable cold boxes over dry ice and transferred to Columbus, Ohio then kept in deep freeze until pesticide residues could be extracted and analyzed.

In February 1998, a similar sampling was made and the samples analyzed in the same way as in August 1997.

(ii) Field Sampling: Six samples of callaloo and six samples of hot peppers were collected at random from farms in the Bushy Park and St. Catherine areas, where there were some records of the kinds and amounts of pesticides used, in August 1997, kept in cold boxes on dry ice, transported to Columbus and transferred to deep freezers until analyzed for residues. No samples were taken in February 1998.

(iii) Pre Clearance Sampling: Six samples of callaloo and six samples of hot peppers were collected from the Pre Clearance Facility at Norman Manley Airport in August 1997, put in cold boxes with dry ice, transported to Columbus and then put into deep freeze until analyzed for residues. In February 1998, four samples of peppers and two samples of callaloo were collected from the Pre Celearance facility at Norman Manley Airport.

b) Residue extraction, clean-up and analyses: The following analytical procedures were used for extraction of the residues from the plant material and analysis:

Procedure 1 - FDA Pesticide Analytical Manual (PAM), Section 212, 13a, Vol 1, 1987 - High Moisture Products. This was used for diazinon, malathion, profenofos, chlorpyrifos, and disulfan.

1. Blend 50g sample with 100 mL of acetonitrile for 2 minutes.
2. Filter through Buchner funnel into filter flask.
3. Transfer to 1 Liter separatory funnel, add 50 mL petroleum ether and shake for 1 minute.
4. Add 10 mL saturated NaCl solution and 300 mL deionized water and shake for about 45 seconds.
5. Allow layers to separate, then drain aqueous portion into beaker.
6. Rinse solvent in separatory funnel with 2-50 mL aliquots of water. Drain these into beaker.

7. Drain solvent layer through sodium sulfate (to remove any residual water) into a Kuderna-Danish apparatus.
8. Concentrate on steam bath and exchange to 10 mL of hexane.

No further cleanups were performed. Extracts were analyzed using Gas Chromatography with Nitrogen-Phosphorus Detector.

Procedure 2 - FDA Pesticide Analytical Manual (PAM), Section 232.43a, Vol 1, 1987 - High Moisture Products using acetone Extraction. This was used for monocrotophos, methamidophos and dimethoate due to their solubility in the acetontrile/water in procedure 1 above.

1. Blend with 100 mL of acetone for 2 minutes (50 g could not be used for all samples during this extraction sue to the limited amount left after procedure 1).
2. Filter through Buchner funnel into filter flask.
3. Transfer 1 Liter separatory funnel, add 50 mL petroleum ether and 50 mL methylene chloride and shake for 1 minute.
4. Allow layers to separate, then drain aqueous portion into beaker.
5. Drain solvent layer through sodium sulfate (to remove any residual water) into a Kuderna-Danish apparatus.
6. Add 7g NaCl to separatory funnel and shake 30 seconds until most of salt has dissolved.
7. Add 50 mL of methylene chloride, shake 1 minute, then drain lower orgainc phase through sodium sulfate into K-D. Repeat once more.
8. Concentrate on steam bath and exchange to 10 mL of hexane (or less when less than 50g was used).

No further cleanups were performed. Extracts were analyzed using Gas Chromatography with Nitrogen-Phosphorus Detector.

A reagent blank as well as a fortified reagent blank to check for recovery of the analytes of interest was used for each procedure. Surrogate compounds were added to all blanks, fortified blanks, and samples to assess the efficiency of each extraction.

Research Results and Discussion

Residues of pesticides were found in both market basket and preclearance samples of both callaloo and hot peppers. Over the two sampling dates, residues were found in seven of twenty-one market basket samples of callaloo and six of seventeen market basket samples of hot peppers. They were also found in one of four preclearance samples of callaloo but in no hot pepper preclearance samples.

The three pesticide residues found were diazinon and malathion, both of which have been reported in previous market basket samples but also profenphos which had not been reported in any previous survey.

The levels of residues reported ranged from 0.96 to 2.2 ppm of diazinon, in callaloo samples and 0.48 to 1.4 ppm of diazinon in hot peppers, 0.67 to 0.88 ppm of malathion in callaloo and 0.62 to 0.90 ppm of malathion in hot peppers. Profenphos, which did not occur on hot peppers, ranged from 0.47 to 1.10 on callaloo. All of these are significant pesticide residues which would not be acceptable on export crops

Table 1: Characteristics of insecticide, acaricide and fungicide use on Jamaican callaloo, hot peppers and sweet potatoes (Reported in Farm Survey)

Common Name	Trade Name(s)	Use	LD_{50} Rodent (mg/kg)	Persistence (low x _ high xxxxx)	Amount of Use (low x _ high xxxxx)	Solubility (ppm)
<u>Organophosphates</u>						
Chlorpyrifos	Dursban, Lorsban	I	96	xxx	?	2.0
Diazinon*	Basudin	I	85	xxx	xx	40.0
Dimethoate*	Rogor, Cygon, Dimetox	I	30	x	x	20000
Malathion*	Cythion	I	1000	xx	xx	145
Methamidophos	Monitor	I	18	x	?	soluble
Monocrotophos	Azodrin	I	8	x	?	soluble

Table 1 ***continued***

Profenphos*	Selecron, Curacron, Polycron	IA	350	xx	xxxx	20.0
Thioureas						
Diafenthurion*	Pegasus	IA	2000	xxx	xxxx	moderately soluble
Organochlorines						
Endosulfan*	Thiodan	I	100	xxx	x	0.2
Dicofol	Kelthane	A	800	xxxx	?	0.15
Carbamates						
Carbaryl*	Sevin	IA	250	xx	x	500
Methomyl*	Lannate	IA	20	xx	xx	5000
Carbofuran	Furadan	IA	2	xx	?	700
Pyrethroids						
Lambdacyalothrin*	Warrior, Karate, Grenade	IA	80	x	xxxx	0.005
Deltamethrin*	Decis, Butox	I	2000	x	x	0.10
Cyalothrin	Pydrin	I	3000	xxx	?	0.002
Inorganics						
Copper sulfate*	Topcop	F	30	xx	xx	230,000
Copper hydroxide*	Champ, Champion	F	1000	xxx	xxxx	relatively soluble
White oil*	--	F	low	xx	x	relatively insoluble
Fungicides						
Thiophanate* - methyl Ethyl	Spectro, Cercobin, Topsin	F	15,000	xxx	xx	soluble
Mancozeb*	Dithane, Fare, EDB, Maneb	F	5,000	x	x	very low
Benomyl	Benlate	F	10,000	xxx	x	3.8
Chlorothalonil*	Bravo, Daconil	FN	10,000	xxxx	x	0.6
Avermectins						
Abamectin*	Agrimek	IA	20	x	x	7

I = Insecticide F = Fungicide A = Acaricide N = Nematicide

Table 2: Range of pesticide use on vegetables in Jamaica

	Callaloo	Hot Peppers	Sweet Potatoes
Organophosphates			
Chlorpyrifos	X	X	
Diazinon	X	X	X
Malathion	X	X	X
Monocrotophos	X	X	X
Profenfos	X	X	X
Pirimiphos-methyl	X	X	
Dimethoate	X	X	
Methamidophos	X	X	
Ethoprop			X
Thioureas			
Diafenthurion	X	X	
Carbamates			
Carbaryl	X	X	
Methomyl	X	X	X
Carbofuran			X
Organochlorines			
Endosulfan	X		
Dicofol	X		
Pyrethroids			
Lambdacylhalothrin	X	X	
Deltamethrin	X	X	X
Cyalothrin	X	X	
Fenvalerate	X	X	X
Avermectins			
Abamectin		X	
Inorganics			
Copper sulfate		X	
Copper hydroxide	X	X	
White oil			
Fungicides			
Thiophanate methyl	X		X

Table 2 *continued*

Mancozeb	X	X	
Benomyl	X	X	
Chlorathalonil	X	X	

Table 3: Main pesticides used by farmers in the parishes surveyed

Pesticide		Use*	Fungi	Mites	Pest Viruses	Aphids	Total
Common Name	Trade Name						
	Copper Sulfate	F	1	0	2	0	3
	Copper Hydroxide	F	6	0	0	1	7
	Thiophanate	F	2	0	0	0	2
	Shell White Oil	F	2	0	0	0	2
	Dithane	F	3	0	0	0	3
Profenofos	Selecron®	I-OP	0	5	0	1	6
Chlorothalonil	Bravo®	F	1	0	0	0	1
Malathion	Malathion	I-OP	0	1	0	1	2
Diazinon	Basudin®	I-OP	0	1	0	1	2
Lambdacylhalothrin	Karate®	I-Pyr	0	3	0	2	5
Methomyl	Lanate®	I-C	0	1	0	1	2
Dimethoate	Roger®	I-OP	0	1	0	0	1
Diafenthurion	Pegasus®	I-OP	0	6	0	0	6
Carbaryl	Sevin®	I-C	0	1	0	0	1
Deltamethrin	Decis®	I-Pyr	0	1	0	0	1
	Agromec®	?	0	1	0	0	1
	Dimatix®	?	0	1	0	0	1
Endosulfan	Thiodan®	I-OC	0	1	0	0	1

Use* F=Fungicide I=Insecticide A=Acaricide

Table 4: Pesticide residues in market basket samples of callaloo (8 August 1997)

Pesticide	Bushy Park Crossroads)	St. Catherine (Crossroads)	Old Harbour (Crossroads)	St. Catherine (Papine)	St. Andrews 1 (Papine)	St. Mary 1 (Papine)	St. Andrews 2 (Papine)	St. Mary 2 (Papine)	St. Andrews (Constant Spring)	St. Catherine (Constant Spring)	Old Harbour (Constant Spring)	Limit of Quantitation (µg/kg)
Diazinon						1300						390
Malathion								880				390
Chlorpyrifos												390
Profenphos							940					200
Dimethoate												4000
Disulfoton												390
Fenthion												390
Methamidophos												300
Monocrotophos												300

Table 5: Pesticide residues in market basket samples of hot peppers (8 August 1997)

Pesticide	St. Thomas (Crossroads)	Bushy Park (Crossroads)	St. Cathernie (Crossroads)	St. Andrews (Papine)	Trelawny (Papine)	St. Morris (Papine)	St. Andrews (Constant Spring)	St. Ann (Constant Spring)	Limit of Quantitation (µg/kg)
Diazinon	480						740		390
Malathion				620					390
Chlorpyrifos									390
Profenphos									200
Dimethoate									4000
Disulfoton									390
Fenthion									390
Methamidophos									300
Monocrotophos									300

Table 6: Pesticide residues in preclearance samples of callaloo (8 August 1997)

Pesticide	St. Andrews	St. Cathernie	Clarendon	Limit of Quantitation (µg/kg)
Diazinon				390
Malathion				390
Chlorpyrifos				390
Profenphos				200
Dimethoate				4000
Disulfoton				390
Fenthion				390
Methamidophos				300
Monocrotophos				300

Table 7: Pesticide residues in market basket samples of callaloo (11 February 1998)

Pesticide	Old Harbour (Papine)	Manchester (Papine)	St. Anne (Papine)	St. Cathernie (Papine)	Lawrence Tavern (Constant Spring)	Unity (Constant Spring)	Unknown (Constant Spring)	Old Harbour (Crossroads)	Spanish Town (Crossroads)	St. Catherine (Crossroads)	Limit of Quantitation (µg/kg)
Diazinon				2200				960			390
Malathion		670									390
Chlorpyrifos											390
Profenphos	1100										200
Dimethoate											4000
Disulfoton											390
Fenthion											390
Methamidophos											300
Monocrotophos											300

Table 8: Pesticide residues in market basket samples of hot peppers (11 February 1998)

Pesticide	Old Harbour 1 (Papine)	Old Harbour 2 (Papine)	Linstead (Papine)	Clarendon (Constant Spring)	Unknown (Constant Spring)	Unknown 2 (Constant Spring)	Old Harbour 1 (Crossroads)	Old Harbour 2 (Crossroads)	Old Harbour 3 (Crossroads)	Limit of Quantitation (µg/kg)
Diazinon	1400					780				390
Malathion		900								390
Chlorpyrifos										390
Profenphos										200
Dimethoate										4000
Disulfoton										390
Fenthion										390
Methamidophos										300
Monocrotophos										300

Table 9: Pesticide residues in hot peppers and callaloo samples from pre-clearance facility (11 February 1998)

Pesticide	Hot Peppers			Callaloo		Limit of Quantitation (µg/kg)
	St. Elizabeth	Portland	Hanover	Manchester	St. Catherine	
Diazinon				470		390
Malathion						390
Chlorpyrifos						390
Profenphos						200
Dimethoate						4000
Disulfoton						390
Fenthion						390
Methamidophos						300
Monocrotophos						300

Assessing Insecticide Resistance in Callaloo Arthropod Pests *(Dionne Clarke-Harris, Gene Barlett, Shelby Fleischer.)*

Research Methods

Work is being carried out in 3 phases: colony establishment of field-collected populations suspected of exhibiting resistance; bioassay methods development; and bioassays on selected species relying on well-established colonies.

For colony establishment, larvae were collected from fields suspected of harboring resistant populations due to variable control in the past. Collections occurred on July 1, 1998. Larvae were placed on natural diet and artificial diet, pupae moved to mating chambers, and egg masses collected from these chambers. Bioassay methods development consisted of a range of doses of Karate applied topically with a Hamilton syringe, glass vial bioassays, and leaf-dip bioassays using fresh callaloo leaves. We chose to work with the formulated product Karate to ensure that the results would be most applicable to the field.

Preliminary work used topical bioassays applied with a Hamilton syringe on two field-collected pyralids (*Spoladia recurvalis* , Hawaiian beet armyworm, and *Herpetogramma bipunctalis*, Southern beet armyworm). Choice of pyralids was due to field availability of the pyralids at the time of these early methods development tests. Results suggested that these species were susceptible to Karate, and we shifted emphasis to several *Spodoptera* spp. in the Noctuidae.

Larvae of the Southern armyworm, *S. eridania* collected from the field CARDI, Mona field station and reared on an artificial diet were used for bioassay methods development. Topical application bioassays were undertaken rates from 0.0325 ml / 200 ml to 0.52 ml / 200 ml (twice the field rate), with a sticker/spreader added at approximately 0.1 ml / 50 ml of toxin solution. Large larvae (3rd and later instars) were used in glass-vial bioassays at rates from 0.325 ml / 200 ml H_2O to 1.04 ml / 200 ml H_2O (4 times the field rate). Leaf-dip methods development using fresh callaloo leaves were conducted with 2rd and 3rd instars at rates of 0.0040625 ml / 200 ml H_2O to 0.065 ml / 200 ml H_2O (much lower due to the findings of the glass-vial bioassay. We also initiated work with the beet armyworm, *S. exigua*, because we suspected resistance from literature reports and field control failures. Colonies had failed to develop with field collected material on the same diet that had been used with *S. eridania*, and thus we have not yet run bioassays with colony reared material. We were able to collect more larvae from farms at Bushy Park on 1 to 3 July, 1998, for colony establishment on a new diet, and to run few leaf-dip bioassays. Application rates were from 0.0325 ml / 200 ml H_2O to 0.52 ml / 200 ml H_2O (2 X the field rate). Topical applications were also attempted with later instars.

Research Results and Discussion

Colony establishment on natural diet (callaloo) proved too time-consuming, variable, and increased problems with virus. Rearing on artificial diet from BioQuip^R was determined to be too expensive. Currently, we are rearing on artificial diets from Southland Products, Inc (Lake Village, Arkansas). From early spring collections, colonies of *S. eridania* were becoming established, but *S. exigua* were not when using a single *Spodoptera* diet. New types of diet were transported to CARDI in July 1998, and *S. exigua* were moved to these. We are now working on rearing *S. exigua* and *S. eridania* on separate diets. Bioassay results are preliminary as only a small number of larvae were tested. Full bioassays will require reliance on strong colonies.

Preliminary trials used topical application with a Hamilton syringe to ensure complete control of dose (e.g., the dose delivered with other bioassay techniques can be influenced by factors such as behavior, as in feeding behavior in leaf-dip bioassays). The spreader/sticker reduced beading of the formulated product, but the agent did not dry as fast as it should. Some of the larvae lost toxin as they moved after the droplets were applied. To insure proper application of dose, the technical material in acetone will be used in future work with topical application. For our objectives of relating bioassays to field efficacy, we chose to work with the formulated product and develop other bioassay methods.

The leaf-dip bioassay provided the best results to date, and is the most relevant to the field setting. The larvae of the suspected resistant moth, *S. exigua*, were not killed with a range of Karate® doses from 0.0325 ml / 200 ml H_2O to 0.52 ml / 200 ml H_2O, twice the now recommended field rate. The larvae tested were one to two day old neonates. We know that they had fed on the toxin-covered leaves due to leaf damage and the fact that the larvae changed color from the tan of the artificial diet to the deep green to the callaloo leaves. The other larvae tested with the leaf-dip assay, *S. eridania*, showed a range of mortality at much lower doses than used with *S. exigua*. These *S. eridania* larvae were also larger than the *S. exigua* larvae, probably at least second instars. The *S. eridania* larvae were killed at doses ranging from 0.0040625 ml / 200 ml H_2O to 0.065 ml / 200 ml H_2O (one quarter the field rate). No mortality was seen in the controls and the callaloo leaf disks were skeletonized in both the *S. exigua* and *S. eridania* trials.

Early work was slowed by difficulty with determining the taxa in the lepidopteran complex. This concern has been solved. The primary current constraint is colony establishment, especially of *S. exigua*. Many field-collected larvae from a virus. A variety of rearing methods to obtain vigorous colonies are currently being worked with, including isolation, culling, and disinfection of all materials that come in contact with the larvae or adults. Storage and freshness of the insecticide is also being improved. Early work also helped focus efforts from pyralids to noctuid taxa *(S. exigua*

and S. eridania) and specific toxins (lambda-cyhalothrin). Methods initially developed in training exercises (topical applications with a Hamilton syringe) were not most appropriate. Larvae were able to remove toxin after topical application due slow drying. The addition of a sticker/spreader did not enhance the process. Current work has changed the methods from topical to leaf-dip assays, which we feel is more relevant to field interpretation.

Larvae of the southern armyworm, *S. eridania*, were not resistant to Karate® at the levels used in the glass-vial bioassay. Larval mortality was greater than 80% for all of the doses tested. The leaf-dip bioassay using much lower rates showed a range of mortality at 24 hours and a majority of individuals dead at 48 hours. Larvae of the beet armyworm, *S. exigua*, were more tolerant of the insecticide. The leaf-dip bioassay (much higher rates) revealed that no neonate larvae from the newly hatched egg mass died by feeding within the first 24 hours and only one larva was dead after 48 hours. The dead larva was found dehydrated on the lid of the petri dish, and probably did not die due to feeding on the toxin. No mortality was seen in the controls and the callaloo leaf disks were skeletonized.

Future Work. The establishment of the colony of *Spodoptera exigua* will greatly help the testing with Karate®. Since the preliminary work with the leaf-dip bioassays appeared to be successful, these tests should be expanded and applied to a large number of early instars for the two Spodopteran pests. The toxin rates should be increased for the *Spodoptera exigua* larvae as they appeared to be resistant to Karate®. The new test rates should be increased to 10 X to 100 X the established field rate and the levels of resistance established via probit mortality analysis. Bioassays should also continue on *Spodoptera eridania* to establish its susceptibility to the insecticide. Since the larvae collected for insecticide tests were from a small sample, increased testing should be done to establish a geographical distribution of resistance for these pests in callaloo. Testing could be done at various locations in Jamaica, on other island, or other crops in the Caribbean (these *Spodoptera* are polyphagous). Finding that some of these pests have already established a certain level of resistance to Karate® indicates that they have the resistance mechanism(s) in place and will only increase their levels of resistance with continued exposure to the insecticide. Fortunately, it is feasible to compare *S. exigua* dose-mortality relationships of these field-collected strains to baselines using published data (see Mascarenhas et al. 1998 for one set of baselines).

Impact *S. exigua* is a migratory species, a very important pest in the U.S., and resistance is a major factor influencing it's pest status in the U.S. Recent work (Mascarenhas et al. 1998) showed reduced susceptibility to the only recommended insecticides in Louisiana. Conversely, most field-collected strains from 5 U.S. states and one location in Mexico were susceptible to new biorational materials relevant for control of this pest. Understanding more about the resistance profile of this insect, including the host and geographic range in which this resistance is expressed, is essential for resistance management plans directed against *S. exigua* in the U.S. The proximity of Caribbean populations coupled with the migratory behavior and potential for weather-assisted dispersal into the southern U.S. make it essential to understand the resistance profile of *S. exigua* in the Caribbean.

Networking Activities

- Clive A. Edwards attended the Second Meeting of the Caribbean Integrated Pest Management Network in Kingston, Jamaica on 4-6 February 1998. The aims of this meeting were to review IPM activities in the various Caribbean countries, propose and prioritize regional IPM collaborative projects, and to organize an administrative structure and recommend Regional and National Coordinators who would be responsible for activities in the Network.

About 14 potential collaborative crop/pest IPM projects were identified and prioritized at the meeting. Of these, those most important and relevant to the Caribbean IPM CRSP activities were:

- Inter-country information transfer network
- IPM on sweet potato weevil (*Cylas*) – transfer of our technology
- IPM on whiteflies as vegetable pests – a possible new focus

These are all activities that could be incorporated into Caribbean IPM CRSP activities to extend its work from Jamaica to other Caribbean countries. A detailed prioritized list of Network Activities will be available soon and the full Proceedings of the Workshop are expected to be published within six months, and should be available for circulation within the IPM CRSP. The proceedings of the previous initial workshop which was held in Barbados 16-19 October 1994 with the title "Setting Up an Integrated Pest Management Network for the Caribbean Agricultural Research and Development Institute (CARDI)" (99 pp.) is available from CARDI.

This collaborative Caribbean IPM Network is an ambitious one that has many implications for IPM CRSP activities in other regions. There may be initial organizational problems but these would provide an educational background for similar activities elsewhere. The concept of regional networks involving country and regional coordinators is an excellent one. I would like to see this extended to the pattern used by the International Organization for Biological Control (IOBC) which functions through the formation of international Working Groups, each led by a Coordinator. This arrangement promotes a great deal of excellent research with minimal financial inputs.

- Dr. David Biddinger (Field Research and Development Representative Rohm and Haas Company). Discussions with Dr. Biddinger involved methods for measuring resistance, and use of ecdysone agonist insect growth regulators for control of lepidopterans showing resistance to pyrethroids and acetylcholine esterase agonists. This helps us determine some possible action plans if we determine resistance levels to be sufficient to cause field failure

Publications

None in 1997-98.

References

Mascarenhas, V. J., J. B. Graves, B. R. Leonard, and E. Burris. Susceptibility of field populations of beet armyworm (Lepidoptera: Noctuidae) to commercial and experimental insecticides. J. Econ. Entomol. 91: 827-833.

Training Output

- Clive Edwards conducted one-on-one training during visits to CARDI.
- Dr. Gene Barlett, University of Delaware, provided training in bioassay methods, and insecticide resistance mechanisms to CARDI scientists, at CARDI.

Project Highlights

- A diverse range of pesticides continue to be used in Jamaica, resulting in significant residues on market basket and even export crops. Knowledge of these pesticides and the extent of use will facilitate residue analyses.
- Technology for assessing pesticide resistance that is scientifically valid and appropriate for the Caribbean agricultural scientific community is being developed.
- Leaf dip bioassays suggest that *Spodoptera frugiptera* collected from Caribbean callaloo fields tolerates lambda-cyhalothrin (Karate®), a commonly used pyrethroid in Caribbean agriculture, at twice the recommended field rate.

Social, Economic, Policy and Production System Analyses: Social and Gender-related Issues that Affect IPM Adoption

Investigators: S. Hamilton[1], Gary Schlosser[1] and Tina Schlosser[1]

Collaborating Scientists: Dionne Clarke-Harris[2], Janet Lawrence[2], Raymond Martin[2], Phillip Chung[3], Dave Hutton[4]

Abstract

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).

Introduction

The primary activity of Year 5 was the design and fielding of a 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)

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socioeconomic constraints to IPM adoption and (2) beliefs and practices that contribute to health and environmental problems associated with pesticide use. 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 behavioral observation–were carried out with approximately equal numbers of women and men to ensure valid gender analysis.

Activities during Year 5 included the following. All quantitative and qualitative data collected to date were reviewed. A preliminary survey instrument was field tested and representative preliminary data were analyzed in order to judge the reliability and validity of data measurement. Operationalization of socio-economic indicators was based on a literature review and on analysis of qualitative and quantitative project data. Sampling domains and methodologies were identified during visits to all communities. The survey instrument was revised and methodology finalized during a site visit in June. The survey and related qualitative data collection were carried out during June-August and a brief descriptive report was filed with CARDI in August. Probabilistic sampling methodology was successfully carried out and a statistically valid sample size of 180 (90 women and 90 men) was obtained. Data are currently being coded and entered at Virginia Tech.

Objectives

- Review all socio-economic research to date.
- Design and field a quantifiable, statistically-valid socio-economic household survey

IPM Constraints

- Socio-economic constraints to IPM adoption, including farm size, labor supply, access to export marketing channels, access to technical assistance and extension, and gender
- Knowledge, attitudes, and practices related to pest management
- Knowledge, attitudes, and practices related to disease and health risks of pesticide misuse

Research Methods

The primary methods involved in this phase of socioeconomic survey research involved principles of randomized and sampling and sample stratification; construction of valid measures of socioeconomic variation and of knowledge, attitudes, and practice relating to pest management and health; and reliable field data collection techniques. Methodological training of graduate student researchers was carried out at Virginia Tech and at CARDI, with the participation of CARDI scientists. A review of all qualitative results generated during the first four years of CRSP activity also contributed to the selection of communities and to the design of survey research. A review of gender-related social science research in Jamaica also provided relevant information.

In order to perform multivariate regression analysis that would identify socioeconomic constraints to IPM adoption, a sample size of at least approximately 180 individuals (90 women and 90 men) was determined. 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. Sample sizes of 60 (30 women and 30 men) were determined for each community. Preliminary analysis of data collected during a field test of the survey instrument contributed to the decision to sample equal numbers of women and men, and confirmed the importance of utilizing probabilistic, rather than opportunistic, samples. 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. 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.

The survey was fielded successfully, yielding a probabilistic sample of appropriate size and gender distribution. Data coding and entry began in September.

Research Results and Discussion

Results of the socioeconomic household survey will be presented during Year 6. The following patterns were observed in the preliminary data analysis of the survey's field test. Field-test preliminary data were collected from an opportunistic sample of groups of sweet potato and pepper farmers who attended IPM farmer workshops organized with the assistance of RADA in the parishes of Clarendon and St. Mary. Although the nonprobabilistic nature of the field-test sample preclude generalization to a research population, the distribution of landholdings and sources of employment suggest that the field test sample is representative of farmers producing these commodities in the study areas. The workshops were attended primarily by male farmers; thus the survey results describe agricultural resources and practices for male farmers, although the household division of agricultural labor is described for the entire farm household. The sample is comprised of farmers from areas

known to be centers of production for commodities included in the IPM CRSP program in Jamaica. None of the farmers had been previously incorporated into any IPM CRSP research activities. These field-test results identify some likely sources of socioeconomic variation with respect to land access and tenure, relative importance of agriculture to the farmer's livelihood, pesticide usage, IPM knowledge and usage, market channels and interest in producing for export markets.

Forty-six farmers were surveyed: 24 pepper producers from St. Mary and 22 sweet potato growers from Clarendon. For both groups, agriculture is the primary means of earning a living for a large majority of farmers. In St. Mary, 88% listed agriculture as their only or primary means of livelihood; in Clarendon, 95% rely primarily on agriculture. Other means of producing income for farmers' households include remittances (to the farmer or other members of his household), and farmers' earnings from transportation, trades, and shop keeping. Although many farmers listed their wives as full-time income earners on the survey's household census, they did not include their wives' sources of income in their portfolio of income sources. Nor did the survey elicit amounts of income for respondents or for others in their households. Therefore, we cannot conclude that farm income is the primary means of livelihood for the entire farm household among surveyed farmers, but rather that it is the most critical source of income for most male farmers. With respect to land tenure and the amount of land accessed by farmers, results also apply only to male farmers. Previously collected qualitative data from St. Mary suggest that women do own land; however, none of the surveyed farmers listed any land owned or otherwise accessed by their wives. The distribution of land for surveyed farmers is summarized in the following table.

FARM SIZE	ST. MARY N = 24	CLARENDON N = 17*
Less than 5 acres	14 (58%)	6 (35%)
5 - 10 acres	6 (25%)	5 (29%)
More than 10 acres	4 (17%)	6 (35%)
Total	**24 (99%)**	**17 (99%)**
LAND TENURE **		
Own	12 (50%)	12 (75%)
Rent	7 (29%)	4 (25%)
Lease	7 (29%)	2 (13%)
Family land	17 (71%)	9 (56%)
Rent free	6 (25%)	1 (6%)
Capture	1 (4%)	0 (0%)

** N with reliable data, ** Most farmers access several plots, each of which may be accessed differently (i.e. one may be owned, another rented); columns will not sum to 100%.*

Given the small size and nonrandom nature of the field-test sample, no tests of statistical significance were applied to comparisons between sub-samples. It would appear that farmers in Clarendon are more likely to own their land, and thus are perhaps more able to secure certain types of credit and to institute long-term land improvements. It appears that farmers in St. Mary may have greater access to rent-free land than farmers in Clarendon. It may be that farmers in St. Mary are more likely to access family land, a somewhat precarious form of tenure in that other family members may also make claims to the land, than farmers in Clarendon.

With respect to pesticide use on the target commodities, some interesting differences emerge between the two sub-samples. Although 100% of farmers in both regions use pesticides on some of their crops, pepper farmers in St. Mary are much more likely to use pesticides on their targeted crop (91%) than are sweet potato farmers in Clarendon (13%). Pepper farmers in St. Mary may be somewhat more likely to have knowledge of alternative methods of pest control (46%) than are the Clarendon sweet potato farmers (33%), but this suggestion will have to be confirmed by the diagnostic survey of pest management administered to the same sample, as the difference is not large. In both groups, farmers do not always use this knowledge in current production. Only 33% of pepper farmers and 19% of sweet potato farmers actually use alternate methods of pest control, according to the socio-economic baseline. The primary alternative method mentioned is the use of ash, a practice some farmers say they learned from their parents and which may have been more prevalent in the past.

Market channels vary considerably among members of both groups of farmers as well as between groups; additionally, many farmers rely on more than one market channel for the targeted commodity. As the table below shows, current data suggest that more pepper farmers in St. Mary sell to exporters, and more sweet potato farmers in Clarendon market their own crops to the public.

MARKET CHANNEL per commodity, current season *	ST. MARY N = 24 pepper growers	CLARENDON N = 17 sweet potato growers
Sold by self/family to public, restaurant, supermarket	8 (33%)	10 (59%)
Higgler	17 (74%)	12 (71%)
Exporter	10 (43%)	2 (12%)
Preference for export market	16 (67%)	11 (65%)

Many growers use more than one channel per commodity; columns will not sum to 100%

In both groups, the largest number rely on higglers (market intermediaries who may buy relatively small amounts of a crop at the farm gate, requiring repeated interactions throughout the harvesting seasons) as one of their market channels. Many farmers gave lack of choice as their reason for marketing through higglers, though one farmer noted that higglers offer a relatively good price, but sale may be delayed.

In both groups, around 2/3 of the farmers prefer (or would prefer) selling to exporters (St. Mary), or to exporters and other entire-harvest buyers, preferably at the farm gate (Clarendon). Thus addressing issues of pesticide residue reduction and other export quality requirements that can be met using IPM technologies and strategies would appear to offer farmers improved potential for access to their choice of market channel.

These field-test results proved helpful in designing the socioeconomic household survey, and also provided information to the project that could help design project activities for new groups of farmers in Clarendon and St. Mary.

Impact

The findings of the socioeconomic household survey were not collected until near the end of Year 5, and thus will not yield impacts during Year 5. Potential impacts include increasing the number and number of women IPM adopters, as constraints to adoption are identified and addressed.

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 5, background information had been researched on the socio-economic needs of the IPM CRSP project in Jamaica. From September 1997 to February 1998, preliminary data was collected on farming activities in Jamaica. The data included: literature reviews of policies affecting IPM, modeling techniques with IPM, and economic evaluations of IPM, background data on the economic conditions within Jamaica, and preliminary farming techniques used by Jamaican farmers.

In February 1998, the 2nd Meeting of the Integrated Pest Management Network was attended by Bosch and Ogrodowczyk. This meeting allowed for networking opportunities between the VPI & SU investigators and the collaborating scientists from CARDI. In addition, initial contacts were established at the Ministry of Agriculture, RADA, the Pesticide Control Authority and the Agri-business Council of Jamaica. These contacts formed a base from which further contacts were established.

From February 1998 to the end of June 1998, data was gathered in a variety of areas including: farming methods, domestic policies within Jamaica, literature review on modeling IPM policies, evaluations of economic policies within Jamaica and economic evaluations of IPM techniques. Collaborators in Jamaica provided data on the IPM CRSP systems and the potential benefits from the systems.

A three week research visit was made to Jamaica by Ogrodowczyk from June 27, 1998 to July 18. The purpose of the trip was to collaborate with the CARDI scientists in gathering data regarding Jamaican policies potentially affecting the IPM program and regarding production methods of farmers in Ebony Park, Clarendon. Interviews were conducted to collect the necessary information and included: local farmers, CARDI scientists, the Ministry of Agriculture, the Bank of Jamaica, RADA, and the Agricultural Credit Bank. The

[1] Virginia Tech [2] CARDI

conceptual framework was established as a result of the information obtained from this trip. In addition, preliminary results were obtained regarding the economic incentives for farmers in Ebony Park to adopt the IPM systems being developed by the IPM CRSP research.

Final results will be available by the middle of November 1998. A third visit to Jamaica in November of 1998 will allow for the presentation of the results and further data collection on production methods of farmers in Bushy Park, St. Catherine. The new information will be assembled into the model and analyzed in conjunction with the previous results. The project is expected to be completed by the end of January 1999.

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 identified and a farm programming model was developed to provide a framework within which government policies could be evaluated. The identification was accomplished through interviews with government officials, IPM CRSP scientists and farmers as well as enterprise budgets and personal observations. The interview process required two visitations to Jamaica in 1998 (February 3 - 10 and June 27 – July 18) and the information was assembled into a linear programming model. The decision making variables within the farm model include growing and selling: hot pepper, pumpkin, sweet potato, corn, cassava, sugar cane and callaloo. The constraints are the inputs required for each of the crops: labor, fertilizer, herbicides, insecticides, water, and financial capital. The objective function of the farm model was 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 classified and 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, but are not limited to: credit and personal income tax subsidies, an APHIS preclearence program, inflation reduction goals by the Bank of Jamaica, Uruguay Round trade agreements, concessionary water rates, and pesticide import tariffs.

The evaluation of the policy effects on IPM adoption is being accomplished by incorporating policies into the model as exogenous variables. Parameters describing the effects of policies on farmers' incentives are set within the model. Policy changes can then be simulated by the variation in these parameters to determine how the changes affected farm enterprises, income and incentives to IPM adoption. The policies not quantifiable, such as research and extension allocation, will be discussed in terms of potential impacts and trends over time. Comparisons between the policies included and those excluded from the model will conclude the analysis.

Expected Research Results and Discussion

The model will be run in three stages to evaluate the IPM technologies and government policies on the production practices of farmers. The first stage will analyze the behavior of farmers as predicted by the mathematical optimization model. Constraints restricting crop acreage will then be superimposed to simulate the effects of risk aversion on farmers' output decisions. Preliminary results suggest that these crop acreage restrictions play a significant role in determining the crop mixture of a farm.

The second stage of evaluation will incorporate the IPM technologies as an option for the farmer, both with and without the crop acreage restrictions. These results will highlight the conditions in which the IPM systems developed by the IPM CRSP program hold economic incentives for farmers. Preliminary results strongly suggest that without the crop acreage restrictions, farmers will specialize in crops without the IPM systems and thus have no need to consider pest management techniques. However, with the acreage restrictions, farmers choose not to specialize and the IPM systems then became a viable option for farmers to increase their returns to their fixed assets.

The final stage of analysis, to be completed by the middle of November 1998, will be to implement policy changes among the variables included in the model reflecting the government policies. Simulation of the policy changes will be accomplished through the manipulation of these parameters. This manipulation will yield results pertaining to the direction of the IPM CRSP program and whether or not particular policies are hindering or assisting the implementation of the program.

Impact

There are no studies evaluating the impact of the IPM CRSP program on the production methods of Jamaican farmers for non-traditional export crops. Preliminary results indicate that when constrained to diversify production to manage risks, farmers receive higher returns to their fixed assets from the IPM technologies. The potential for policy changes affecting the production methods is high and the final stage of analysis will provide information on the specific policies with the greatest impact on farmers' net returns. The project will provide recommendations for future IPM CRSP policies given the economic and political environment in which the program operates.

Networking Activities

Workshops

1. Second Meeting of the Integrated Pest Management Network, Kingston, Jamaica, February 4-6, 1998. (attended by Bosch and Ogrodowczyk).

2. IPM CRSP Second Symposium, Planning Workshop, and Technical Committee Meeting, Virginia Tech, Blacksburg, Virginia, May 15-18, 1998. (attended by Bosch, Orden, and Ogrodowczyk).

Research Investigator Exchanges

Joe Ogrodowczyk, project Graduate Research Assistant, visited the Jamaica site from June 27 to July 18, to collect data and exchange information with CARDI scientists collaborating on the project.

Publications and Presentations

None.

Project Highlight

An evaluation of the economic incentives for farmer adoption of the IPM systems will be completed by January 1999. Preliminary results indicate that farmers in Ebony park who are not specializing will receive higher returns to their fixed assets as a result of adopting the IPM systems.

Research Enhancement through Participatory Activities: Information Systems for Collaborative Research

Investigators: Larry Grossman[1], Andy Roberts[1], Bill Ravlin[5], and Janet Lawrence[2]

Collaborating Scientists: Glynis Ford[3], J. Reid[2], S. McDonald[1], and P. Chung[4]

Abstract

The goal of this topic is to address the fundamental problems which are encountered when conducting interdisciplinary, multinational, collaborative IPM research. These include: (1) Constrained communications due to distance, language, and culture, (2) The ability of scientists from the U.S. and developing countries to understand the technical and practical aspects of research problems and components of those problems, (3) Sensitivity of scientists to the diversity of opinions and perspectives that characterize these types of research teams, (4) Development of a shared set of expectations and end products that should result from collaborative research. In addition, this topic areas seeks to promote a substantive and continuous flow of information among IPM CRSP Caribbean site team members. This means that formal approaches such as workshops provide vehicles to

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share ideas on specific topics (e.g., information systems, pesticide resistance management). However, by the very nature of workshops they occur for only a limited period of time (e.g. a few days) thus, a substantive flow of information is achieved but not a continuous one. Therefore, it is essential to use other approaches that foster continuous communications using a variety of classical (telephone, fax, mail) and new technologies (e-mail, world wide web, teleconferences). The project described below seeks to provide both substantive and continuous flow of information and ideas through workshops, collaborative experiments, and eventually multiauthored presentation of research results.

Introduction

In August 1998, a workshop was held in Kingston, Jamaica with the ultimate goal of enhancing the capability of Jamaican scientists in GIS software and analytical techniques and Global Positioning System (GPS) technologies. The researchers from CARDI, MINAG, RADA and UWI attended the 3 day workshop and overall found the experience most worthwhile and directly relevant to their research experiences. Electronic presentations which were developed for the workshop have been posted on the World Wide Web.

Objectives

- Enhance site researchers capabilities GIS software and analytical techniques and Global Positioning System (GPS) technologies
- Facilitate data analysis and sharing among researchers

Research Methods, Results and Impacts

After much discussion with CARDI personnel, it was decided that Virginia Tech personnel would conduct a workshop training Jamaican participants to use GIS software and analytical techniques and Global Positioning System (GPS) technologies. Employing GIS methodologies has several advantages for IPM scientists:

- provides a database system for managing and storing IPM data
- enhances analysis of data to reveal relationships among variables
- encourages scientists to think and interpret their data from a spatial perspective
- stimulates hypothesis formation to facilitate additional research
- increases ability to visualize relationships among variables
- focuses on combining both environmental and social data in analyses
- improves ability of scientists to communicate results of research

Collaborating scientists from Jamaica also expressed the need for data capture--to accurately record locations of gardens in the field onto maps and into GIS databases. Thus, it was decided to add a component of training in the use of GPS hand-held units.

Initial Planning

- Initial planning about the workshop was conducted in 1997 and 1998 through e-mail communications, two conference calls, and discussions with Jamaican scientists during their visit to Virginia Tech in May, 1998.
- Roberts traveled to Jamaica from June 15-18, 1998 to consult with Jamaican scientists in CARDI and the Ministry of Agriculture to further discuss how best to structure the GIS workshop to meet the felt needs of Jamaican IPM scientists. Roberts also investigated GIS resources and coverages available in Jamaica to determine resources available for inclusion in the workshop.
- L. Grossman arranged with Dr. Hugh Semple, Dr. David Barker, and Dr. Balfour Spence of the Department of Geography of the University of the West Indies, Mona, to use the computer lab of the Department of Geography for the workshop.
- L. Grossman prepared a 167 page manual to serve as a tutorial to assist participants in learning to use GIS. In addition, he wrote the tutorial in HTML so that it could be accessed by participants though the World Wide Web.
- Roberts prepared a lecture on the fundamentals of GIS in Powerpoint format.
- Mannin Dodd, employee graduate student from the Department of Geography, Virginia Tech, prepared a written tutorial on the use of hand-held GPS units and on incorporating GPS data into GIS. He also digitized a base map of the area around the University of the West Indies to use in the workshop GPS exercise.

Table 1. Workshop Participants - Geographic Information Systems Workshop (August 18-20, 1998)

Participant	*Organization*	*Position*
Janet Lawrence	CARDI	Entomologist
Julian Seaton	CARDI	Agronomist (Forages)
Joseph Lindsay	CARDI	Soil Scientist
Raymond Martin	CARDI	Research Assistant
Phillip Chung	RADA	Subject Matter Specialist
Winston Graver	Ministry of Agriculture (MINAG)	Agronomist
Jasmin Holness	MINAG	DeputyDirector Livestock
Christopher Prendergrast	MINAG	Plant Protection Officer
Glynis Ford	Rural Physical Planning, MINAG	Regional Rural Planner
Balfour Spence	Geography, UWI	Lecturer
Leonard Notice	Geography, UWI	Lab Technician
Raymond Stewart	Earthquake Unit, UWI	Researcher

Workshop Content

GIS and its applications to IPM

- History of GIS use in Jamaica and its contemporary applications on the island.
- National plans to use GIS, the various organizations employing GIS, and sources of computer data for GIS in Jamaica.
- Map reading and interpretation exercise.
- Benefits of using GIS in IPM research
- Fundamentals of the ArcView GIS software program *(workshop participants used the ArcView GIS software program at their computers engaging in a variety of exercises).*
- Identification, manipulation, and displaying of data in ArcView.
- The use of GIS in IPM data analysis.
- Use of GPS units (lecture and lab)
- IPM data analysis in GIS and in using ArcView as a database.

Evaluation by workshop participants

Participants evaluated each presenter separately and then evaluated the overall workshop experience, using a scale from 1 to 4. The summary of the results, which were tabulated by A. Roberts, are listed in the table below:

	Lowest			*Highest*
Introduction to GIS Lecture and Discussion (Roberts)	**1**	**2**	**3**	**4**
How valuable was this information to you?			2	9
Was the information presented in sufficient depth?			6	5
Was sufficient time devoted to this topic?	1	1	6	3
How well was the material presented?			4	6
Did the presenter appear to have a firm understanding of the material?			3	8
Were the handouts valuable and relevant to the material?			3	7

workshop evaluation *continued*

Were the exercises helpful in understanding the material?			5	6
Do you think you will use this information in your work?			3	7
Introduction to ArcView (Grossman)	**1**	**2**	**3**	**4**
How valuable was this information to you?			2	9
Was the information presented in sufficient depth?		1	5	5
Was sufficient time devoted to this topic?		3	6	2
Did the presenter appear to have a firm understanding of the material?				11
Were the handouts valuable and relevant to the material?			6	5
Were the exercises helpful in understanding the material?			4	5
Do you think you will use this information in your work?			2	9
Introduction to GPS (Dodd)	**1**	**2**	**3**	**4**
How valuable was this information to you?			2	8
Was the information presented in sufficient depth?			8	3
Was sufficient time devoted to this topic?		2	7	2
How well was the material presented?			6	5
Did the presenter appear to have a firm understanding of the material?			3	8
Were the handouts valuable and relevant to the material?			8	3
Were the exercises helpful in understanding the material?			5	6
Do you think you will use this information in your work?			2	9
Overall Evaluation	**1**	**2**	**3**	**4**
How valuable was this workshop to you?			1	10
Do you have projects in which GIS would be a valuable tool?		1	4	6
Do you have the computing resources to use this technology?	1	2	5	4
Will you be able to incorporate GIS into your program?		2	2	6

General Comments:

How practical do you think this material is for your program? What additional resources/materials/training would you want or need to implement this technology in your program?

Please make any comments you want concerning the presentation, content, and/or relevance of this workshop.

Observations

It is very clear from the results of the evaluations that the participants found the experience most worthwhile and directly relevant to their research experiences. For example, when asked "How valuable was this workshop to you?", ninety-one percent of the respondents indicated the highest score possible. The only concern raised was the amount of time available. Participants preferred to have more time devoted to all aspects of the workshop. Extending the workshop another day would have been beneficial. That participants did want more time in the workshop should also be viewed as an expression of their interest in the subject matter.

In addition, Glynis Ford expresses considerable support for the value and utility of the workshop. For example, she has

requested on behalf of the Ministry of Agriculture additional copies of the manual prepared by L. Grossman.

Networking

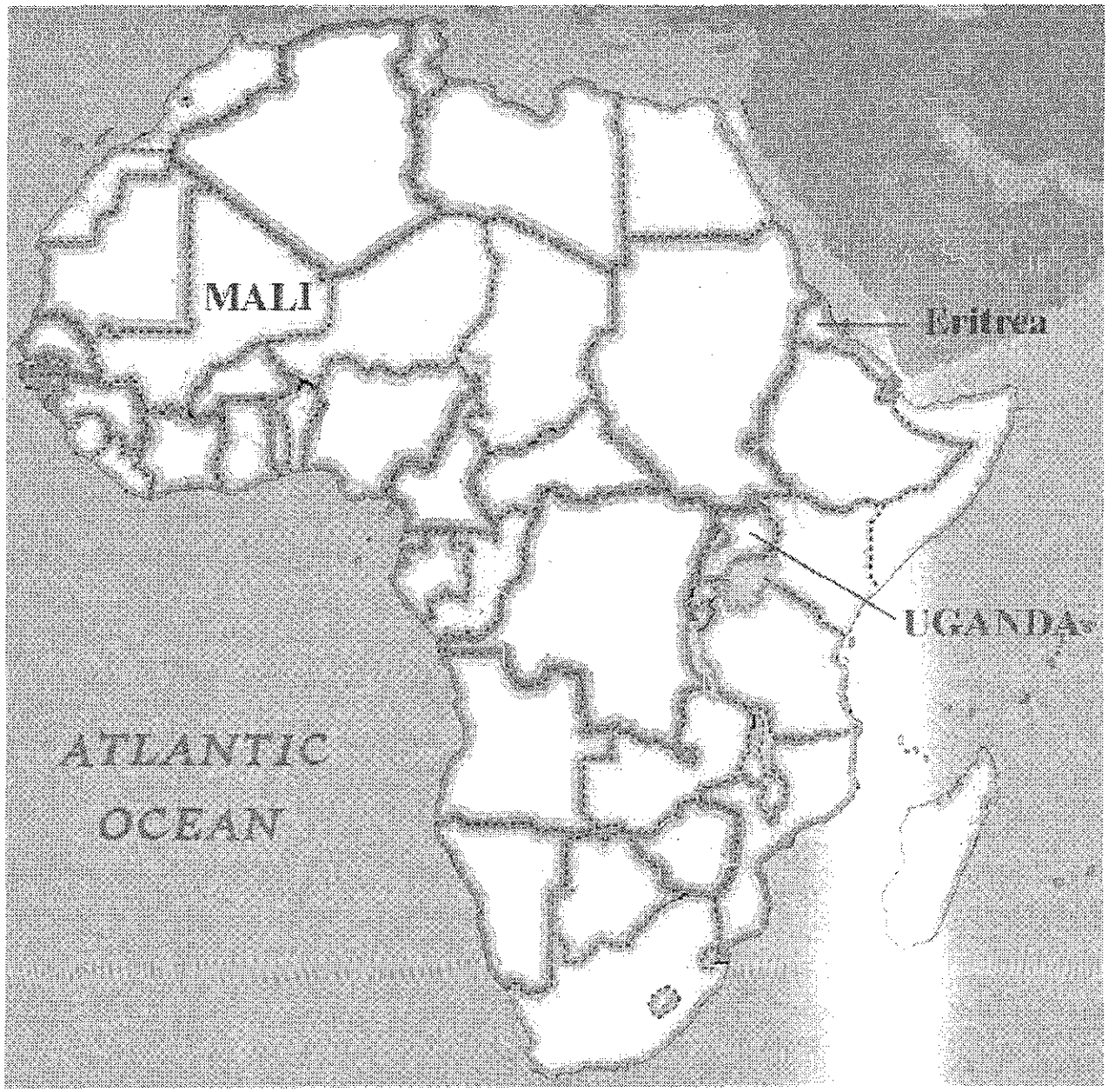
- Most materials taken to Jamaica for the workshop were left in Jamaica to facilitate the participants' subsequent GIS efforts.
- CARDI received two Garmin 12 GPS units, one copy of Homesite HTML-editing software, and one copy of SnagIt image-capturing software.
- The Department of Geography, as compensation for use of its facilities, received one Garmin 12 GPS unit, one copy of Homesite HTML-editing software, one copy of SnagIt image-capturing software, one surge suppresser, one Iomega Zip drive, and two Zip disks. It is expected that CARDI and the Department of Geography, UWI, will use these materials to collaborate in future GIS endeavors.

Publications

- L. Grossman has prepared a revised and slightly expanded version of *MANUAL FOR USING ARCVIEW.* He has also posted all his GIS tutorials on the World Wide Web at: **http://www.majbill.vt.edu/geog/3104/Jamaica/J-arc1.htm**
- Roberts is developing a WWW site on the GIS workshop activities.
- L. Grossman has prepared a CD-ROM containing all lectures presented at the GIS workshop and all data used in the workshop to enable participants in Jamaica to further their learning of GIS and GPS.

Highlights

The capabilities of Jamaican scientists in GIS software and analytical techniques and Global Positioning System (GPS) technologies was enhanced through an interactive workshop.



AFRICA

Farmer Implemented Crop Pest Monitoring in Uganda

Investigators: S. Kyamanywa[1], H. Willson[2], H. Warren[3], and M. Erbaugh[2]

Collaborating Scientists: T. Kauma[1], E. Mwanje[4], and W. Tibairira[4]

Abstract

A farmer implemented crop monitoring program was initiated during the first rainy season of 1996 with the cooperation of two farmer associations and extension officers of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) in Iganga and Kumi districts. In Iganga district, the emphasis has been on maize, beans, and groundnuts. In Kumi district, the emphasis has been on sorghum, millet, cowpeas, and groundnuts. To date, five growing seasons of data have been accumulated. A database of farmer collected information has been established at Makerere University. Data accumulated on maize and beans in Iganga district has been most reliable due to effective cooperation between participating farmers, local extension officers, and researchers. Observations of the maize pest complex focus on the seasonal incidence of foliar, stalk and ear injury by maize stalk borers and the impact of termites. Observations on the bean pest complex emphasize the importance of bean fly in comparison to other pests such as black bean aphid and striped bean weevil.

Objectives

The primary objectives of the project are to (1) initiate a crop pest monitoring system that will document over time the relative impact of pests and diseases impacting crops, and (2) demonstrate the concept of farmer implemented crop pest monitoring within a participatory IPM program.

IPM Constraints

On-farm research depends on the cooperation of farmers who are aware of the need to follow specific procedures in plot management and have a basic interest in the outcome of experiments implemented. The pest monitoring program enhances farmers awareness, cooperation, and participation in the implementation of replicated field experiments. In addition, the pest monitoring program generates additional data on pest and diseases activity that can be compared with that observed in experimental plots.

Research Methods

Farmers of Iganga District were trained to use standardized sampling procedures to monitor the pest complex impacting maize and beans. In general, the sampling procedure was to include inspection and recording of selected pests on four samples of 10 plants. The pest complex monitored was based on pests and diseases identified during participatory appraisals conducted in 1995. The pest complex targeted has been continued throughout the 1996, 1997 and 1998 growing seasons to maintain consistency in the monitoring program. During each growing season, five farmers from each farmer association participated in the monitoring project under the supervision of a group leader and the local agriculture extension officer. At the end of each growing season, records were forwarded to the IPM program supervisor at Makerere University and entered into a database for statistical processing and analysis. Similar procedures were also employed for monitoring groundnuts in Iganga and Kumi Districts and for monitoring sorghum, millet and cowpeas in Kumi District in seasons when the crops were grown.

Results on Maize in Iganga

The average proportion of stand exhibiting foliar stalk borer injury (primarily *Chilo partellus* and *Busseola fusca*) is relatively low (Average per season = 15%; Range: 11-25%). However, since growers may apply rescue treatment to individual plants, an average of 10% stalk injury and 5% ear infestation may be reduced by timely treatment. To date, stalk borer infestation has been higher during the 1st rainy season of each year than that of the following 2nd rainy season (see Table 1).

[1] Makerere [2] Ohio State University [3] Virginia Tech [4] MAAIF

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Table 1. Summary of biomonitoring data on maize.

Year:	1996		1997		1998	Average
Season:	1st Rain	2nd Rain	1st Rain	2nd Rain	1st Rain	
	Percent of Stand Observed Infested or Impacted					
Stalk Borer:						
Foliar Injury	24.5	13.1	16.1	12.0	11.0	15.3
Stalk Injury	15.6	4.7	9.6	10.0	8.2	9.6
Ear Injury	7.5	3.1	6.0	5.5	3.2	5.1
Termites	39.4	12.5	16.1	0.8	19.8	17.7
Root Rat	0.0	0.6	6.4	0.2	0.0	1.4
Mz. Streak Virus	11.5	20.0	13.9	36.2	14.5	19.2

Since Uganda farmers may apply insecticides on a plant by plant basis as opposed to total stand treatment, the farmer measurements of stalk borer foliar infestation provide an indicator of the proportion of maize stand that may be treated under such an insecticide treatment procedure. Furthermore, the subsequent observations of stalk and ear infestation provide an indication of damage that may be prevented by application of an insecticide treatment (such as beta-cyfluthrin granules).

The average proportion of stand with termite infestation was 18% with a high of 39% in the 1st rainy season of 1996 and a low of 1% in the 2nd rainy season of 1997. To date, the level of termite infestation is higher each year during the 1st rainy season. Since termites are reported to be the most significant pest problem but vary from year to year, use of a rescue treatment on a selective basis may be warranted during seasons of high incidence.

The proportion of stand impacted by root rat has been low (ca. 1%). However, it should be noted that in a severe year, 6% or more of stand was lost. Stand exhibiting maize streak virus averaged to date 19%. This level of infection may be reduced by planting MSV resistant Longe-1.

Results on Beans in Iganga

Farmer observations of pest activity on their bean plantings clearly demonstrates that the bean fly complex, *Ophiomyia sp.*, is the primary pest problem on bean production in Iganga District. However, it should be noted that average stand infestation ranges from a high of 85% in the 2nd rainy season of 1996 to a low of 18% in the first rainy season of 1997. In seasons of high infestation, significant stand losses (up to 50% or more) may be observed.

Other insect pest infestations commonly observed on Iganga bean plantings include the black bean aphid, *Aphid fabae*, and the striped bean weevil, *Alcidodes leucogrammus*, for which stand infestation averaged 21% and 11% respectively over five growing seasons (see Table 2).

Table 2. Summary of biomonitoring data on beans.

Year:	1996		1997		1998	Average
Season:	1st Rain	2nd Rain	1st Rain	2nd Rain	1st Rain	
	Percent of Stand Observed Infested or Impacted					
Bean Fly	63.5	85.0	18.2	35.5	66.9	53.8
Aphids	12.0	31.8	25.2	3.3	31.1	20.7
Bean Weevil	23.3	15.8	8.0	0.0	6.9	10.6
Fusarium	11.8	10.5	7.3	6.7	14.1	9.2

Networking Activities

The farmer biomonitoring project has required close cooperation among farmer participants, MAAIF extension officers, and specialists of Makerere University and NARO research stations. Farmers participating in the biomonitoring project have become primary cooperators in subsequent field trials on maize, bean, groundnut, and striga pest management. Maize and sorghum sites monitored have also been included as release sites for the introduction of a beneficial parasite, *Cotesia flavipes* Cameron, on the exotic stem borer, *Chilo partellus* (Swinhoe). This biological control program includes cooperation of the NARO/NAARI biological control unit and ICIPE scientists based in Nairobi, Kenya. On-farm field trials on bean fly management have be conducted with the cooperation of farmers participating in the crop monitoring project. Application of insecticides as seed treatments have increased bean yields more than 50%.

Publications & Presentations

Results of the farmer biomonitoring project have been included in presentations on the Uganda IPM/CRSP delivered in seminars at Makerere University, ICIPE (Nairobi, Kenya), and NRI (Chatham England) during the past year.

Training Output

Field days were conducted in Iganga and Kumi Districts to inform local farmers and extension personnel on the progress of the IPM/CRSP activities.

Project Highlights

The average proportion of maize stand exhibiting foliar stalk borer injury was 15% over five growing season in Iganga District. This level of foliar infestation resulted in 10% stalk injury and 5% ear injury. Such levels of infestation based on grower observations provides an indication of the proportion of stand that may be treated if growers apply granular insecticide treatments limited to plants exhibiting foliar injury. The average proportion of maize impacted by termites was 18% over five growing seasons. Given the devastating effect of termites on maize, the impact of termites on maize in Iganga District is likely greater than that of the stalk borer complex. Farmer observations of pest activity on beans clearly demonstrates that bean fly is the major constraint of bean production with stand infestation averaging 54% over five growing seasons. Significant stand and yield losses are associated with such levels of bean fly infestation and can be prevented by application of a preventive seed treatment.

Characterization of Maize Inbred Lines for Resistance to *Cercospora zeae-maydis* in Uganda

Investigators: G. Bigirwa[1], D. T. Kyetere[1], R. Pratt[2], Pixle[3], S. Kyamanywa[4], and E. Adipala[4]

Objectives, IPM Constraints

Gray leaf spot is a fungal foliar disease caused by *Cercospora zeae - maydis* Tehon and E. Y. Daniels. The disease is now of concern in many maize growing countries. In the USA severe epidemics were first noticed in early 1970s (Coates and White, 1994). On the African continent, first reports were got from South Africa with severe outbreaks occurring in 1997/1998 season (Ward *et al.*, 1997). The disease is now reported in several African states. In Uganda, a devastating epidemic was first observed in 1994 on farmers fields in Mubende district (Bigirwa *et al.*, 1998). Pixley (1997) reported the disease to be of concern in Zimbabwe and Kenya in 1995. In Malawi, it was noted to be of concern in 1997 (P. Ngwira personal communication) and also in the same year in Cameroon and Ethiopia (Z. Ngoko and A. Tessferi, personal communication respectively). Increased levels of inoculum and severity are associated with continuous maize production and tillage practices (Latterell and Rossi, 1983 and de Nazareno *et al.*, 1993).

Cereospora zeae - maydis overwinters in crop debris, and its survival is reduced when crop debris is buried (de Nazareno *et al.*, 1992 and Leonard, 1974). Yield losses of 10 to 25 % have been reported in USA (Donahue *et al.*, 1991), and losses of up to 100% among inbreds have been recorded in South Africa (Ward *et al.*, 1997). Several attempts are being made to control the disease or reduce losses. They include breeding for resistance, cultural to fungicide. Resistance to *C. zeae - maydis* is controlled quantitatively, and additive genetic effects are important for expression (Donahue *at al.*, 1991 and Elwinger *et al*, 1990). Gray leaf spot progress and severity are also influenced by lesion type (Freppon *et al.*, 1996 and Freppon *et al* 1994). The objective of the study was to identity resistant maize lines for use in the national maize research program of Uganda and by other regional countries. The other objective was to identify sources of resistance.

[1] Namulonge [2] Ohio State University [3] CIMMYT [4] Makerere

Research Methods

Field Plots

Experimental plots were established in 1997 and 1998 at Kamenyamiggo district farm institute in Masaka district. Both *Exserohilum turcicum* and *Cercospora zeae - maydis* pressure are high at this site. In 1997, a total of 140 inbreds were evaluated for resistance to gray leaf spot and materials included domestic and unreleased lines from the program, and foreign. Two replication of inbreds arranged in a randomised complete block design were planted on September 21, in 2 row plots, 5m long at a plant population of 44,000 plants per hectare. In 1998, 256 inbreds were evaluated and got planted on April 9, the majority of which were tested in 1997. The design was randomised complete block arranged in a factorial manner, with inoculation method in the main plot and test materials (inbreds) in sub-plots. The experiment had 2 replications of 2 row plots, 3m long at a plant population as for 1997.

Inoculum Preparation, Inoculation and Rating

Two types of inocula were used during the study. In 1997 ground infected leaves were used. The infected leaves had been collected in January 1997 from 3 different districts. Prior to inoculation, they were ground into powder (dust) form then mixed into a composite and kept. At V6 stage (Ritchie *et al.*, 1989) a pinch of the dust was placed into the plant whorls. This was repeated 2 times at an interval of one week. In 1998, the above method was used together with sorghum grains that were colonised with *C. zeae - maydis* isolates. The inoculum was placed in the whorls as done for the dust. In 1997, two rating methods were used: a 1-5 scoring methods where 1=no or very minor disease, and 5= heavily infected (severely blighted). The second method was by estimating the amount of ear leaf affected (PLAA) in percentages as described by Freppon *et al.*, (1996). To evaluate disease progress over time, five plants in each plot were selected randomly and tagged, and ear leaves were rated for PLAA. Assessments were made 2 weeks after the last inoculation and a total of 4 assessments was made at an interval of 7-10 days. In 1998, stem strength of the test materials using a rind penetrometer was taken on 5 plants per plot twice, i.e. a week before and after flowering.

Data analysis. The area under disease progress curve (AUDPC) was estimated by the mid-point rule method (Campbell and Madden, 1990). Values were standardised by dividing AUDPC values by the duration in days of the epidemic. Means and standard errors of severity scores, AUDPC and stem strength were all determined using MSTATC statistical analysis software.

Results and Discussion

Gray leaf spot disease was more severe in 1997 than in 1998. This is attributed to favourable weather conditions during the growing season. The season experienced plenty of rainfall which was well spread and high cloud cover. On the contrary the 1998 growing season was generally dry particularly from 2 weeks to flowering upto maturity. Disease development and progression were retarded forcing even the susceptible materials to remain clean (Table 1). Over 50% of the inbreds evaluated in 1997 had a mean rating of 3 and above on the 1-5 scale implying that they were susceptible. About 48 inbreds had a mean rating below 2 (Table 1) and these came from the NZ 4700 series. Some few hybrids developed from this background have shown good levels of resistance. We further interpret this to indicate that these inbreds could have genes for resistance and that they may be of value as sources of resistance. Four inbreds; EIL97~13, EAIL97~54, EAIL97~37 and EAIL96~45 had a mean rating of 5 like the susceptible local check, the popcorn. The same inbreds had higher mean PLAA and AUDPC values (Table 1).

Table 1. Means and standard errors of gray leaf spot rating of selected inbreds; 33 susceptible and 18 resistant evaluated in 1997 and 1998 at Kamenyamiggo

Inbred	Mean Score 1-5 scale)	Mean-PLAA[b]		AUDPC -PLAA[c]	
		1997	1998	1997	1998
EAIL97~11	4.75±0.25	43.2±2.8	2.95±1.49	14.29±0.5	0.88±0.28
EAIL97~13	5.00±0.00	46.95±3.05	1.10±0.10	14.42±0.9	0.47+0.01
EAIL97~4 4.	85±0.15	46.15±3.85	1.40±0.23	13.69±0.37	0.64±0.09
P.corn (check)	5.0±0.12	48.53±3.27	2.40±0.53	14.23±2.39	0.77±0.14
EAIL97~8	4.3±0.20	41.1±1.10	1.30±0.30	11.93±0.83	0.53±0.06
EAIL97~3	4.1±0.10	38.3±2.9	5.23±1.47	13.32±0.73	2.28±0.33
EAIL97~54	5.0±0.00	50±0.00	1.35±0.21	17.52±0.30	0.59±0.06
EAIL97~40	4.95±0.05	49.45±0.55	1.85±0.61	17.93±0.58	0.89±0.37
EAIL97~5	4.6±0.10	44.3±2.9	6.73±0.12	15.21±0.98	2.06±0.26
EAIL97~22	4.95±0.97	44.9±1.61	1.20±0.20	14.02±0.36	0.51±0.04
EAIL97~37	5.0±0.0	46.9±3.10	1.00±0.00	14.88±1.67	0.47±0.00
EAIL97~12	4.2±0.10	43.15±0.05	8.87±2.05	14.04±0.58	2.60±0.73
EAIL97~27	4.5±0.20	29.55±7.25	1.00±0.00	8.30±2.39	0.54±0.06
EAIL97~31	4.8±0.12	44.53±3.27	26.98±1.03	14.23±2.39	8.65±0.55
EAIL96~23	4.35±0.65	33.65±6.75	2.30±0.93	10.33±1.29	0.75±0.17

Table 1 ***continued***

EAIL96~117	4.30±0.20	41.05±3.45	1.80±0.49	12.37±2.48	0.83±0.22
EAIL96~194	4.15±0.35	36.05±6.35	3.20±0.77	9.73±0.05	0.88±0.15
EAIL96~188	4.55±0.45	43.30±5.60	2.70±0.50	12.24±2.16	0.82±0.13
EAIL96~24	4.70±0.10	48.60±1.4	4.33±1.42	15.66±0.44	1.25±0.4
EAIL96~45	5.00±0.00	48.25±1.75	2.63±0.91	13.48±0.25	0.81±0.19
NZ 1201	4.90±0.10	47.70±2.30	2.52±0.36	15.80±0.05	0.93+0.05
NZ 1203	4.65±0.15	45.35±2.45	2.75±0.87	14.56±0.14	0.90±0.14
NZ 1204	4.90±0.10	49.75±0.15	2.25±0.56	14.94±0.79	1.14±0.15
NZ 1207	4.90±0.10	48.25±1.55	3.67±1.15	13.32±0.67	0.96±0.21
NZ 1209	4.50±0.30	39.60±0.35	3.80±0.91	11.39±0.62	1.32±0.22
NZ 1213	4.15±0.35	35.90±5.60	2.35±0.76	9.01±1.97	0.84±0.20
NZ 1217	4.90±0.10	43.39±5.35	1.33±0.24	13.61±2.99	0.51±0.03
NZ 1112	4.75±0.25	45.50+3.50	1.65±0.52	10.81±1.65	0.54±0.06
NZ 1109	4.85±0.15	48.35±1.65	1.05±0.05	11.75±1.16	0.47±0.00
NZ 1103	4.85±0.15	47.65±2.35	1.00±0.00	14.21±0.46	0.50±0.03
NZ 1117	4.80±0.00	39.80±2.30	1.05±0.05	12.33+1.62	0.47±0.00
NZ 1134	4.50±0.50	40.85±1.25	1.82±0.73	12.33±1.62	0.91±0.26
NZ 1113	4.50±0.30	27.90±1.55	1.00±0.00	6.35±1.09	0.48±0.01
EAIL97~39	1.60±0.40	2.00±0.0	3.85±0.84	0.62±0.08	1.83±0.33
EAIL96~104	1.30±0.10	2.85±0.05	1.00±0.00	0.92±0.03	0.47±0.0
EAIL97~38	1.90±0.10	13.10±0.70	1.90±0.61	3.42±0.12	0.69±0.1
EAIL97~34	1.50±0.00	3.40±3.40	1.00±0.00	1.36±0.08	0.48±0.02
EAIL96~121	1.95±0.35	10.95±7.34	4.30±2.36	2.81±1.80	1.30±0.67
EAIL96~283	1.35±0.05	2.65±0.17	1.02±0.03	0.80±0.08	0.50±0.03
EAIL96~104	1.30±0.10	2.85±0.05	1.00±0.00	0.92±0.03	0.47±0.01
NZ 4730	1.10±0.10	5.80±2.40	1.65±0.52	1.13±0.12	0.54±0.08
NZ 4791	1.75±0.75	2.20±0.20	1.25±0.25	0.62±0.08	0.52±0.05
NZ 4769	1.00±0.00	1.35±0.35	1.00±0.00	0.54±0.07	0.50±0.03
NZ 4761	1.70±0.10	8.05±5.74	1.00±0.00	1.32±0.59	0.45±0.00
NZ 4754	1.25±0.25	2.05±0.05	1.00±0.00	0.55±0.01	0.48±0.01
NZ 4787	1.20±0.00	1.85±0.15	1.05±0.05	0.53±0.01	0.47±0.00
NZ 4743	1.25±0.25	2.10±0.10	1.02±0.01	0.55±0.01	0.42±0.05
NZ 4782	1.30±0.30	4.20±2.10	1.52±0.43	1.07±0.52	0.55±0.07
NZ 4707	1.25±0.25	2.20±0.10	1.00±0.00	0.56±0.01	0.47±0.00
NZ 4765	1.25+0.25	2.95±0.55	1.65±0.59	0.62±0.04	0.65±0.2
NZ 4735	1.25±0.025	7.00±4.70	1.00±0.00	2.05±1.30	0.47±0.00

[a] Because of the long list, only inbreds with a score of 4 and above on 1-5 scale are shown for the susceptibles; while for resistant only those with less than 2.
[b] PLAA=percent ear leaf area affected and represents the fourth score
[c] AUDPC= area under disease progress curve based on four assessments and was standardised by dividing calculated values by duration of epidemic in each year

A comparison of the 2 inoculation methods (sorghum grains against ground infected leaves) did not show much difference. The majority of the inbreds behaved the same irrespective of the method. This is again attributed to the unfavourable weather conditions since even the susceptible inbreds had low mean ratings. There were however, a few exceptions with no clear trend. Five inbreds showed higher mean ratings with sorghum grains than with ground infected leaves while 7 showed a reverse trend (Table 2). No meaningful deductions can be made since the experiment was greatly affected by drought. There were also no differences in stem strength. The testing of the 2 inoculation methods requires further investigation.

Table 2. Means and standard errors of percent ear leaf area affected (PLAA) and stem strength of some selected inbreds with varying scores when inoculated with sorghum grains (SG) and ground infected leaves (GIL)

	PLAA		Stem Strength[a]	
Inbred	SG	GIL	SG	GIL
EAIL 97~9	8.20±1.80	7.85±2.38	4.65±0.60	4.63±0.82
EAIL 97~12	10.00±0.00	7.74±4.75	4.41±0.00	4.13±0.48
EAIL 97~47	5.40±1.60	9.60±1.60	4.11±0.11	3.67±0.36
EAIL 97~55	1.50±0.50	7.50±3.50	4.17±0.35	2.81±0.08
EAIL 96~100	2.50±0.10	7.70±3.50	2.75±0.11	2.46±0.16
EAIL 96~145	1.90±0.09	6.90±0.50	2.60±0.13	4.44±0.29
EAIL 96~158	4.50±1.30	11.00±3.00	3.18±0.11	3.56±0.17
EAIL 96~186	5.29±5.11	12.40±7.60	3.94±0.25	1.95±0.04
EAIL 96~207	7.75±6.75	3.00±0.40	2.58±0.08	3.03±0.03
Popcorn (L.Check)	28.55±0.95	25.40±0.70	3.42±0.06	4.54±0.12
NZ 1207	6.20±0.80	5.30±1.50	4.86±0.51	4.54±0.12
EAIL 96~54	3.80±0.20	9.80±2.4	3.29±0.09	4.36±0.69

Impacts

The study has shown varied response of inbreds to *C. zeae-maydis,* with materials being categorised into 3; resistant, moderate and susceptible. Some lines are extremely good and well adapted to the Ugandan environment, and therefore, this attribute offers great potential for usage in the region and Uganda in particular. As part of the project a new set of hybrids (25) sent by Dr. R.C. Pratt from the US has been planted during this month.

Networking Activities

A joint GLS survey to assess the extent of severity and its impact in major maize growing areas of Uganda was carried out by NARO staff, G. Bigirwa, Ohio University Professor R.C. Pratt and Makerere University Professor E. Adipala. It is our wish to conduct another one during a normal season because in the last one drought hampered disease development and expression.

Publications

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Biological and Economic Severity of Gray Leaf Spot Disease and Stemborer Infestation on Maize

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Collaborating Scientist: P. Thomison[1]

Abstract

Screening of mid-altitude germplasm across two seasons was completed and accessions resistant to *Cercospora zeae-maydis* were identified. Rind puncture resistance was evaluated to allow selection of germplasm with rigid stalks. The first testcross evaluation of gray leaf spot (GLS) resistant tropical breeding lines from the OSU program was

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performed in Ohio, and has been planted in Uganda. Several lines exhibit high levels of resistance to GLS and have acceptable stalk strength. A survey of farmer's fields in several districts of Uganda was completed. It was established that gray leaf spot occurrence is widespread, even during an unfavorable drought season. The survey findings establish gray leaf spot as one of the leading economic pathogens of maize in Uganda. Research has been initiated to identify genes for resistance to gray leaf spot in African maize germplasm. Polymorhpic simple sequence repeat (SSR) molecular markers have been identified and will be used to ascertain quantitative trait loci associated with resistance to *Cercospora zeae-maydis*.

Objectives

i. To assess the degree of disease incidence and severity of GLS in important maize production regions of Uganda.

ii. To examine the impact of GLS disease severity on stalk strength and economic yield.

iii. To examine the degree to which stalk integrity is impacted by combined action of stemborers and GLS.

iv. To identify sources of resistance to GLS in tropical adapted maize germplasm.

IPM Constraints

Gray leaf spot is a fungal foliar disease caused by *Cercospora zeae - maydis* (Tehon and E.Y. Daniels). The disease is now a constraint to stable food production in many maize growing countries. In the USA, severe epidemics were first noticed in the early 1970s (Coates and White, 1994). On the African continent, first reports arose from South Africa where severe outbreaks occurred during in 1997/1998 season (Ward *et al.*, 1997). The disease is now reported in several African states. In Uganda, a devastating epidemic was first observed in 1994 on farmers fields in Mubende district (Bigirwa *et al.*, 1998). Pixley (1997) reported the disease to be of concern in Zimbabwe and Kenya in 1995. In Malawi, it was noted to be of concern in 1997 (P. Ngwira personal communication) and also in the same year in Cameroon and Ethiopia (Z. Ngoko and A. Tessferi, personal communication respectively).

Increased levels of inoculum, which result In higher disease severity, are associated with continuous maize production and tillage practices (Latterell and Rossi, 1983 and de Nazareno *et al.*, 1993). *Cereospora zeae - maydis* overwinters in crop debris, and its survival is reduced when crop debris is buried (de Nazareno *et al.*, 1992 and Leonard, 1974). Yield losses of 10 to 25% have been rePorted in USA (Donahue *et al.*, 1991), and losses of up to 100% among inbreds have been recorded in South Africa (Ward *et al.*, 1997). Attempts to manage the disease include breeding for resistance, manipulation of cultural practices, and treatment with fungicides.

Deployment of host-resistance and cultural techniques offer the most appropriate methods of disease management, however, good sources of host resistance are not yet generally available, and cultural practice recommendations employed in the U.S. no-tillage production do not apply to African cropping systems.

Breeding for resistance to *C. zeae - maydis* appears to be The best strategy foR managing the disease; however, it is controlled quantitatively, and progress in breeding for resistance in the U.S. has been difficult (Donahue at al., 1991 and Elwinger *et al*, 1990).

Research Methods

To assess the degree of disease incidence and severity of GLS in important maize production regions of Uganda. During July 1998, Prof. Pratt traveled to Uganda to assist with the first survey to examine the presence and severity of gray leaf spot disease in maize producing regions of Uganda. Drs. Bigirwa and Pratt formulated the assessment instruments and conducted the initial surveys in Mosaka District with Dr. Ekwamu. Farmer's fields of suitable size and maturity were observed from the road, and inquiries were made to obtain permission from local farmers to examine the fields. Destructive sampling of 45 maize plants was performed in utilizing a 3 X 3 grid system, with 5 plants randomly sampled within each grid, to ensure adequate representation of the entire field. A leaf from the middle portion of the plant (generally the ear leaf) wasvisually assessed to determine the area of the mid-leaf affected by gray leaf lesions (percent leaf area affected, PLAA). Severity assessments, and determinations of the presence or absence of other diseases, were made by two raters who reached consensus before recording data. All leaves were removed and the entire stalks were cut lengthwise to investigate the extent of tunneling within the stalk caused by stem-borers. Stem-borers were recovered whenever possible and identified. The grain moisture content was estimated and scored on a one to five scale - 1 indicated an immature ear (pre-milk) and 5 indicated dry, filled ears.

Farmers were also interviewed to ascertain whether or not they knew the GLS foliar symptoms were associated with disease, and when they first observed the symptoms. Data were also recorded concerning the rotation system and what companion crops were planted in the field. Farmers were also asked if fertilizer had been incorporated in the soil and what the variety of maize was that had been sown. Data were recorded, entered into a spreadsheet, and descritive statistics performed using Microsoft Excel software. Data were summarized by districts and the most severe diseases were identified within each district.

To examine the impact of GLS disease severity on stalk strength and economic yield. Approximately 20 test crosses of selected gray leaf spot resistant tropical breeding lines were crossed with Corn Belt maize inbred Mo17. The test crosses and suitable resistant and susceptible checks were planted in replicated, two-row plots at the Agricultural Technical Institute farm near Apple Creek, Ohio during May 1998. The site is characterized by the presence of maize stubble (no tillage practiced) and poor air drainage which makes the site conducive to gray leaf spot epiphytotics.

Gray leaf spot severity was assessed visually three times during a one month period beginning at flowering. Stalk (rind) puncture resistance was determined using a modified force guage (rind penetrometer) two times, commencing at flowering. Plots have not yet been harvested for yield determinations. Stalk lodging will be assessed just prior to harvest.

To examine the degree to which stalk integrity is impacted by combined action of stemborers and GLS. In 1998, stem strength of the test materials using a rind penetrometer was taken on 5 plants per plot twice, i.e. a week before and after flowering. Disease inoculation and severity assessment protocols are presented in the next section.

To identify sources of resistance to GLS in tropical adapted maize germplasm. Experimental plots were established in 1997 and 1998 at Kamenyamiggo district farm institute in Masaka district. Both *Exserohilum turcicum* and *Cercospora zeae - maydis* pressure are high at this site. In 1997, a total of 140 inbreds were evaluated for resistance to gray leaf spot and materials included domestic and unreleased lines from the program, and foreign. Two replications of inbreds were arranged in a randomised complete block design and planted on September 21, in 2 row plots, 5m long at a plant population of 44,000 plants per hectare. In 1998, 256 inbreds were evaluated following planting on April 9. The majority of these entries also were tested in 1997. The design was randomised complete block arranged in a factorial manner, with inoculation method in the main plot and test materials (inbreds) in sub-plots. The experiment had 2 replications of 2 row plots, 3m long at a plant population as for 1997.

Two types of inocula were used during the study. In 1997 ground infected leaves were used. The infected leaves had been collected in January 1997 from 3 different districts. Prior to inoculation, they were ground into powder (dust) form then mixed into a composite and kept. At V6 stage (Ritchie *et al.*, 1989) a pinch of the dust was placed into the plant whorls. This was repeated 2 times at an interval of one week.

In 1998, the above method was used together with sorghum grains that were colonised with *C. zeae - maydis* isolates. The inoculum was placed in the whorls as done for the dust. In 1997, two rating methods were used: a 1-5 scoring methods where 1=no or very minor disease, and 5= heavily infected (severely blighted). The second method was by estimating the amount of ear leaf affected (PLAA) in percentages as described by Freppon *et al.*, (1996).

To evaluate disease progress over time, five plants in each plot were selected randomly and tagged, and ear leaves were rated for PLAA. Assessments were made 2 weeks after the last inoculation and a total of 4 assessments was made at an interval of 7-10 days.

The area under disease progress curve (AUDPC) was estimated by the mid-point rule method (Campbell and Madden, 1990). Values were standardised by dividing AUDPC values by the duration in days of the epidemic. Means and standard errors of severity scores, AUDPC and stem strength were all determined using MSTATC statistical analysis software. Work was also initiated to conduct genetic studies on GLS resistance to support breeding efforts. (This is a stated objective in the current IPM/CRSP project proposal.)

1. Suitability of Simple Sequence Repeat (SSR) Molecular Techniques for Quantitative Trait Locus (QTL) Mapping in Maize: Efforts to optimize the methods to establish a suitable system to characterize maize genotypes with SSR-markers were initiated by a student from the University of Hohenheim who worked with my post-doctoral research associate for three months. One-half of the students effort was funded through the IPM-CRSP project.

2. DNA Extraction Methods: The technical feasibility of two different DNA extraction methods was investigated. The CTAB-method (after Saghai-Maroof *et al.* 1984 in UMC Maize Procedures Manual, University of Missouri-Columbia, 1995) and a rapid and simple NaOH extraction method were evaluated for the preparation of plant tissue samples for PCR reactions (Wang *et al.* 1993). The time and effort required for DNA isolation is often a time limiting step.

3. Oligonucleotide Primers: All primers were purchased from Research Genetics, Inc.. From 171 available primers, 125 were screened. Some of them were not useful, because they showed no amplification, or the data were not reproducible. All chosen primers were distributed over the whole genome, to get a representative coverage.

4. PCR-reactions: All reactions were set up in a 96 well polypropylene microtiter-plate.

Research Results and Discussion

Survey results demonstrated the prevalence of GLS throughout important maize producing regions inspite of its fairly recent arrival in Uganda. For example, in Masaka District, where drought reduced the suitability of the environment to support disease development, *C. zeae-maydis* had infected 100% of the plants examined in three fields. Please see tables 1a and 1b. The midleaves bore appreciable damage (an average as high as 15% of the leaf surface was covered by gray leaf spot lesions). Because the grain was fairly mature (past milk stage) the economic impact will not be too severe. However, the high frequency of infection, coupled with the degree of progress of the disease in a highly unfavorable season, does not bode will for future maize production in Uganda. It is clear that, during more favorable environmental conditions, *C. zeae-maydis* may become an extreme threat to maize production in Uganda, and very likely throughout East Africa. Maize streak virus (MSV), tropical rust, and Northern leaf blight (NLB) were also present in the field. Please see attached figures for illustration of specific diseases. Farmers in the Masaka district were not aware that the leaf symptoms are caused by infection with the fungal pathogen. An average tunnel length per plant of 5 cm demonstrated the important threat also posed by stem borer infestation.

Table 1a. Survey results from Masaka District.

Fld. #	Farmer	Location	District	Variety	Spac. (M)	Companion Crop	Rotation	Knows Disease ?
01	Matia Kiatu	Kyabakoza	Masaka	Nandi	1.5 1.5	beans, cassava	fallow-maize	no
02	Byganje Peace	Kaboya, Kimonu	Masaka	Local	1.5 2.5	beans, cassava	maize/beans maize/beans	no
03	-----	----	Masaka	Local	2.0 1.5	beans, cassava	beans-maize	no

Table 1b. Survey results from Masaka District.

Masaka Fld. #	GR. MAT.	GLS PLAA	GLS (%)	MSV (%)	NLB (%)	RUST (%)	DMAC (%)	STEM BOR (cm)
01	2.9	15	100	4	4	20	0	3
02	2.6	5	100	2	11	2	0	8
03	2.2	14	100	16	22	29	0	4
AVG	2.6	11	100	7	12	17	0	5

Examination of plots in Mukono District also revealed the high incidence of GLS, although the severity was somewhat less than in Masaka District. The high incidence of rust in fields was noticeable. Stem-borers were also active in fields in Mukono District and MSV, NLB, and rust were again noted.

GLS was also prevalent in Jinga District but it had caused considerably less damage on the midleaves than had occurred in other districts. MSV, NLB, and rust were again present. Stem borers were also present but tunneling damage was less than at other locations.

Iganga is an important maize producing region so more intensive sampling was undertaken. Again, GLS and rust were found to be prevalent throughout the area (Tables 2a and 2b).

Table 2a. Survey results fom Iganga District

Fld. #	Farmer	Location	District	Variety	Spac. (M)	Compan. Crop	Rotation	Knows Disease ?
08	H. Mutesi	/busei	Iganga	Local	1.5 1.5	---	maize-maize	no
09	Zainabu	Butaba	Iganga	Longe 1	1.5 1.0	banana	sw. potato-maize	no
10	Jamawa Mwonoha	Bulugwi	Iganga	Popcorn	1.5 1.0	sole	cassava/potato maize	no
11	Mudyope	Idudi	Iganga	Local	3.0 2.0	sesame	sesame/sw. potato-maize	no

Table 2b. Survey results from Iganga District

Iganga Fld. #	GR MAT.	GLS PLAA	GLS (%)	MSV (%)	NLB (%)	RUST (%)	DMAC (%)	STEMBOR (cm)
08	2.8	4	84	0	4	18	0	3
09	2.1	1	76	11	44	82	4	1
11	2.1	3	96	20	18	53	0	3
AVG	2.3	2	84	12	21	46	1	2

Gray leaf spot development at the ATI site in Ohio was very good. Post flowering ratings (9/01) showed 50% of the midleaf 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 3). Verification of performance in Uganda is awaited.

Table 3. IPM/CRSP GLS Tolerance and Stalk Strength Test, ATI Apple Creek Farm, Ohio, 1998

ENTRY	RIND RESISTANCE FORCE			GLS PLAA
	7/24 (kg)	9/02 (kg)	SVG (kg)	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

Table 3 *continued*

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 xOSU: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	3.5	11
Testcross AVE	3.7	3.2	3.4	8

A comparison of the 2 inoculation methods (sorghum grains against ground infected leaves) did not show much difference. The majority of the inbreds behaved the same irrespective of the method. This is again attributed to the unfavourable weather conditions since even the susceptible inbreds had low mean ratings. There were however, a few exceptions with no clear trend. Five inbreds showed higher mean ratings with sorghum grains than with ground infected leaves while 7 showed a reverse trend (Table 4). No meaningful deductions can be made since the experiment was greatly affected by drought. There were also no differences in stem strength. The testing of the2 inoculation methods requires further investigation.

Gray leaf spot disease was more severe in 1997 than in 1998. This is attributed to favourable weather conditions during the growing season. The season experienced plenty of rainfall which was well spread, and accompanied by high cloud cover. On the contrary the 1998 growing season was generally dry particularly from 2 weeks to flowering up to maturity. Disease development and progression were retarded forcing even the susceptible materials to remain clean (Table 3). Over 50% of the inbreds evaluated in 1997 had a mean rating of 3 and above on the 1-5 scale implying that they were susceptible. About 48 inbreds had a mean rating below 2 (Table 3) and these came from the NZ 4700 series. Some few hybrids developed from this background have shown good levels of resistance. We further interpret this to indicate that these inbreds could have genes for resistance and that they may be of value as sources of resistance. Four inbreds; EAIL97~13, EAIL97~54, EAIL97~37 and EAIL96~45 had a mean rating of 5 like the

susceptible local check, the popcorn. The same inbreds had higher mean PLAA and AUDPC values (Table 5).

Table 4. Means and standard errors of percent ear leaf area affected (PLAA) and stem strength of some selected inbreds with varying scores when inoculated with sorghum grains (SG) and ground infected leaves (GIL)

	PLAA		Stalk Strength	
Inbred	SG	GIL	SG	GIL
EAIL 97~9	8.20±1.80	7.85±2.38	4.65±0.60	4.63±0.82
EAIL 97~12	10.00±0.00	7.74+4.75	4.41+0.00	4.13+0.48
EAIL 97~47	5.40+1.60	9.60+1.60	4.11+0.11	3.67+0.36
EAIL 97~55	1.50+0.50	7.50+3.50	4.17+0.35	2.81+0.08
EAIL 96~100	2.50+0.10	7.70±3.50	2.75±0.11	2.46+0.16
EAIL 96~145	1.90+0.09	6.90+0.50	2.60+0.13	4.44+0.29
EAIL 96~158	4.50+1.30	11.00+3.00	3.18+0.11	3.56+0.17
EAIL 96~186	5.29+5.11	12.40+7.60	3.94+0.25	1.95+0.04
EAIL 96~207	7.75±6.75	3.00±0.40	2.58±0.08	3.03±0.03
Popcorn (L.Check)	28.55+0.95	25.40+0.70	3.42+0.06	4.54+0.12
NZ 1207	6.20+0.80	5.30+1.50	4.86+0.51	4.54+0.12
EAIL 96~54	3.80±0.20	9.80±2.4	3.29±0.09	4.36±0.69

Table 5. Means and standard errors of gray leaf spot rating (1-5) of selected inbreds; 33 susceptible and 18 resistant evaluated in 1997 and 1998 at Kamenyamiggo

Inbred	Mean Score 1-5 scale)	Mean-PLAAb		AUDPC -PLAAc	
		1997	1998	1997	1998
EAIL97~11	4.75±0.25	43.20±2.8	2.95±1.49	14.29±0.5	0.88±0.28
EAIL97~13	5.00±0.00	46.95±3.05	1.10±0.10	14.42±0.9	0.47+0.01
EAIL97~4	4.85±0.15	46.15±3.85	1.40±0.23	13.69±0.37	0.64±0.09
P.corn (check)	5.0±0.12	48.53±3.27	2.40±0.53	14.23±2.39	0.77±0.14
EAIL97~8	4.3±0.20	41.10±1.10	1.30±0.30	11.93±0.83	0.53±0.06
EAIL97~3	4.1±0.10	38.30±2.90	5.23±1.47	13.32±0.73	2.28±0.33
EAIL97~54	5.0±0.00	50.00±0.00	1.35±0.21	17.52±0.30	0.59±0.06
EAIL97~40	4.95±0.05	49.45±0.55	1.85±0.61	17.93±0.58	0.89±0.37
EAIL97~5	4.60±0.10	44.30±2.9	6.73±0.12	15.21±0.98	2.06±0.26
EAIL97~22	4.95±0.97	44.90±1.61	1.20±0.20	14.02±0.36	0.51±0.04
EAIL97~37	5.00±0.00	46.90±3.10	1.00±0.00	14.88±1.67	0.47±0.00
EAIL97~12	4.20±0.10	43.15±0.05	8.87±2.05	14.04±0.58	2.60±0.73
EAIL97~27	4.50±0.20	29.55±7.25	1.00±0.00	8.30±2.39	0.54±0.06
EAIL97~31	4.80±0.12	44.53±3.27	26.98±1.03	14.23±2.39	8.65±0.55
EAIL96~23	4.35±0.65	33.65±6.75	2.30±0.93	10.33±1.29	0.75±0.17
EAIL96~117	4.3±0.20	41.05±3.45	1.80±0.49	12.37±2.48	0.83±0.22
EAIL96~194	4.15±0.35	36.05±6.35	3.20±0.77	9.73±0.05	0.88±0.15
EAIL96~188	4.55±0.45	43.30±5.60	2.70±0.50	12.24±2.16	0.82±0.13
EAIL96~24	4.70±0.10	48.60±1.40	4.33±1.42	15.66±0.44	1.25±0.40
EAIL96~45	5.00±0.00	48.25±1.75	2.63±0.91	13.48±0.25	0.81±0.19
NZ 1201	4.90±0.10	47.70±2.30	2.52±0.36	15.80±0.05	0.93+0.05
NZ 1203	4.65±0.15	45.35±2.45	2.75±0.87	14.56±0.14	0.90±0.14
NZ 1204	4.90±0.10	49.75±0.15	2.25±0.56	14.94±0.79	1.14±0.15
NZ 1207	4.90±0.10	48.25±1.55	3.67±1.15	13.32±0.67	0.96±0.21
NZ 1209	4.50±0.30	39.60±0.35	3.80±0.91	11.39±0.62	1.32±0.22
NZ 1213	4.15±0.35	35.90±5.60	2.35±0.76	9.01±1.97	0.84±0.20
NZ 1217	4.90±0.10	43.39±5.35	1.33±0.24	13.61±2.99	0.51±0.03
NZ 1112	4.75±0.25	45.50+3.50	1.65±0.52	10.81±1.65	0.54±0.06
NZ 1109	4.85±0.15	48.35±1.65	1.05±0.05	11.75±1.16	0.47±0.00
NZ 1103	4.85±0.15	47.65±2.35	1.00±0.00	14.21±0.46	0.50±0.03
NZ 1117	4.80±0.00	39.80±2.30	1.05±0.05	12.33+1.62	0.47±0.00
NZ 1134	4.50±0.50	40.85±1.25	1.82±0.73	12.33±1.62	0.91±0.26
NZ 1113	4.50±0.30	27.90±1.55	1.00±0.00	6.35±1.09	0.48±0.01
EAIL97~39	1.60±0.40	2.00±0.0	3.85±0.84	0.62±0.08	1.83±0.33
EAIL96~104	1.30±0.10	2.85±0.05	1.00±0.00	1.92±0.03	0.47±0.0

Table 5 ***continued***

EAIL97~38	1.90±0.10	13.10±0.70	1.90±0.61	3.42±0.12	0.69±0.1
EAIL97~34	1.50±0.00	3.40±3.40	1.00±0.00	1.36±0.08	0.48±0.02
EAIL96~121	1.95±0.35	10.95±7.34	4.30±2.36	2.81±1.80	1.30±0.67
EAIL96~283	1.35±0.05	2.65±0.17	1.02±0.03	0.80±0.08	0.50±0.03
EAIL96~104	1.30±0.10	2.85±0.05	1.00±0.00	0.92±0.03	0.47±0.01
NZ 4730	1.10±0.10	5.80±2.40	1.65±0.52	1.13±0.12	0.54±0.08
NZ 4791	1.75±0.75	2.20±0.20	1.25±0.25	0.62±0.08	0.52±0.05
NZ 4769	1.00±0.00	1.35±0.35	1.00±0.00	0.54±0.07	0.50±0.03
NZ 4761	1.70±0.10	8.05±5.74	1.00±0.00	1.32±0.59	0.45±0.00
NZ 4754	1.25±0.25	2.05±0.05	1.00±0.00	0.55±0.01	0.48±0.01
NZ 4787	1.20±0.00	1.85±0.15	1.05±0.05	0.53±0.01	0.47±0.00
NZ 4743	1.25±0.25	2.10±0.10	1.02±0.01	0.55±0.01	0.42±0.05
NZ 4782	1.30±0.30	4.20±2.10	1.52±0.43	1.07±0.52	0.55±0.07
NZ 4707	1.25±0.25	2.20±0.10	1.00±0.00	0.56±0.01	0.47±0.00
NZ 4765	1.25±0.25	2.95±0.55	1.65±0.59	0.62±0.04	0.65±0.2
NZ 4735	1.25±0.025	7.00±4.70	1.00±0.00	2.05±1.30	0.47±0.00

a Because of the long list, only inbreds with a score of 4 and above on 1-5 scale are shown for the susceptibles; while for resistant only those with less than 2.

b PLAA=percent ear leaf area affected and represents the fourth score

c AUDPC= area under disease progress curve based on four assessments and was standardised by dividing calculated values by duration of epidemic in each year

The NaOH protocol allowed extraction of a sufficient quantity of DNA in an appropriate buffer for direct use in PCR reactions. The PCR technique requires only a minimal amount of DNA and has a good tolerance toward crude DNA preparations. We have shown that this procedure is working for maize leaf tissue samples, regardless of their age. A few changes in the method were necessary, so the volume of NaOH was double the amount recommended when grinding the leaf discs in the tube. The isolated DNA can be used for the PCR reaction immediately and this method is very recommendable for handling large sample sizes. It accelerated the working process in the lab significantly, and many polymorphisms between a gray leaf spot resistant (V0613Y) and susceptible inbred (Pa405) were identified (Table 6).

Table 6. Maize inbred lines (in combinations used for production of progenies for gene mapping studies), their number of polymorphic primers and degree of polymorphisms among parents in %.

Chromo-some	total tested	nup	H99 x A619	Pa 405 x V0613Y
1	19	6	4	4
2	13	4	3	4
3	9	3	1	1
4	21	3	5	5
5	19	5	5	4
6	21	5	5	2
7	15	1	7	5
8	12	2	6	4
9	23	4	5	3
10	18	3	1	2
	125	36	42	34
polymorphic degree [%]		43.6	53.1	

Impact

The study has shown varied response of inbreds to *C. zeae-maydis,* with materials being categorised into 3; resistant, moderate and susceptible. Some lines are extremely good and well adapted to the Ugandan environment, and therefore, this attribute offers great potential for usage in the region and Uganda in particular. Identification of resistant germplasm and molecular selection tools will enhance breeding efforts both in Uganda and in the U.S. to achieve high levels of resistance in adapted, elite cultivars.

Networking Activities

Bigirwa, G., Kyetere, D.T., Imanywoha, J.B. and Okanya, S. presented paper at the sixth regional maize conference for eastern and southern Africa, 21-25 September, Addis Ababa, Ethiopia.

Pratt, R. presented seminar "Strategies for improving host resistance to *Cercospora zeae-maydis* -- causal agent of gray leaf spot disease of maize (*Zea mays* L.)." University of Hohenheim, Institute for Plant Breeding, Seed Secience and Population Genetics, Stuttgart, Germany. 7/21/98.

Pratt, R. presented seminar "Host resistance of Maize to *Cercospora zeae-maydis* -- causal agent of gray leaf spot disease of maize (*Zea mays* L.)." Makerere University, Faculty of Agriculture and Forestry, Kampala, Uganda. 7/28/98.

Communication has been undertaken between OSU and the Rep. of South Africa, Grain Crops Institute, Agric. Research Council to conduct cooperative gene mapping studies of resistant X susceptible progenies derived from African X Corn Belt germplasm. The first experiments should be planted within the coming week.

Publications and Presentations

Bigirwa, G., Kyetere, D.T., Imanywoha, J.B. and Okanya, S. 1998. Response of maize genotypes to gray leaf spot disease in Uganda. Paper presented at the sixth regional maize conference for eastern and southern Africa, 21-25 September, Addis Ababa, Ethiopia (In press).

Training Output

Inge Matthies, student, the University of Hohenheim, Use of SSR molecular markers for genetic studies in maize. Short term study (3 mo.).

Project Highlight

It was determined that gray leaf spot disease of maize is now widespread throughout maize procucing regions of Uganda. Resistant germplasm has been identified. SSR molecular marker technology is successfully being developed for application to plant breeding for resistance.

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The Effects of Intercropping Local and Improved Maize Varities with Beans on Incidence and Progression of Maize Diseases in Iganga District

Investigators: G. Bigirwa[1], H. Warren[2], and S. Kyamanywa[3]

Abstract

Maize and beans constitute a major diet in many parts of Uganda and the two crops are commonly intercropped. For a long time farmers have been growing their own local maize varieties which tend to be susceptible to diseases like maize streak and northern leaf blight (*Exserohilum turcicum*). The local varieties are known to be low yielders and relatively late maturing. However, with the popularisation drive of the improved varieties like Longe 1 several farmers have come to embrace this variety notably for its ability to withstand drought, and mature early and give good yields.

Objectives

1. To compare the performance of the improved open pollinated variety (Longe 1) with a local variety under mono-and inter-cropping systems

2. To monitor the development and progression of maize diseases to identify major pathogens and their relationship to disease severity and crop yield

Research Methods

Work being reported was for 2 seasons; second season 1997 and first season 1998. The trials were established in Iganga district in 2 sub-countries, Baitambugwe and Bulamagi. In each sub-county 2 farmers were used. Plots measured 10 x 10m replicated twice at each farm. The treatment were; Longe 1 sole crop, Longe 1 intercropped with beans, farmers local variety sole crop and local variety with beans. Spacing for maize was 75 x 60 cm 2 plants per hill and 75 x 15 cm for beans (K131 variety). Recording of maize diseases started 60 days after planting and continued to be done every 2 weeks resulting into 4 recordings. On each recording incidence and severity were determined. Disease incidence was recorded on ten plants randomly selected in 3 different positions in each plot. Severity was recorded on 10 plants randomly selected and tagged in a plot. Progression of major diseases on tagged plants was monitored using a disease index severity scale of 1-5 (where 1= no or very minor infection, 5=very heavy infection. Data from successive recordings were used to calculate area under disease progress curve (AUDPC). Data on incidence were subjected to arcsine transformation to harmonise variances (Steel and Torrie, 19). Yield of different treatments was also determined at harvest. All data were later subjected to analysis of variance.

Results and Discussion

Six diseases were observed to be predominant during the second season of 1997; maize streak virus, MSV, gray leaf spot GLS (*Cercospora Zeae maydis*), northern leaf blight, NLB (*Exserohilum turcicum*), diplodia leaf streak DPS (*Diplodia macrospora*), common rust PS (Puccinia sorghi) and tropical rust PP (*Puccinia polysora*). Gray leaf spot was the most predominant disease in all fields (Table 1) with incidence as high as 75%. It was followed by northern leaf blight and maize streak virus. The least were the rusts. The same trend was more or less the same during the first season of 1998 (Table 2).

Table 1. Disease incidence on farmers fields, 1997B

	MSV[a]		GLS[b]		NLB[c]		DLS[d]		PS[e]		PP[f]	
Farmer	AUDPC	Inc. %	AUDPC	Inc. %	AUDPC	Inc. %	AUDPC	Inc. %	AUDPC	Inc. %	AUDPC	Inc. %
Byekwaso	23.2±5.5	16.0±4.0	74.5 ± 2.7	36.7 ± 4.2	44.7 ± 2.2	26.4 ± 1.9	27.5 ± 2.0	17.4 ± 0.8	7.2 ± 2.1	5.7 ± 1.0	4.7±2.1	1.8± 0.5
Kiseke	27.6±6.6	18.9±4.1	74.4 ± 2.8	33.6 ± 2.1	47.4 ± 2.7	32.8 ± 2.5	25.5 ± 1.4	16.8 ± 1.4	16.7 ± 1.9	10.5 ± 1.2	5.7±1.0	2.9± 0.4
Mukalazi	23.4±5.2	14.9±3.1	75.7 ± 2.4	39.2 ± 2.2	54.6 ± 1.6	33.4 ± 1.8	32.8 ± 2.6	20.9 ± 1.4	12.9 ± 2.5	8.7 ± 1.1	4.9±0.8	2.4± 0.4

[a] maize streak virus [b] gray leaf spot [c] northern leaf blight [d] diplodia leaf streak [e] puccinia sorghi-rust [f] puccinia polysora - rust

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Table 2. Disease incidence on farmers fields during 1998A

Farmer	MSV[a] AUDPC	MSV[a] Inc. (%)	GLS[b] AUDPC	GLS[b] Inc (%)	NLB[c] AUDPC	NLB[c] Inc (%)	PP[d] AUDPC	PP[d] Inc %
Byekwaso	41.3 ± 6.7	35.2 ± 6.7	96.3 ± 2.6	75.7 ± 3.3	63.8 ± 6.2	50.4 ± 4.3	35.2 ± 6.7	41.5 ± 4.7
Kiseke	42.5 ± 8.8	40.0 ± 5.5	93.8 ± 2.6	77.9 ± 3.3	65.6 ± 6.2	52.5 ± 3.5	40.0 ± 5.5	47.1 ± 2.8
Mukalazi	43.8 ± 8.2	40.0 ± 6.2	92.5 ± 4.1	82.5 ± 1.6	76.3 ± 8.6	52.7 ± 3.0	40.0 ± 6.7	51.9 ± 2.1
Kulata	38.8 ± 5.5	35.3 ± 4.5	98.8 ± 1.2	81.4 ± 3.1	52.3 ± 3.6	51.7 ± 4.9	35.3 ± 4.5	49.9 ± 4.2

[a] maize streak virus [b] gray leaf spot [c] northern leaf blight [d] puccinia polysora rust [e] puccinia sorghi-rust [f] puccinia polysora - rust

Maize streak virus severity was significantly (P=0.01) higher in the local variety than in Longe 1, whether under mono or intercrop. It was highest in local monocrop (Table 3). There were no significant differences in varieties in disease reaction to GLS, NLB, DPS,PS and PP . The same trend was observed during the first season of 1998 (Table 4). Sorghum downy mildew (*Peronoscleropora sorghi*) was observed in some fields with high incidence of 13% at S. Kiseka, 7.2% at Byekwaso and 2.6% at Kulata's farm.

Table 3. Disease incidence on farmers fields, 1997B

Treatment	AUDPC	Maize streak virus Severity	Maize streak virus AUDPC	Gray leaf spot Severity	Gray leaf spot AUDPC	Northern leaf blight Severity	Northern leaf blight AUDPC	Diplodia leaf streak Severity	Diplodia leaf streak AUDPC	Common rust Severity	Tropical rust AUDPC	Tropical rust Severity
Longe	1.2 ± 0.1b	1.2 ± 0.1b	2.6 ± 0.2	2.0 ± 0.1	1.8 ± 0.1	1.7 ± 0.1	1.4 ± 0.1	1.3 ± 0.1	1.2 ± 0.8	1.2 ± 0.0	1.1 ± 0.1	1.4±0.3
Longe + beans	1.3 ± 0.1b	1.4 ± 0.1b	2.9 ± 0.2	2.2 ± 0.1	1.7 ± 0.1	1.6 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	1.3 ± 0.0	1.2 ± 0.0	1.1 ± 0.5	1.1 ± 0.0
Local	2.3 ± 0.5a	1.9 ± 0.4a	2.7 ± 0.2	2.3 ± 0.2	1.6 ± 0.1	1.4 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	1.1 ± 0.1	1.1 ± 0.0
Local + beans	1.7 ± 0.2b	1.7 ± 0.1a	3.0 ± 0.2	2.3 ± 0.1	1.6 ± 0.5	1.4 ± 0.0	1.5 ± 0.1	1.5 ± 0.1	1.3 ± 0.1	1.2 ± 0.0	1.3 ± 0.1	1.2 ± 0.1

Table 4. Disease severities under 2 cropping systems during 1998A

Farmer	MSV Sev.	MSV AUDPC	GLS[b] Sev.	GLS[b] AUDPC	NLB[c] Sev.	NLB[c] AUDPC	DLS[d] Sev	DLS[d] AUDPC	PP[e] Sev	PP[e] AUDPC
Longe	1.44 ± 0.08b	1.34 ± 0.06	2.74 ± 0.13	2.09 ± 0.10	1.88 ± 0.16	1.58 ± 0.08	1.27 ± 0.56	1.26 ± 0.04	1.25 ± 0.03	1.20 ± 0.03
Longe + beans	1.42 ± 0.09b	1.35 ± 0.05	2.50 ± 0.03	2.11 ± 0.08	1.99 ± 0.18	1.83 ± 0.21	1.46 ± 0.16	1.31 ± 0.06	1.43 ± 0.05	1.35 ± 0.04
Local	2.61 ± 0.22a	2.04 ± 0.11	2.84 ± 0.14	2.20 ± 0.10	1.90 ± 0.18	1.51 ± 0.08	1.31 ± 0.05	1.24 ± 0.04	1.40 ± 0.10	1.34 ± 0.06
Local + beans	2.32 ± 0.15a	1.95 ± 0.11	2.64 ± 0.09	2.04 ± 0.09	1.60 ± 0.11	1.40 ± 0.04	1.31 ± 0.10	1.29 ± 0.08	1.40 ± 0.07	1.84 ± 0.04

[a] maize streak virus [b] gray leaf spot [c] northern leaf blight [d] diplodia leaf streak [e] puccinia polysora

Maize streak virus incidence and severity did not seem to increase with time but GLS, NLB rusts and DLS showed a significant increase with time. By the time the last scoring was made all plants had GLS with an average score of 3 . There was more rust (*Puccinia polysora*) in 1998 than in the previous season.

Yield was only obtained on 2 farms during the 1997 season. In all cases the improved variety outyielded the local variety. Higher yields of maize were obtained from a monocrop than in the intercrop (Table 5). During the first season of 1998 yield of maize was obtained from all farms and the trend in performance was the same as that of 1997. Higher yields were got from Byekwaso's farm followed by Kulata. Yield from Mukalazi farm were considerably low. The yield difference can be attributed to soil fertility are reflected by high plant vigor. At Kiseka's farm the problem of termites was most pronounced.

Table 5. Yields (kg/ha) performance of improved and local maize varieties as a monocrop and intercrop with beans

Farmer	Treatment	Yield Kg/ha 1997B	Yield Kg/ha 1998A
	Longe	3347.7 ± 785.5	9312.1 ± 212.8
Byekwaso	Longe + beans	2968.5 ± 950.3	9166.6 ± 1395.6
	Local	1801.7 ± 152.4	7667.9 ± 677.4

Table 5 ***continued***

	Local + beans	1775.0 ± 80.0	6481.1 ± 715.0
	Longe	2916.2 ± 281.2	6960.0 ± 343.7
Kiseka	Longe + beans	2376.1 ± 168.0	4733.9 ± 261.1
	Local	1848.7 ± 125.6	4232.1 ± 530.2
	Local + beans	1927.0 ± 126.0	5060.7 ± 1235.4
	Longe	_____	3529.1 ± 1172.7
Mukalazi	Longe + beans	_____	2615.6 ± 111.9
	Local	_____	2264.3 ± 126.9
	Local + beans	_____	2219.9 ± 32.8
	Longe	_____	7774.3 ± 2084.1
Kulata	Longe + beans	_____	6206.8 ± 1491.9
	Local	_____	7059.4 ± 634.8
	Local + beans	_____	7548.6 ± 139.9

Incidence of Cereal Stemborer Parasitoids and Establishment of *Cotesia flavipes* (Hymenoptera: Braconidae) in Eastern Uganda

Investigators: S. Kyamanywa[1], T. Matama-Kauma[1], J. Ogwanga[2] Namulonge; H. Willson[3]

Collaborating Scientists: C. Omwega[4] and M. Erbaugh[3]

Abstract

Maize productivity in Uganda is constrained by insect pests among other factors. The lepidopterous stalk borers are the most damaging pests on maize in Uganda. A study was conducted in two districts (Iganga and Kumi) of Eastern Uganda to investigate establishment of the exotic parasitiod *Cotesia flavipes* and the impact of both the local and exotic parasitoids on stalk borer population in Eastern Uganda. Results so far obtained indicate that *Chilo partelus* was the dominant stem borer species followed by *B. fusca*. Larval parasitism by a local parasitiod, *Cotesia sesamia* was low (7.7%) and it occurs in very low populations. Therefore if it's to be utilised in the control of *B. fusca*, it requires augmentation. The introduced parastiod, *C.flavipes* had a higher parasitism of 30.3% in Kumi and 7% in Iganga. This suggests that *C. flavipes* is a promising parastiod for *C. partelus*, it is very likely to established in Eastern Uganda.

Objectives

To investigate the establishment of *C. flavipes*, an introduced parasitoid of *C. partellus* in Uganda.

To monitor population dynamics of an indigenous parasitoid, *Cotesia sesamiae*.

IPM Constraint

Maize (*Zea mays* L.) and Sorghum (*Sorghum bicolor* L. Meonch) are the major cereal crops in Africa and in Uganda in particular. However, their production is constrained by insect pests. And the lepidopteran stemborers are generally considered among the most damaging insect pests of maize and sorghum in mainland Africa (Mohyuddin and Greathead, 1970). In Uganda, *C.partellus*, *Busseola fusca*, *Sesamia calamistis*, and *Eldana saccharina* are the most important (Girling, 1978). Of all the stemborers in Africa, with the exception of *C. partellus* (Swinhoe) are indigenous. *C. partellus* is native to Asia and it has now spread to many regions in Africa. Being an exotic pest, therefore renders it a good candidate for classical biological control. This is particularly, because of its cryptic nature, it can not be

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easily accessed by insecticides and cultural practices alone have limited potentials. Consequently, in the early 1970's CIBC attempted to introduce an exotic parasitoid of *C. partellus* in Uganda and Kenya. Most recent surveys in Kenya and Uganda, however, indicated that the exotic parasitoid *C. flavipes* against *C. partellus* did not establish (Omwega *et al.*, 1995). The International Centre for Insect Physiology and Ecology (ICIPE) is once again implementing a biological control program targeted at *C. partellus* in East Africa. This parasitoid has been introduced into several countries, including Uganda (Overholt *et al.*,1994). *C. flavipes* is reported to have already established in Madagascar, and Mauritius (Mohyuddin, 1970) the coastal and South west regions of Kenya (Omwega *et al.*,1995). Therefore, in case of Uganda, the present studies were instituted to monitor establishment of this parasitoid. This is classical biological control aimed at the re-association of the parasitoid *C. flavipes,* with its aboriginal host *C. partellus* (Swinhoe) (Lepidoptera: Pyralidae) from the Indo-Australian region.

Research Methods

A survey was carried out in the districts of Iganga and Kumi in eastern Uganda to monitor the incidence of the indigenous and exotic parasitoids of cereal stem borers. Iganga and Kumi were selected for this study, because pest monitoring under the IPM/CRSP activities, had already been conducted and identified stem borers as a limiting factor to maize/sorghum production. The exotic endo parasitoid *C. flavipes* Cameron (Hymenoptera: Braconidae) was obtained from Pakistan and reared by ICIPE in Kenya. ICIPE then sent live cocoon masses which were introduced into the study areas in collaboration with the National Agricultural Research Organisation (NARO). The first releases were made early 1998 and then in June and July. In Iganga the parasitoids were released in 4 maize farms while in Kumi it was released on 2 maize farms, 1 farm with maize intercropped with sorghum and 3 sorghum farms. Two months after releasing the parasitoid, maize and sorghum plants were randomly sampled and dissected to expose stem borer larvae which were collected, identified and recorded. Larvae in their 3rd to 6th instars and parasitoid cocoons obtained were placed in vials and the larvae were provided with a piece of maize stemor sorghum as diet. The collected larvae were maintained in the laboratory at Namulonge (NAARI) until the larvae pupated, died or parasitoids emerged. The diet was changed every after 3 days. Small larvae were not reared for parasitism to avoid under estimation of parasitism since *Cotesia* spp do not infest 1st and 2nd instars (Overholt *et al.*, 1994). *Cotesia* spp were then identified to species. Identification: *C. sesamiae* and *C. flavipes* were distinguished by examination of the male genitalia (Polaszek and Walker, 1991). The emerged parasitoids were preserved in alcohol and then identified. At least 1 to 4 males from each cocoon mass collected were identified by examining the male genitalia under a microscope.

Results and Discussion

In Iganga, the incidence of stem borer species is shown in table 1. The dominating stemborer species, in the 2nd rains of 1997, was *B. fusca* (Lepidoptera: Noctuidae) at 70% followed by *C. partellus* (Lepidoptera: Pyralidae) at 26% of the larvae collected. *E. saccharina* and *S. calamistis* occurred only in very low populations at 2.94% of total season's collections.

Table 1: Larval counts and % of cereal stem borer complex in Eastern Uganda during the 2nd rains 97 and 1st rains 98

Species	Second rains 97	First rains 98	
	Iganga	Iganga	Kumi
Chilo partellus	82(26.8)	405(66.4)	275(89.9)
Busseola fusca	215(70.3)	191(31.3)	27(8.8)
Sesamia calamistis	2(0.7)	10(1.6)	4(1.3)
Eldana sacharina	7(2.3)	4(0.7)	0

% of each species is shown in the parentheses.

The situation however, changed in the 1st rains of 1998, *C. partellus* became the dominating stemborer at 66.4% and *B. fusca* followed at 31.3% *C. partellus* also was predominant in Kumi taking up 89.9% of the stemborer collected. In Iganga, no egg and pupal parasitoids were encountered in course of sampling. Of the larval parasitoids, *C. sesamiae* was the most common, and attacked both *C. partellus* and *B. fusca*. Generally, C.sesamiae, caused very low parasitism (7.7%) in the 1st season in Iganga (Table 2).

Table 2. Number of larvae (3rd-6th instar collected, parasitised and percentage parasitised and percentage parasitism).

	Second rains 97		First rains 98	
	Iganga		Iganga	
Host species	Sample Size	Numbers Parasitised	Sample Size	Number parasitised
Chilo partellus	38	5(13.2)	249	21(8.4)
Busseola fusca	77	4(5.2)	120	4(3.3)
Sesamia calamistis	1	0.00	1	1(100)
Eldana saccharina	0.00	0.00	4	0.00
Total Parasitism	116	9(7.7)	374	26(7.0)

C. flavipes was encountered only once and this was before its introduction from ICIPE in the second rains of 1997. In the 2nd season however, larval parasitism rose by *C. flavipes* up to 26 larvae parasitised out of 373 larvae collected (7%). In Kumi where data was not collected until after the introduction of *C. flavipes, there was* higher parasitism on only *C. partellus* of about 33.9%. Of all the stemborer species *C. partellus* was the most parasitised

species in both locations. In Iganga where parasitism was recorded on *B.fusca* it accounted for only 1.07% of total parasitism in the second season. *C. flavipes* was the most common in parasitoid both locations (Table 3).

Table 3. Parasitism by *Cotesia flavipes* and *Cotesia sesamiae*

	Number of cocoon masses obtained	
Species	2nd rains 97	1st rains 98
Cotesia flavipes	1	43
Cotesia sesamiae	8	7

Parasitism for the second rains is based on 50 specimen identified out of 100 collected.

Research Results and Discussion

Seasonal fluctuations in *C. partellus* and *B. fusca* populations were observed in Iganga; where in the 2nd rains of 97, *B. fusca* was the dominant species while in 1st rains of 1998 *C. partellus* was the dominant species. The causes of the observation are not clear in Kumi *C. partellus* was predominant. This seem to confirm Ingram (1958), observation who noted that *C. partellus* was the commonest in Eastern Uganda (Kumi) and *B.fusca* wide spread in Southern Busoga (Iganga). Further studies need to be conducted, establish the apparent reversal in abundancy of stem borer species in the two seasons in Iganga. Larval parasitism by the local parasitoid *C. sesamiae*, of *C. partellus*, *B. fusca* and *S. calamistis* was low. Its parasitism only reached 7.7% in the 2nd rains of 1997. Kalule and Ebellu (1994) also observed low parasitism by the local some parasitoid at 2-17% only. This is also in agreement with work by Overholt *et al* (1994), who observed very low parasitism by *C. sesamiae* over a period of 2 years. The recovery of *C. flavipes from C. partellus* before its release by ICIPE. parasitoid was already existing in Eastern Uganda.. The source of this observed *C. flavipes,* was not clear, it could have been from the releases made by CIBC in Uganda (Masindi, Namulonge, Kawanda, Lugazi, Mbale and Serere) in 1968 - 1970. This however does not seem to be true because serious recovery surveys in the 1970s by F. Schulthess (IITA) in 1994 proved fruitful less (Omwega *et al.*, 1995). The second and most probable source is that the parasitoid come from Southwestern Kenya (Mbita) where *C. flavipes* is now established (Overholt *et al.*, 1994). This phenomenon is encouraging as it suggests, in a way, that *C. flavipes* is likely to establish in Eastern Uganda. In the first rains of 1998, *C. flavipes* was recovered and larval parasitism was higher compared to the previous season. This is an indicator that *C. flavipes* is establishing particularly in Kumi where percent parasitism is already high at 30.3%.

Networking Activities

The graduate student, Kauma, visited ICIPE for one week to acquaint herself with identification of *C. flavipes*. ICIPE met the costs. The graduate student, Kauma, attended a two week course in management of stalk borer at ICIPE. The cost was met by ICIPE. The ICIPE reared the parasitoid and exported it to Uganda. The Biological Control Unit of NARO released the parasitoid. Dr. B. Overholt and Dr. C. Omwega of ICIPE visited the study area.

Project Highlights

- *C. partellus* is the most prevalent stalk borer in Kumi.
- Predominancy of either *C. partellus* or *B. fusca* in Iganga appear to vary with season. This needs further investigation.
- The introduced parasitoid of *C. partellus* seems to be establishing.
- The local parasitoid, *C. sesamiae* seems to cause very low parasitism in all the stalk borers species.

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Effect of Seed Dressing and Some Cultural Practices on Bean Fly (*Ophiomyia* sp), Bean Aphid (*Aphis fabae*) and Fusarium Root Rots on Beans in Iganga District

Investigators: S. Kyamanywa[1] and H. Willson[2]

Collaborating Scientists: M. Erbaugh[2] and F. Opio[3]

Abstract

Farm trials in Iganga district were conducted to determine the effect of seed dressing and earthing-up on bean fly incidence and damage. The results indicated that seed dressing and earthing-up significantly reduce bean fly damage and bean root rot. There was an increase in bean grain yield of between 72% and 213% associated with seed dressing. Earthing-up at first weeding resulted in 32% to 36% increase in grain yield. Earthing-up and seed dressing, however, did not significantly influence incidences of bean aphid and bean striped weevils.

Introduction

The bean fly or stem maggot (*Ophiomyia* sp., Agromyzidae Diptera) and bean aphid (*Aphis fabae*, Aphidudae Homoptera) are the most important insect pest of beans in Uganda. The beanfly attacks bean seedling; adults lay eggs on the first leaves. On hatching the larvae enters the leaves, feed towards the root and pupates at the collar. The damage results in disruption of nutrients up take, swelling of the collar, yellowing of leaves. The seedlings may die under severe infestation and environmental stress. The majority of farmers, unfortunately associate the yellowing symptoms with poor soil fertility and drought stress. Consequently, they do not take action. *Ophiomyia* sp. cause severe losses ranging between to 30% to 72%. In the IPM/CRSP trials of first rains of 1997, it was observed that seed dressing with endosulfan reduced the damage due to *Ophiomyia* sp. and increased bean grain yield by 34 to 75 % on farmer's fields. This trial was repeated in second rains of 1997 and first rains of 1998 and earthing up was added on as a treatment.

Objectives

1.) To compare the effects of earthing-up and seed dressing with farmer's way of growing beans on beanfly damage.

2.) To determine the effect of seed dressing and earthing up on incidence of bean aphid (*Aphis fabae*), striped weevil (*Alcidodes leucogrammus*), and bean root rots.

Research Methods

The study was conducted during the second rains of 1997 (October to December) and first rains of 1998 (April to June) in Baitambogwe and Bulamagi sub counties of Iganga District. Six farmers, three from each sub county, were selected. The treatments included: (1). Seed untreated and grown as sole crop. (2). Earthing-up (ridging) at first weeding in a sole crop. (3). Seed dressing with Endosulfan. (4). Seed dressing and earthing-up at first weeding. (5). Seed dressing and intercropping with maize. In the seed dressed treatments, bean seeds were mixed with Endosulfan (a. i35 w/u) at a rate of 10 ml in two litres of water for 20 kg bean seed. Each treatment was planted in plots of size 8m x 10m. All the treatments were replicated two times on each farmer's field. To minimise variations between farmers, the same variety K-132 and the same bean spacing of 50 cm between and 20 cm within rows were used by all farmers.

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The planting was done on 24/10/97 and 19/4/98 for the second and first rains respectively. The farmers maintained the trials, while the data were collected by scientists from Makerere University and Namulonge Agricultural and Animal Research Institute (NAARI). In both seasons data collection started at 2 weeks after bean emergence and continued at 2 weekly intervals for two months. The data collected included:

- Number of plants with yellowing symptoms per 20 plants selected at random.
- Number of bean plants damaged by beanfly per 20 plants up rooted at random.
- Number of bean plants with root rot damage per 20 plants up rooted at random.
- Number of bean plants affected by bean aphid per 20 plants.
- Grain yield at harvest determined from 2 x 2 metre quadrants.
- Number of pupae per 10 plants determined by counting pupae on up rooted plants.

Research Results and Discussion

Effect of seed dressing and earthing up on pest damage. Seed dressing with Endosulfan and Earthing-up significantly affected bean fly incidence and damage (Table 1). The proportion of plants with leaf yellowing symptoms was highest in non-seed dressed plots, followed by earthing-up and least in seed dressed plots. The differences between plots with seed dressing, however, were not significantly different from each other. The proportion of plants damaged by bean fly in the second and first rains, of 91 and 85% respectively, was highest in non-seed dressed plots followed by the earthed-up plot and least in seed dressed plots. The same trend was observed for bean fly pupae population density. In general, seed dressing reduced plants showing yellowing symptoms, by 75% and 99% in the second rains and first rains respectively. Proportion of bean plants damaged due to bean fly in seed dressed plots was reduced by 99% and 89% in the second and first rains respectively. Earthing-up reduced bean fly damage by 19 and 15% in the second and first rains respectively. The incidence of plants damaged by bean fly depended (Table 2) on the seasons and location. In the second rains of 1997, bean fly damage and pupae density were significantly higher in Bulamagi than in Baitambogwe, while in first rains of 1998 the reverse occurred.

Table 1. Effect of seed dressing and Earthing-up on Bean fly damage averaged over sub counties

	% Plants showing leaf yellowing		% Plant damaged by bean fly		No. of Bean fly pupae per 10 plant	
Rain season	2nd 1997	1st 1998	2nd 1997	1st 1998	2nd 1997	1st 1998
Not seed dressed seed	5.8 ± 6	26.6 ± 26	91.4 ± 11	85.3 ± 14	34.1 ± 17	19.3 ± 11
Earthing-up	4.7 ± 5	21.9 ± 21	90.7 ± 14	72.8 ± 22	31.0 ± 14	205 ± 13
Seed dressed + Earthing-up	1.4 ± 4	2.2 ± 4	0.4 ± 2	9.1 ± 11	0.00 ± 0	0.1 ± 0.3
Seed dressed + intercropping	2.3 ± 4	---	0.0 ± 0	---	0.00 ± 0	---
Not seed dressed + intercropping	---	20.9 ± 20	---	82.8 ± 19	---	17.6 ± 11
P-valve	0.0001**	0.00001**	0.0000**	0.0000**	0.000**	0.0000**
CV	63.5%	35.0%	19.09%	19.8%	17.56%	26.2%

** = highly significant.

Table 2. Incidence of bean fly damage in Baitambogwe and Bulamagi sub counties averaged over treatments

	2nd rains 1997		sub county p-value	1st rain 1998		sub county p-value
	Baitambogwe	Bulamagi		Baitambogwe	Bulamagi	
% plants yellowing	2.8 ± 5	3.4 ± 5	NS	27.2 ± 22	2.7 ± 4	0.000***
% plants damaged by BF	34.0 ± 42	39 ± 48	0.000**	53.6 ± 43	57.7 ± 31	NS
No. BF pupae/10 plants	122.5 ± 16	13.5 ± 21	0.000**	17.9 ± 15	5.1 ± 6	0.000**

NS = Not significant; ** = Highly significant.

Table 3 shows results of the effects of seed dressing and earthing-up on incidences of bean aphids, fusarium root rot and bean striped weevil. Seed dressing significantly reduce incidence of bean aphid in the second rains. In the first rains of 1998, however, the influence was not significant. In both seasons, seed dressing significantly reduced the damage due to fusarium root rot. Seed dressing, however, did not significantly affect the incidence of striped bean weevil. Incidence of bean aphid and striped weevil depended on location (Table 4).

Table 3. Influence of seed dressing and earthing-up on aphid, fusarium, stripped weevils and root rot incidence averaged over sub counties.

	% plants with *Aphis fabea*		% plants with root rot		% plant with striped weevils	
	2nd rains 97	1st rains 98	2nd rains 97	1st rains 98	2nd rains 97	1st rains 98
Not seed dressed	6.5 ± 10	20.6 ± 23	2.8 ± 5	23.1 ± 21	0.9 ± 3	4.3 ± 6
Earthing-up	4.3 ± 8	21.3 ± 25	4.0 ± 6	18.7 ± 14	0.3 ± 1	5.0 ± 8
Seed dressed	2.5 ± 5	23.7 ± 23	1.2 ± 3	4.3 ± 8	0.0 ± 0	2.5 ± 5
Seed dressed + Earthing	2.1 ± 6	---	0.6 ± 2	---	0.0 ± 0	---
Seed dressed + Intercropping	0.6 ± 2	19.4 ± 22	0.3 ± 3	9.3 ± 13	0.3 ± 1	1.2 ± 3
Not seed dressed + intercropping	---	13.7 ± 20	---	9.3 ± 10	---	1.8 ± 5
P. Value	0.0005**	0.164NS	0.0016**	0.0002**	0.298NS	0.1044Ns

Table 4. Incidence of bean aphid, fusarium root rot and striped weevils in Baitambogwe and Bulamagi sub counties averaged over treatments

	2nd rains 1997		P-value for sub counties	1st rains 1998		P-value for sub counties
	Baitambogwe	Bulamagi		Baitambogwe	Bulamagi	
% plants with Aphid	5.0 ± 8	1.5 ± 5	0.0001**	38.0 ± 20	1.5 ± 4	0.0000**
% plants with root rot	2.0 ± 4	1.6 ± 4	NS	14.2 ± 19	11.7 ± 11	NS
% plants with striped weevils	0.5 ± 2	0.1 + 1	0.253NS	4.7 ± 7	1.2 ± 4	0.0013**

Effect of seed dressing and earthing-up on bean yield. Seed dressing and earthing-up significantly increased grain yield of beans (Table 5). Seed dressing alone resulted in 213 and 72% increase in grain yield in the second and first rains respectively. Similarly, earthing-up increased grain yield by 32 and 36 % in the second and first rains respectively.

The results of three seasons (1st and 2nd rain 1997 and 1st rains 1998) trials have clearly demonstrated that seed dressing reduced the incidence of bean fly damage and bean root rots, resulting in bean grain yield increase of between 34% to 200% increase in bean yield. Economic analysis has indeed indicated that this practice is cost effective. Furthermore, seed dressing would appear to be environmentally friendly because very little is added to the environment, and above all the method is targeted. Environment safety of using seed dressing may further be improved by selecting less persistent insecticides. Future trials will look at safer seed dressing chemicals.

Table 5. Effect of seed dressing and earthing-up of grain yield of bean in Baitambogwe and Bulamagi sub counties

	2nd rains 1997			1st rains 1998		
	Baitambogwe	Bulamagi	Treatment mean	Baitambogwe	Bulamagi	Treatment mean
Not seed dressed	1500 ± 204	875 ± 322	1187 ± 417	1062.5 ± 218	368 ± 106	715 ± 403
Earthing-up	1938 ± 515	1187 ± 314	1562 ± 562	1460.9 ± 444	484 ± 285	972 ± 626
Seed dressed	4437 ± 554	3000 ± 1190	3718 ± 1152	1968.7 ± 148	490 ± 190	1229 ± 805
Seed dressed + earthing	3875 ± 520	2812 ± 1106	3343 ± 981	---	---	---
Seed dressed + intercropping	1500 ± 204	1000 ± 408	1250 ± 400	820 ± 204	328 ± 111	574 ± 313
No seed dressing + Intercropping	---	---	---	585 ± 93	306 ± 108	446 ± 240
Sub county mean	2650 ± 1341	1775 ± 1177	---	1179 ± 560	395 ± 174	---
P-value	0.0008***		---	0.0008***		---
% increase due to seed dress	196%	242%	213%	85%	33%	72%
% increase due to earthing-up	29.2%	35%	32%	37%	32%	36%

Earthing-up reduced bean fly damage and resulted in between 32% to 37% increase in yield. The result suggests the need to include earthing up among the recommendation for reducing impact of bean fly on bean grain yield.

Impact

Bean grain yields from seed dressed plots on farmers' field were very high compared to the untreated ones that some farmers in the groups have adopted seed dressing technology. What is left is to increase the rate of diffusion of this technology. Furthermore, there is need to look for better seed dressing materials. Adoption of this technology on large scale is likely to boost bean production in the region, leading to reduction in malnutrition and poverty.

Networking Activities

- One day meeting of Uganda IPM Network was organised in November 1997 in which IPM/CRSP activities were discussed.
- An open day was organised in June 1998 in Baitambogwe and Bulamagi sub counties. Over 50 farmers, from each sub county, participated and were able to see the difference in bean fly damage between seed dressed, earthing-up and non-seed dressed plots.
- Produced brochures on bean fly damage and its control.

Publication and Presentation

Kyamanywa- S., H. Willson, F. Opio and M. Erbaugh (1998): The effect of seed dressing and earthing-up on bean fly (*Ophiomyia sp*) and other pests of bean. Proceeding of IPM/CRSP symposium Virginia Tech.

Kyamanywa. S, A. Katwijukye and F. Opio (1998): Pest management in beans, a profitable venture in Uganda: A paper present at Faculty of Agriculture and Forestry Conference and will be published in the Faculty Bulletin.

Project Highlight

- Seed dressing against bean fly increased bean grain yield by 30% to 200%.
- Seed dressing reduced the incidence of bean root rot.
- Earthing-up reduced the impact of bean fly damage on grain yield by 33 to 37%.
- Farmers were introduced to IPM methods of controlling bean fly damage.

Influence of Minimum Insecticide Application on Insect Pest Populations and Yield of Cowpeas in Kumi District

Investigators: S. Kyamanywa[1], A. Ekwamu[1], and J. Karungi[1]

Collaborating Scientist: H. Willson[2]

Abstract

Insect pests are a major constraint to cowpea production in Kumi. To mitigate against the pest problem, many farmers use insecticides, applied up to over 8 times in cowpea growing season (3-4 months). This level of application is not only expensive but also harmful to the user and environment. Hence the need to reduce frequency of application. IPM/CRSP on-farm trials were therefore conducted, to evaluate different spray regimes against the major insect pest of cowpeas. Four spraying schedules were compared against an unsprayed control. The results indicated spraying at the vegetative stage significantly reduced aphid infestation but had a low marginal return. Single spray at flower initiation, flowering and podding reduced thrips, maruca and pod sucking bugs and had the highest marginal returns. This spray is considered as a minimum insecticide regime for controlling pests of cowpeas in Kumi.

Objective and IPM Constraints

Participatory appraisal conducted in Kumi indicated that insect pests were a major constraint to cowpea production in Kumi District. Early studies indicated that *Aphis fabae, Maruca testulalis* and pod sucking bugs are the most important pests of cowpea in Kumi. Consequently some farmers over (20%) apply between 8 and 10 sprays per season. Although this spray program gives immediate results, it is hazardous both to the user and environment can

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not be encouraged. There is, therefore, a need to reduce frequency of chemical sprays on cowpea in Kumi. This could be achieved by determining the critical stages of cowpea growth which require protection in order to minimise yield loss. The objective of this study therefore was to determine the influence of minimum insecticide application on cowpeas pest and yield.

Research Methods

On farm trials were conducted at in Kumi District Eastern Uganda in short rains of 1997 (August-November) and long rains of 1998 (March to June). Planting was done on 28 July 1997 and 24 April 1998. A local cowpea variety, Ebelat was used in the study and was planted at a spacing of 60 cm and 20 cm between and within rows respectively.

The following treatments were used: (1) No insecticide applied; (2) Insecticide applied weekly for five weeks in the vegetative stage, starting 10 days after planting (DAP); (3) Insecticide applied thrice, once at vegetative, flowering and podding stages, that is at 20, 45, and 55 DAP; (4) Insecticide applied 3 times; once at budding, flowering and podding stages i.e 30, 45, 55 DAP; (5) Farmers' insecticide spray regimes of applying insecticides at weekly interval through out the crops' growing season (8 times) starting 10 DAP.

The cowpeas were planted in plots of size 3 x 3 metres separated by 2 m in a complete block design with 3 reps. A cock tail mixture of cypermethrin (600g ai/ha) a contact insecticide directed at *Aphis craccivoro, Megalurothrips sjostedti* and *Maruca testulalis*, and Dimethoate 200g ai/ha, a systemic insecticide directed at the pod sucking, were used in the above treatments.

Data was collected *on A. craccivora, M. testulalis M. sjostodti* and pod sucking bugs. *A. craccivora* population densities were estimated using a visual scale of 1-6 where 1 = no aphids, 2 = 100 aphids, 3 = 100-300 aphids, 4 = 300-600 aphids, 5 = 600-1000 aphids and 6 = >1000. Assessment was done at 10 days interval starting 10 days after crop emergence (DAE). *M. sjostedti* population density was estimated by counting nymphs and adults on 20 flowers randomly picked from each plot. *M. testulalis* population density was estimate by counting the larvae in 20 flowers selected at random per plot.

Population densities of pod sucking bugs were estimated per plot starting, starting at 50 DAE, by moving carefully between rows and counting nymphs and adults observed. At maturity, dry pods on all plants in each plot were harvested and grain weight recorded. The data were subjected to analysis of variance using the Gen stat computer package. The costs associated with different spray regimes were estimated and marginal returns (MR) calculated.

Research Results and Discussion

The different spray regimes significantly affected population densities of *A. cruccivora, M. sjostedti, M. testulalis* and pod sucking bugs (Table 1). Aphids infestation was highest in the untreated plots and in plots which were sprayed 3 times after flower bud initiation lowest. The least aphid infestation was in plots sprayed weekly throughout the crop growing season and in plots spread weekly in the vegetative stages. Similarly, spraying at flower bud formation onwards was as effective as spraying through-out, in controlling thrips population density. Spraying cowpea during vegetative stages only significantly increased thrips population density compared to the control.

Table 1. Influence of different insecticide spray schedules on insect population densities and grain yield averaged over two seasons

	% Plants showing leaf yellowing		% Plants damaged by bean fly		No. Of Bean Fly Pupae per 10 Plants	
Rain Season	2nd 1997	1st 1998	2nd 1997	1st 1998	2nd 1997	1st 1998
Not Seed Dressed	5.8 +/-6	26.6+/-26	91.4+/-11	85.3+/-14	34.1+/-17	19.3+/-11
Earthing-up	4.7+/-5	21.9+/-21	90.7+/-14	72.8+/-22	31.0+/-14	205+/-13
Seed dressed + Earthing-up	1.4+/-4	2.2+/-4	0.4+/-2	9.1+/-11	0.00+/-0	0.1+/-0.3
Seed dressed + intercropping	3.2+/-4	---	0.00+/-0	---	0.00+/-0	---
Not seed dressed + intercropping	---	20.9+/-20	---	82.8+/-	---	17.6+/-11
P-valve	0.0001**	0.0001**	0.0000**	0.000**	0.000**	0.000**
CV	63.5%	35.0%	19.09%	19.8%	17.56%	26.2%

** = highly significant

Spraying throughout the crop cycle or starting at flower bud iniation stage onwards significantly reduced *Maruca* larvae per flowers. There were significantly more *Maruca* population in plots sprayed in the vegetative phase than the

un sprayed one. For pod sucking, spraying in vegetative stage only, resulted in significantly higher infestation than un sprayed control. Furthermore spraying continously and in podding stage did not significantly reduce pod sucking bug population compared to un sprayed control. Spraying in vegetative stage alone did not significantly increase cowpea grain yield compared to the control. Similarly there was no significant difference in grain yield between plots sprayed continously for 8 times and those sprayed three time starting at flower bud initiation. Nevertheless grain yield was highest in continously sprayed plots. Plots sprayed 3 times at flower initiation, flowering and podding had the higest returns (Table 2) Consequently, it is considered as being a minimum pesticide application regime compared to what the farmers were using.

Table 2: Marginal returns for different insecticide spray schedules averaged over season

	Grain yield kg/ha	Yield grain kg/ha	Marginal returns
No spray (control)	268.0	---	---
Sprayed 5 times in vegetative phase	590.1	322.0	0.28
Sprayed 3 times once in vegetative, flower and podding	983.7	715.8	1.01
Spraying 3 times 2 in flower and once in podding	1293.3	1025.3	1.44
Sprayed 8 times at weekly intervals	1561.5	1293.5	0.73

Impacts

Farmers have observed that more than three sprays were uneconomical. It is hoped that adoption of this information will result in reduced pest application in the District. Furthermore, adopting this spray regime would ensure farmer eat the leaves which have not been exposed to insecticide sprays and hence reducing health hazards.

Highlights

- Spraying in vegetative phase does not significantly increase cowpea grain yield
- Spraying 8 times in seasons resulted in similar grain yield as spraying 3 times, once at flower initiation, flowering and podding
- Highest marginal return were in plots sprayed 3 times starting at flower intiation than those sprayed 8 times in a season.
- Spraying 3 times once at flower initiation, flowering and podding is consisdered a minimum insecticide application regimes for cowpeas.

On-farm Post-harvest Management of Bruchids in Beans and Cowpeas

Investigators: J. Agona[1], S. Nahdy[1], S. Kyamanywa[2], and H. Willson[3]

Collaborators: F. Owera[1] and H. Muyinza[1]; Farmers of Baitamboque and Bulamagi in Iganga District and Malera and Bhukadea in Kumi District

Abstract

Seven post-harvest treatments of common beans, *Phaseolus vulgaris* L., including three botanical treatments (Mexican marigold , lantana, and tobacco), an ash treatment, a solar heat treatment, Actellic (chemical control), and an untreated control were evaluated on farm stored beans to prevent damage by bruchids, *Acanthoscelides obtectus* Say and *Zabrotes subfasciatus* Boh.. After three months of storage, significant differences in bean damage by bruchids were observed among treatments. Bruchid damage to beans treated with Actellic, tobacco, and solar heat was significantly less than that observed in beans treated with ash, marigold, lantana, and the untreated control. The lowest level of damage was 0.35% in beans treated in a solar dryer utilizing layers of black and clear plastic. The highest level of damage of 19.6% in beans treated with ground latana. Bruchid damage in the chemical control

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(Actellic) and untreated control were 2.75% and 15.7% respectively. Test of germination after three months of storage demonstrated a significant difference between that of the solar heat treatment (50%) and the other six treatments, in which germination ranged from 81.1% to 90.2%. Based on preliminary results, the solar heat treatment can be recommended as an effective treatment of post-harvest beans to reduce bruchid injury, but not for seeds due to a loss in germination. In the case of beans for seed, the tobacco treatment provides an alternative having a level of efficacy equivalent to the use of Actellic.

Objectives

To evaluate the efficacy of bio-rational botanical treatments, ash, and a solar heat treatment in comparison to a synthetic chemical, Actellic, and an untreated control for prevention of bruchid damage in stored beans.

IPM Constraints

Bruchid damage to stored beans and cowpeas is a significant problem impacting post-harvest operations of Uganda farmers. Use of approved chemical pesticides as post-harvest protectant is effective, but considered to be expensive for widespread use. Investigation of bio-rational non-chemical treatments to provide alternative options for protecting stored beans and cowpeas against losses due to bruchid damage.

Research Methods

This study was initiated following the harvest of beans of the first rainy season of 1997 in Iganga District. Seven Kg of beans were obtained each of ten participating farmers for evaluation of the seven treatments. At each farm household, beans were bulked and sampled by coning and quartering into one Kg units for treatment. Botanical treatments of marigold, lantana and tobacco were prepared from dried fresh leaves, ground into powder, and applied at the rate of 2% w/w. The ash treatment used ash from farmers' kilns and applied at a rate of 2% w/w. The Actellic (1% a.i.) was applied at a rate of 0.5 g per Kg of beans. The solar heat treatment included two hours of solar drying of beans placed in a shallow pit of black plastic covered with clear plastic on a monthly schedule. Treated and untreated beans were placed in muslin-cotton bags and stored in the farmers' households. Samples of each treatment were drawn monthly and returned to the lab for determination of percent beans exhibiting emergence holes. After three months of storage, beans were tested for moisture content and germination. An equivalent study has been conducted in Kumi District on cowpeas in 1997, but the results have not been compiled in time for this report. A second trial on beans harvested in the first rainy season of Iganga District in 1998 is underway.

Results and Discussion

Significant differences ($p<0.05$) in bruchid injury to beans were found among treatments. Bruchid damage in beans treated with tobacco and solar treatments were not significantly different from that of the Actellic treatment. In contrast, bruchid damage in beans treated with ash, marigold, and latana treatments were not significantly different from that of the untreated controls. Thus, solar and tobacco treatments are as effective as the use of an synthetic chemical grain protectant, but ash, marigold, and latana treatments were not effective for prevention of bruchid damage. In the evaluation of bean germination, seed viability generally decreased as bruchid infestation increased. However, germination of the beans subjected to solar heat treatment was significantly less than that of the other five treatments and the untreated control. Thus, the solar heat treatment for prevention of bruchid damage to beans should not be applied to beans stored for seeding. However, the tobacco treatment may be regarded as a useful alternative treatment to Actellic for seed beans since it does not affect germination.

Impacts

The effective treatments (Actellic, tobacco and solar heat) reduce bruchid infestation from 16% to less than 3% resulting in improved food quality. In the case of seed viability, tobacco and Actellic treatments improve germination ca. 15%.

Table 1. Effects of treatments on bruchid infestation of stored beans.

Treatment	Percent Bean Injury @ Months After Treatment (MAT)			Germination %
	1 MAT	2 MAT	3 MAT	
Actellic	2.30	2.47	2.75	90.22
Ash	1.70	4.27	13.85	81.11
Marigold	2.20	12.69	19.05	83.33
Latana	2.35	8.59	19.65	82.89
Tobacco	0.85	1.40	1.85	88.00
Solar Heat	0.20	0.04	0.35	50.00
Untreated	1.65	6.02	15.70	81.79
CV (%)	119.82	177.88	155.26	25.40
SED (43 d.f.)	0.86	4.03	7.07	9.53

Networking Activities

This project represents a collaborative effort among the post-harvest research team at the Kawanda Agriculture Research Station, Makerere University, Ohio State University, and farmer groups in Iganga and Kumi Districts.

Publications & Presentations

Publication is anticipated following completion of trials under implementation.

Training Output

Farmers participating in the study have observed the results of the experiment. Results of the experiment have been reported in field days conducted by the IPM CRSP program in Iganga and Kumi districts.

Project Highlights

Solar heat and tobacco treatments, to date, has been demonstrated as effective methods for prevention of bruchid damage in stored beans comparable in efficacy to application of Actellic as a preventive treatment. Since solar heat treatment has a negative effect on bean germination, this treatment should be limited to beans used for food consumption. Since tobacco treatment does not have a negative effect on bean germination, this treatment may be a useful treatment for seed beans.

Understanding Farmer Knowledge of Cowpea Production and Pest Management in Eastern Uganda

Investigators: M. Erbaugh[1] and P. Isubikalu[2]

Collaborating Scientists: A. Ekwamu[2], S. Kyamanywa[2], and A. Semana

Abstract

Goal preference, as indicated by the level of market participation, influences the choice of production practices, including pest management practices, used to grow crops. Many farmers in Eastern Uganda are now producing cowpea (*Vigna unguiculata (L.)* Walp.) for cash markets. Traditionally, cowpea was grown almost exclusively as a food crop. The purpose of this investigation is to examine the influence of differing production goals on local (indigenous) knowledge regarding cowpea production and pest management practices. A case study investigation of 18 cowpea producers was initiated during the second season 1997 in 3 districts in Eastern Uganda. Production goal influenced cowpea acreage, varietal choice, seasonal planting, perception of problematic pests, and stage and frequency of pesticide application. Farmers preferred to use pesticides as the primary method of pest control because they insured a marketable crop, were associated with yield increases, permitted two season cropping, and reduced demand for labor at key times during the cropping season. They were used by all farmers except two subsistence producers who claimed their local variety did not require pesticides. The only limitations on pesticide use were local availability and cost. Local knowledge of alternative methods for controlling pests besides the use of pesticides included early planting, varietal choice, weeding, leaf picking and intercropping. Farmers were generally not aware or knowledgeable about cowpea diseases. Future research should seek to introduce resistant varieties; investigate efficacy, timing and rate of pesticide application; and, educate farmers regarding proper pesticide use and safety.

Objectives

1. To investigate farmer knowledge of cowpea production and pest management practices in Eastern Uganda.

2. To examine the influence of farmer production goals on production practices and pest management of cowpea.

3. To identify knowledge gaps in pest management practices that might be added to future research and development of an IPM package for cowpea.

IPM Constraints

Two previous surveys of cowpea growers in Eastern Uganda documented the increasing use of pesticides in the production of cowpea (Erbaugh and Kyamanywa, 1997; Sabiiti, 1995). Additionally, both of these surveys indicated that many farmers were now producing cowpea for cash markets as opposed to its former role as primarily a food crop. Alternative pest control practices including IPM are

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not known in Uganda and have only recently begun to receive attention from agricultural research organizations. The development of an IPM system hinges upon enhanced knowledge of farmer production and pest management strategies and rationales. Since farmers co-evolved with cropping systems, their cumulative knowledge and experience pertaining to cowpea production represents a potential source of valuable information and a foundation upon which to build IPM interventions. To date in Uganda, a comprehensive exploration of farmer knowledge regarding cowpea pests and management is lacking and has impeded the development of viable pest management alternatives.

Research Methods

A multiple case study that included cases from the districts of Pallisa, Kumi and Katakwi was initiated in 1997. These three districts represent some of the major cowpea growing areas of the country. "How and why" questions pertaining to cowpea production and pest management dictated the use of a case study approach in order to provide an in depth understanding from the farmers perspective of the relationship between production goals and practices. Three categories of cowpea farmers were designated. The categories included those growing the crop mainly for cash markets (commercial); growing primarily for home consumption (subsistence); and, those growing for cash markets and home consumption (dual purpose). Farmers in each category were selected based on previous surveys, interviews with knowledgeable local extension agents, and other local informants. The main criterion used to select farmers was their "representativeness" of a particular production category. Meetings were held with selected farmers to explain study objectives, and to obtain their consent and participation in fieldwork. A total of 18 cases were eventually selected. Theoretical propositions and a case study protocol were developed prior to fieldwork. Data was collected using interviews, direct observation and participant observation. All field work was conducted by Makerere University graduate student Prossy Isubikalu over the course of four growing seasons.

Research Results

Differences in farmer production goals influenced production practices, perceptions of priority pests and pesticide application (Table 1).

Table 1: Production Goals and Cowpea Land Use

Production Goal	Commercial	Dual Purpose	Subsistence
Land Use			
Land Owned	17.33 ha.	7.00 ha.	4.80 ha.
Land in Crops	7.50 ha.	3.30 ha.	3.25 ha.
Land in cowpea	2.40 ha.	0.90 ha.	0.56 ha.
Total farmers	6	6	6

All figures represent averages for farmers by production goal categories.

All farmers except two subsistence farmers in Katakwi relied on pesticide spraying as the primary pest control strategy. Analyzing the relationship between production goal and socioeconomic background was not an objective of this study, however, summary descriptive data presented in Table 1 appears to indicate a relationship between land resource base and commercial goal orientation of cowpea growers.

Differences in Production Practices by Production Category

Varietal Selection: Three varieties of cowpea were identified as being grown in this study: Icirikukwai (semi-spreading, indeterminate), Ebelat (erect, determinate) and a black seeded variety called Kenyan. No improved cowpea cultivars were recorded in this study nor have they been encountered in survey reports. Icirikukwai was only grown in one district solely for local consumption of leaves and grain. Kenyan was grown solely for sale in Kenya because local farmers do not prefer the leaves nor the sauce produced by this variety and because of its higher market value when sold in Kenya. Ebelat was grown by both subsistence, dual purpose (transition) and commercial farmers. Three of the farmers were growing both Ebelat and Kenyan varieties. The market value for Icirikukwai was less than the other two varieties: Icirikukwai = 800 Ug.Sh./Kg; Ebelat = 1350 Ug.Sh./Kg; and, Kenyan = 2500 Ug.Sh./Kg. Explanations for the low market value of Icirikukwai were that it produced a small seed, took longer to cook and had low yield potential. As one farmer commented, "In order for one to get better and more profits, it is better to sell fewer things and get more, than selling more and getting less".

Farmers indicated that they needed to spray both Ebelat and Kenyan varieties in order to obtain a crop. According to commercial farmers who produced Kenyan, this variety required frequent spraying. Farmers indicated that they did not spray Icirikukwai, thus potentially indicating that this variety may contain some natural resistance to local pests and diseases. The additional costs for purchasing and applying insecticides coupled with the transportation costs for selling the Kenyan variety in external markets explain why this variety was only grown by commercial farmers. Thus, varietal choice appears to depend on production goal and locality.

All cases broadcast seeded their cowpea, and all cases except two commercial farmers purchased seed for planting. Farmers said they relied on seed purchases for cowpea because they were unable to store it for longer than three months because of the cowpea bruchid (*Callosobruchus maculatus*). The only exceptions to this commonly held perception were two commercial farmers who stored cowpea with malathion or atelic, and two subsistence farmers who grew the variety Icirikukwai. These subsistence farmers indicated that this variety was less affected by the cowpea bruchid.

Seasonal planting: Traditionally, cowpea was only grown during the second season (short rains). In the traditional rotation it followed the harvest of first season finger millet. All farmers in this study grew cowpea during the second season. However, 13 of 18 farmers grew cowpea during both seasons. None of the farmers in this study grew cowpea only during the first season (long rains). The reasons farmers gave for preferring the second season were: the first season had heavier pest pressure; constrained labor supply during first season due to production of millet, groundnuts, cassava and sorghum; and, heavier first season rains produced too much vegetative growth, delayed seed ripening and reduced grain yields. Several reasons were provided for growing cowpea during both seasons: to insure a constant supply of food (leaves and grain); to insure cash flow; to provide seed for the second season; and, according to several farmers "cowpea can now be grown anytime as long as it is sprayed". Commercial and dual purpose growers were more likely than subsistence producers to be growing cowpeas during both seasons because they had the resources to purchase seed, insecticides, labor and depended on the cash and food generated by the crop.

Seven farmers (5 being subsistence farmers) who grew cowpea only during the second season said that pest pressure and labor demands for other crops were less, and that they could not afford to purchase seed and pesticides. In reference to pest pressure subsistence farmers specifically mentioned that there were fewer foliage beetles during the second season. Since subsistence farmers were more dependent on cowpea leaves as a food source and less able to afford pesticide purchases their concern with foliage beetles appears to be rationale.

Planting date: Early planting is recognized by most farmers as a key factor in moderating aphid damage on cowpea. However, several factors impeded the capacity to plant early. First, weather patterns are more erratic than they used to be, and thus reliance on traditional planting dates less dependable. Second, lack of labor, particularly during the first season, makes early planting more difficult. In order to stretch labor supply several farmers relied on relay planting of cowpea. Relay planting also prolongs the availability of leaves and reduces the risk of total crop loss due to unpredictable climatic conditions. Relay planting also provides a continuous supply of food and habitat for insect pests.

For the first growing season, April-June, planting in April is considered early planting. For the second growing season June-September, June is considered early planting. Commercial and dual purpose farmers were more likely to have planted early than subsistence farmers.

Leaf Harvesting: Cowpea leaves are harvested prior to flowering to make a spinach sauce. After flowering, leaves lose desired texture and palatability. All farmers harvested leaves, however, only two farmers (one commercial and one dual purpose) harvested leaves and sold them in local markets. Farmers believed that leaf picking also increased yields and reduced pests. According to farmers, foliage beetles and pod borers were attracted to dense leaf canopies, and reducing the leaf canopy through leaf picking, exposed pests to sunlight and improved the performance of pesticide applications.

Most farmers waited 3-5 days following pesticide application to pick leaves. Several farmers picked leaves and then sprayed; however, several women growers indicated that they picked leaves immediately following spraying because of "hunger and poverty".

Weeding: All farmers weeded only once but commercial farmers weeded one to two weeks earlier than dual purpose and subsistence farmers. Late weeding was attributed to lack of labor. In addition to recognizing the beneficial effects of weeding on plant health and yield, 4 commercial farmers preferred earlier weeding because they thought that weeds created an environment that harbored pests, particularly foliage beetles, and that weeds wasted pesticides.

Cowpea cropping system: Most farmers commonly grew cowpea in an intercrop with cassava or maize during first season. Three commercial farmers and one dual purpose grower sole cropped cowpea indicating an influence of production goal on cropping system. The main reasons provided by farmers for intercropping was to diversify food source, to keep fields in continuous production, and to maximize labor inputs. Only one farmer expressed awareness that intercropping reduces pest infestation, particularly of maruca and thrips. This is consistent with finding by Omongo *et al* (1997). Traditionally cassava is the last crop in the rotation. Farmers believe that cassava "rests the fields". Commercial farmers were less interested in intercrops because they believed it lowered cowpea plant population and their cash return. This was more pronounced during the second season in which all commercial cases sole cropped their cowpea.

Perception of Priority Pests

Farmers indicated that aphids (*Aphis craccivora*), Maruca (*Maruca testulalis & vitrata*) and different pod sucking bugs (Heteroptera) were the three most important pests. Other insect pests often mentioned by cases were foliage beetles (*Ootheca mutabilis*), flower beetles (*Mylabris* spp.) and thrips (*Megalurothrips sjostedti*). Aphids were considered by most farmers to be the most important pest of cowpea particularly at the vegetative stage prior to flowering. Subsistence farmers growing cowpea primarily for leaf harvest ranked foliage beetles as the most important pest. Only four commercial growers of cowpea indicated thrips as an important pest specie. Only four farmers (2 commercial) recognized thrips as pests and were familiar with damage they caused.

In general, commercial farmers were more concerned with seed eating insects (pod borers and suckers), while subsistence cases considered leaf eating pests to be more important, reflecting the differing production priorities of the two different categories of producers.

Pest Management

All farmers except two subsistence farmers in Katakwi relied on pesticide spraying as the primary pest control strategy. The farm perception that cowpea yield is enhanced by pesticide application is explained by comparing Tables 2 and 3. Commercial farmers who sprayed more frequently had higher yields than did the other two production categories. Farmers' stated belief was that the more they sprayed the better their yields would be. One farmer stated, "that it is hard to spray cowpea too much".

Table 2: Average Yields by Production Goal Categories

Production Goal	Commercial	Dual Purpose	Subsistence
Yields (Kg/Ha)	766	375	162

All figures represent averages for farmers by production goal categories.

Commercial cowpea growers commenced spraying earlier and they also sprayed more frequently than did transition and subsistence growers (Table 3).

Table 3: Cowpea stage at first spraying and frequency of application.

Stage (Weeks)	Commercial	Dual Purpose	Subsistence	Total
Not spraying	-	-	2	2
1-3	5	3	-	8
3.5-5	1	3	1	5
5.5-8	-	-	3	3
Total	6	6	6	18
Frequency				
Not spraying	-	-	2	2
8-10	3	-	-	3
4-6	2	6	1	9
1-3	1	-	3	4
Total	6	6	6	18

Commercial growers were more interested in the grain than the leaves, thus they viewed spraying as a form of insurance that protected the crop and their investment. Most commercial growers began spraying 2 - 3 weeks after germination to prevent the build up of pest populations and they sprayed as often as 6 - 10 times over the course of the season. Transition farmers tended to commence their spray programs 1 - 2 weeks later; they sprayed less frequently, generally 4 - 6 times; and their rationale for spraying was to control pests that had already accumulated in their cowpea fields. Both commercial and transition growers indicated that spraying after the sixth week was not as effective as spraying earlier because they believed the leaf canopy protected the insects from the spray.

Those farmers who delayed spraying until after the 6-7 week indicated that they did so in order to harvest cowpea leaves or because they could not afford to purchase pesticides. Farmers indicated an awareness of the health hazards from eating leaves that had recently been sprayed.

The interval between spraying was longest (10 days) during the vegetative stage; it was reduced to 5-7 days during flowering; and further reduced to 3-5 days during podding. Again this appears to indicate the interest of commercial farmers in protecting grain production. It also indicates an awareness of different pests species that may be present at differing stages of plant growth.

Cowpea farmers used a total of 10 different commercial pesticides. The most commonly used pesticides were Super-Ambush and Dimethoate. There was a high degree of variability in farmer perception of pesticide efficacy; pesticide efficacy at different growth stages; pesticide efficacy on different pests; pesticide formulation (concentration); and, perceptions of pesticide impact on plant health and pollinators. In general, three perceptual criteria emerged that impacted farmer choice of pesticide: pest control efficacy, minimizing impact on plant health and availability of pesticides in local markets.

Research Discussion

For many farmers in the study area, cowpea has become an increasingly important cash crop. The increasing commercialization of cowpea has led to changes in the production system including the intensified use of land, labor and capital inputs. Cowpea is now regularly planted during both cropping seasons; seed is generally purchased from markets not saved from previous season harvests; and, pesticides are relied upon as the primary form of pest control. Increasing commercialization of cowpea production and increased use of pesticides appear to be mutually reinforcing. Pesticides are the only means currently available to control the pest complex found on cowpea, and the cash generated by cowpea is required for the purchase of pesticides. Although we cannot say on the basis of this study alone that pesticide use is increasing, it does appear on the basis of application frequency that pesticides are perhaps being abused and potentially leading to pesticide resistance. Two farmers in this study associated the increase in aphid populations with the increased use of pesticides. Thus, it appears that there are indications of a developing "pesticide treadmill" associated with cowpea production in this region of Uganda. These conditions appear to indicate a favorable environment for the development of an IPM program, particularly in terms of reducing pesticide use.

Future Research Suggestions

Pesticide management research, including timing, application rate and efficacy of different pesticides should be emphasized along with the development of relatively simple action thresholds. The concept of field scouting has already been introduced by the IPM CRSP. However, this practice needs to be disseminated to more growers in combination with action thresholds.

Strategies to control all the pests and diseases which attack cowpea in Eastern Uganda may not be viable. Efforts must focus on determining which pests are the most damaging and the stage of plant growth damage occurs. For instance, farmers perceive aphids as the most important pest, however, researchers (Omongo *et al*, 1997) indicate that maruca and thrips are the most important.

The germplasm base appears to be limited. Thus, the introduction and field testing of new genetic cultivars with resistance to pests and diseases should be considered (Resistant varieties developed at IITA are currently being field tested by the IPM CRSP and the Makerere University Cowpea Improvement Program supported by the Rockefeller Foundation) and existing sources of resistance fully exploited. As inidicated by several farmers, the possibility that the land race, Icirikukwai, was resistant to pests in the field and in storage requires more investigation.

The impact of certain agronomic practices on various pests needs to be evaluated. Practices such as early planting, plant spacing, earlier and multiple weedings, leaf harvesting and intercropping have demonstrated effects on lowering pest populations (Planting dates and plant spacing are currently under investigation by the IPM CRSP).

All farmers in this study planted cowpea by broadcasting the seed by hand. As a result, field densities were uneven resulting in reduced land use efficiency, lowered per hectare yields and potentially providing improved habitat for pests and weeds. Farmers preferred to broadcast seed because it was perceived to be faster and saved labor. Despite farmer reluctance to row plant cowpea, this practice should be introduced on a trial basis for several reasons. First, row planting will facilitate the evaluation of different plant densities on pests and disease occurrence. Higher plant populations are expected to reduce aphid infestations with a concomitant reduction in aphid-borne diseases. Second, row planting might reduce seed wastage that occurs with broadcasting and save farmers money. Third, row planting may facilitate easier weeding, a critical labor and yield constraint. Fourth, row planting may lead to higher per hectare yields.

Farmers' lack a well developed concept of natural enemies, pesticide resistance, and pesticide safety including handling and potential negative impacts on human health. IPM CRSP field activities should continue to educate farmers about these negative side-effects of pesticide abuse. In turn, increased awareness regarding pesticides should facilitate the adoption of IPM practices that reduce or eliminate pesticides.

Networking Activities

Workshops: Ms. Isubikalu has participated in two conferences hosted by the Rockefeller Foundation and the Makerere University Legume Improvement Project.

Research Investigator Exchanges: Dr. Erbaugh wrote the initial proposal and has reviewed two drafts of the thesis with Ms. Isubikalu in Uganda.

Publications and Presentations

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Project Highlights

Production goal influences cowpea acreage, varietal choice, seasonal planting, perception of problematic pests, and stage and frequency of pesticide application. Commercial cowpea growers commenced spraying earlier and they sprayed more frequently that did dual purpose and subsistence growers. Commercial farmers were more concerned with seed eating insects (pod borers and suckers), while subsistence cases considered leaf eating pests to be more important.

Increasing commercialization of cowpea production and increased use of pesticides appear to be mutually reinforcing. Pesticides are the only means currently available to control the pest complex found on cowpea, and the cash generated by cowpea is required for the purchase of pesticides.

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Farmer Open Day and Field Training

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Collaborating Scientists: J. Oryokot[3], and G. Epieru[3]; A. Ekwamu[1], T. Kauma[1], and M. Orawo[1]; D. Kyetere[4], P. Opio[4], B. Sekamanti[4] and G. Bagirwa[4]; E. Mwanje[5] and W. Tibairira[5]; and J.P Oonyu[6] and S. Epukalin[6]

Abstract

Farmer open days were conducted at each of our four research sites in Iganga and Kumi Districts. Each field day was conducted in collaboration with farmers who were active participants in IPM CRSP field trials, cooperating extension agents and research scientists. Since the field days were open, farmers who had not participated in the past with IPM CRSP activities were also invited. The main objective of the field days was to provide information and results about the trials to the farmers. This activity was created in response to requests from farmers for more information and feedback about trial results. A total of 144 farmers participated in these field days with 6 extension agents, 6 NARO research scientists and 2 scientists and 2 graduate students from Makerere University. Fact sheets on maize stalk borer and bean fly prepared by Drs. Willson and Kyamanywa were distributed to farmers and extension agents in both districts.

Objectives

1) To disseminate knowledge of IPM and IPM CRSP field trials to a wider range of farmers

2) To inform extension agents and farmers of on-farm trial results

IPM Constraints

The failure of many IPM programs in sub-Saharan African can be traced to deficient efforts to educate and raise the awareness of farmers regarding IPM and component technologies. IPM is knowledge intensive, and many small scale farmers in sub-Saharan Africa often lack requisite knowledge to understand and adopt IPM recommendations.

Research Methods

Farmer open days engaged groups of farmers including both trial participants and neighbors in discussions of pests and diseases, IPM and IPM trial technologies. Each took place at the home of one the farmers who was actively participating in pest monitoring and field trials. An open day protocol was developed that combined visits to and descriptions of nearby field trials by farmer participants with demonstrations, presentations and discussions of field trial results by scientists. Each meeting took approximately 5 hours to complete.

Research Results and Discussion

In general, the field day exercise succeeded in providing field trial results to farmers and in exposing additional farmers to IPM CRSP activities at research sites in Uganda. It became apparent that farmers have knowledge of obvious and reoccurring insect pests such as stalk borer and aphids but little knowledge of diseases. The concept of parasitoids was also novel for most of the farmers. Farmers were very interested in results of post-harvest treatment trials. However, because it was mid-season we were unable to demonstrate treatments at this time. Other selected comments from the field days follow.

On-Farm Trials with Beans

Many of the farmers were not familiar with the bean fly (*Ophiomyia* sp.) The participating farmers who did the explanations were able to find the bean fly maggot and show it to other farmers. Dr. Kyamanywa demonstrated how we sample fields for incidence of bean fly. Farmers prefer the bean variety Kannyebwa. All farmers said this variety tastes best (Is delicious), has a shorter cooking time, and a higher market price than do other varieties. However, they said that bruchids also prefer this variety for the same reason as people.

Question to Farmers: Why do they intercrop maize and beans ? Responses were lack of land; "When you have to

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use the hoe to open land it is difficult to open much, so we intercrop"; "Plants can share nutrients, lack of labor to open much land". What became apparent through our discussions was that farmers intercrop to save land and labor. The possible impact of intercrops on reducing the incidence of harmful pests was a new idea for them.

Biological Control of Stem Borers: Graduate student Teddy Kauma made this presentation in Iganga because Lusoga is her native dialect. Farmers knew nothing about the beneficial parasitoid *Cotesia flavipes*. Farmers found the presentation interesting and followed the presentation with many questions. Some of these questions were: "How can something so small kill something so much larger"; "Where can we get them ?"; "If parasitoids eat all the stalk borer where will they go and what will they then eat ? Maybe they will eat our crops ?". Since our participating farmers were equally uninformed about the parasitoid release we later emphasized to Miss Kauma that future releases and monitoring of releases should be done with participating farmers.

Presentation on Maize Diseases: Farmers often lump insects and diseases together. Most farmers were unfamiliar with maize diseases except maize streak. As one farmer stated after the field tour on diseases "This is my first time to learn [about diseases]". Another farmer asked "How do diseases affect the plant ?" Many farmers in Bulumagi thought disease symptoms on maize were a result of stalk borer or drought. They did not know that insects (e.g. leafhoppers) spread diseases (e.g. maize streak). The analogy of mosquitos spreading malaria was useful and facilitated understanding of insect borne diseases.

Chemical Pesticide Usage: In Baitambogwe 14 out of 50 farmers had used a chemical pesticide during the season. In Bulumagi, 27 farmers out of 42 had used chemical pesticides during the season. Most commonly sprayed were groundnuts, tomato and cabbages. We inquired about the unexpectedly high number of farmers using pesticides in Bulumagi. Farmers said that they are well organized and that several of their members distribute pesticides as a business. Only 4 farmers in both locations were spraying maize, usually for termites and only one was spraying her beans.

Post-harvest Trials: Participating farmers confirmed that solar drying and tobacco were the most effective post harvest control methods. However, they also commented that the solar dried beans and cowpea did not germinate. Dr. Kyamanywa explained that the solar dried beans would be good for consumption but that beans needed for next season's planting would need to be stored differently.

Groundnuts: Groundnuts were generally not sprayed this year in Kumi because, as the farmers explained: "They would normally spray groundnuts if they saw a large number of aphids and crinkling of the leaves (rosette disease). However, this year there were few aphids and not much rosette so they didn't need to spray". Most farmers agreed that the spray they would normally prefer to use on groundnuts (they didn't say aphids) is dimecron. Farmers maintained that groundnut rosette disease is still their most important problem and that they had completely stopped using the variety Red Beauty because of its susceptibility to rosette.

The groundnut variety Igola 1 demonstrated high levels of resistance to rosette disease during the previous two seasons. These previous seasons were characterized by low rainfall and high incidence of aphids. As a result, rosette had devastated traditional varieties such as Erudurudu. However, this season, heavy early rains (El Nino) and cooler temperatures resulted in low aphid populations and not much evidence of rossette. These heavy early rains had also caused spotty and delayed germination of Igola 1. Thus, treatments using the traditional variety Erudurudu looked better - larger and fuller - than those using Igola 1. Dr. Epieru explained that the early rains had induced or prolonged dormancy in Igola 1. Norah, a well educated farmer and former teacher, countered by saying that the Igola 1 that she had dried sufficiently from the previous season did well, but that those dried insufficiently germinated unevenly.

It was noted by several that more farmers in both areas in Kumi are growing Igola 1 this year than last year. When asked why, farmers explained that people are aware of its resistance to rosette. Other farmers said people are growing Igola 1 because it fetches about 2000 shillings/kilo, whereas Erudurudu brings 1000 shillings/kilo. This IPM CRSP promoted technology appears to be diffusing rapidly.

Cowpea: Farmers said that they had problems with aphids on cowpea this year. When I asked why they had problems with aphids on cowpea but not on groundnuts the farmers said that aphids prefer cowpea to groundnuts.

One woman of BUWOSA proudly described her own experiment on cowpea. She said she borrowed the idea of higher plant populations through row cropping for groundnuts and applied it to cowpea. The idea is that closer spacing creates a more humid and cooler micro environment which repels aphids. She said it is also working with cowpea and that she has not had a problem with aphids on her closely spaced cowpea.

Of the three cowpea varieties being grown, Ebelat, Ecurukukwai, and Kenya (black seeded variety sold to markets across the border in Kenya) farmers say that Ebelat taste the best but is most susceptible to pests; Ecurukukwai has the better tasting leaves, and because it is small seeded, farmers believe it more resistant to bruchids in post-harvest. However, the women say it also takes longer to cook.

Suggestions for future open days

1. Field trials should be marked by signs that would describe varieties and treatments.

2. For this first attempt at an open day we decided that we would ask farmer participants to explain all trials except those on diseases and parasitoid releases. Farmers were generally eager to do this and in most cases, they did an excellent job. The discussion of research results would have been facilitated by additional visual displays. Although, farmer comprehension of graphs and charts used to display results may have been limited, these materials appeared to be convincing to farmers. As one farmer commented, "When I see these graphs, I know the scientists are doing their job".

3. Use of the semi structured protocol following the field trial explanations was cumbersome, time consuming and detracted from time available for presentation of results and questions.

4. The main purpose of the open day was to expose and inform non-participating farmers of our trials. This was successful. However, we also wanted to come away with some quantifiable evaluation results. In this we did not entirely succeed. The methodology for having large groups of farmers evaluate trials and document their evaluations needs improvement. Since many farmers cannot read or write giving them individual evaluation forms is not an option. We used hand voting, but this was awkward, time consuming and not very precise. A conclusion drawn from this experience is that large group meetings are an effective method for raising awareness and educating farmers but not for collecting quantifiable data.

6. Attempts to use a tape recorder to record responses did not work very well. The recorder had to be very close to the speaker and this proved to be quite cumbersome and interrupted dialogue.

7. Complex integrated trials are difficult for farmers to understand and evaluate. Single treatment trials, such as trials that compare varieties are much easier for farmers to understand and evaluate. As we progress with our trials and look at the effects of various treatments on various pests and diseases, the task of explaining results to farmers will become increasingly more difficult. This complexity factor may be one of the main constraints to adoption of IPM practices.

8. Open days might be improved by restricting the scope to one crop and its IPM treatments; or by organizing them to be held at one of the District Farm Institutes or Varietal Testing Centers.

Impact

As a result of the open day 140 new farmers were exposed to IPM and IPM CRSP field trials.

Networking Activities

Workshops Planned or Participated In

1. Four open days were planned and held at research sites in Eastern Uganda.

2. Prior to the Open Day activity two, one day planning sessions were held at Namulonge and Serere Agricultural Research Institutes. All participating research scientists, graduate students and extension agents participated in these sessions.

3. Following each of the Open Day activities, debriefing sessions were held with participating research scientists and extension agents.

Research Information and Product Exchanges

1. Three fact sheets were produced by Drs. Hal Willson and Kyamanywa and distributed to farmers at the Open Days.

2. Open day protocol was developed.

Project Highlights

- IPM CRSP Open Days held at research sites in Eastern Uganda exposed 140 new farmers to IPM and IPM CRSP field trials.

- The resistant groundnut variety Igola 1, promoted and extended by the IPM CRSP is being adopted by farmers near research sites in Kumi District.

- New farmers were generally unaware of most plant diseases except maize streak, sorghum smut, and groundnut rosette disease and, in concurrence with initial PA results, were not familiar with the bean fly.

- The concept of beneficial insects such as the parasitoid of stalk borer was new for all farmers.

- Farmers stated that they intercrop to save land and labor. The possible impact intercrops might have on reducing the incidence of harmful pests was a new idea for them.

Development of an Integrated *Striga* Management Strategy and Innovative Complementary Approaches

Investigators: Joseph Oryokot[1], Chester L. Foy[2], and Brhane Gebrekidan[3]

Abstract 1. (Uganda Field Research)

In the second rains of 1997, the strategy of developing an integrated management strategy for *Striga* was expanded to allow evaluation of several options. The number of treatments was increased from three to five. This was done to quantify the contribution of *Celosia argentea* (corrected identification of *Striga* 'chaser') and nitrogen fertilizer. In this season, there were no differences among the different integrated management options on either *Striga* emergence or sorghum plant height. Combination of nitrogen fertilizer and interplanting with *C. argentea* did however, appear to have better effect on these two parameters than when each was applied separately. In the first rains of 1998, germination and crop establishment of Dobbs was very poor at all sites and no data could be taken at three of these sites. Germination conducted on-station to explain this poor germination showed the seed used to plant the experiment had very low germinability, <50%. This was attributed to poor seed storage conditions prior to planting. This has been rectified and trial will be repeated in the second rains of 1998. In two of the five sites, with fair although still patchy established, data was collected on *Striga* emergence, plant height at flowering and grain yield. No meaningful statistical analysis could be carried out and only trends in *Striga* emergence is presented. These indicate *Striga* count to progressively increase with time only under farmer management.

Abstract 2. (VT Lab Research)

Two growth hormone herbicides, 2,4-D and dicamba, and two sulfonylurea herbicides, halosulfuron and prosulfuron, all recommended for postemergence treatments in sorghum, were tested. Eight *Striga*-resistant sorghum lines (P9401 through P9408) were obtained from Dr. Gebisa Ejeta of Purdue University. All experiments were conducted under greenhouse conditions at Virginia Tech. Germination of seeds of most sorghum lines was poor; P9401 and P9407 lines germinated best. Detailed results are presented for these two lines. Herbicides were applied as foliar sprays or soil drenches at various rates, or as seed treatments (seed soaks) at various concentrations. Herbicides applied as foliar sprays caused minor injury overall, except for 2,4-D at a recommended rate and dicamba at twice the recommended rate. Tolerance of the sorghum lines, except P9403 and P9404, to soil drenches with the herbicides was good although prosulfuron at higher than recommended rates reduced plant heights of some lines. When herbicides were tested as seed treatments on lines P9401 and P9407, plant growth was acceptable with: 2,4-D at 0.001%; dicamba at 0.001 and 0.01%; halosulfuron at 0.001, 0.001, and 0.01%; and prosulfuron at 0.0001, 0.001, 0.01, and 0.1%. The addition of an adjuvant to some herbicide solutions resulted in less tolerance.

Striga continues to be a major constraint to food production in sub-Saharan Africa. The IPM CRSP places high priority on attempting to solve this important problem. In addition to the Mali site, the CRSP has an ongoing activity on *Striga* research in Uganda. The field work in Uganda focuses on developing an integrated Striga management strategy. Concurrently a complementary innovative approach has been investigated in Chester Foy's laboratory at Virginia tech in Blacksburg. The results reported here cover the two complementary activities.

1. Development of an Integrated Striga Management Strategy: Field Research in Uganda

Reaserch Objectives

To develop a cost effective and technically feasible integrated *Striga* management strategy for small-scale sorghum farmers

To evaluate this strategy on farm

To minimise yield loss in sorghum due to Striga infestation

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Research Methods

The research was undertaken on-farm. Five treatments consisted of:

Dobbs (a sorghum variety tolerant on Striga) + CAN fertilizer applied at 80 kg N ha^{-1} + interplanting with *Celosia argentea*, a Striga "chaser' + Two hand weedings at 2 and 6 weeks after planting.

Dobbs + Farmer management (a single hand weeding at 2 - 4 weeks after crop emergence).

Farmer variety + Farmer management were evaluated.

Dobbs + CAN fertilizer at 80 kg N ha^{-1} + Two hand weedings.

Dobbs + Celosia argentea + Two hand weedings.

The trial was planted in five farmers' fields belonging two farmer groups; BUWOSA and Kachede UNFA. The farmers constituted the replicates. Field preparation included ploughing two times and levelling by hand hoe. Plot measured 12 m x 9.8 m. Treatments were randomly allocated in each farmer field. Sorghum was planted at a spacing of 60 cm x 20 cm except under farmer management where seed was broadcast at farmers' rate. For treatments that included nitrogen application, CAN was applied at planting. *Celosia argentea* was intersown in sorghum in the relevant plots at planting, at approximately 1 g to 500 g of sorghum seed. *Celosia argentea* seed was mixed with soil as filler to allow for convenient planting. Emerged Striga counts were conducted three times; during early season (5-7 leaf stage), mid (10-12 leaf stage) and at harvest. Four permanent quadrants measuring 1.0 x 1.0 m were established in each plot and Striga counts taken within these. Visual observations were made to assess plant vigour. In the second rains of 1997, sorghum plant height were measured at flowering. Ten plants were randomly measured and mean height derived. Data collected included: crop height, Striga count, visual score on plant vigour and plant stand.

Research Results

Effects of *Striga* management on plant growth parameters

In the second rains of 1997, farmer varieties were taller than Dobbs regardless of *Striga* management option (Table 1). Management option however, influenced plant height significantly ($P<0.05$) in Dobbs only during the second rains of 1997. A single hand weeding resulted in a shorter plant height at flowering. Application of nitrogen fertilizer together with the *Striga* 'chaser' alone increased plant height significantly ($P<0.05$) compared to interplanting with *Striga* 'chaser' (Table 1).

Table 1. Effect of *Striga* management on crop parameters (2nd rains 1997)

Management option	Plant Stand (Plants M^{-2})	Plant height at flower (cm)
1. Dobbs+80kg N ha^{-1}+*Striga* 'chaser'+2 weedings		149
2. Dobbs + 80kg N ha^{-1} + 2 weedings	7	147
3. Dobbs + *Striga* 'chaser' + 2 weedings	7	140
4. Dobbs + Farmer Management	11	132
5. Farmer variety + Management	12	158
LSD	1.4	9.0
CV%	12	4.6

Effect of *Striga* management on *Striga* emergence

Striga emergence was influenced by management option in the second rains of 1997. Two hand weedings resulted in significantly ($P<0.05$) fewer emerged *Striga* plants compared to the farmer management practice of single weeding. Application of fertilizer alone did not have a significant effect compared to interplanting with the *Striga* chaser alone on emerged *Striga* although it did depress emergence somewhat.

It was not possible to measure the effect *of Striga* management on yield in the second rains of 1997 as the intense rains at flowering due to the "El-Nino" effect did not allow pollination and seed formation. Considering the positive impact on *Striga* emergence, however, it is likely that yield would have been positively influenced by either application of fertilizer or *Striga* chaser with two hand weedings during this season.

In the first rains of 1998, germination and establishment of Dobbs was very poor at all the sites and no useful data was collected at three of the sites. Data from the remaining two sites was used to observe *Striga* emergence trends only as no meaningful statistical analysis could be carried out. This is presented in Figure 1. In all the treatments that a second hand weeding was carried, emerged *Striga* plants declined in the third count. This supports the observation that a second hand weeding four weeks after the first weeding is a useful practice and can contribute to reduced *Striga* parasitism and seed return to the soil.

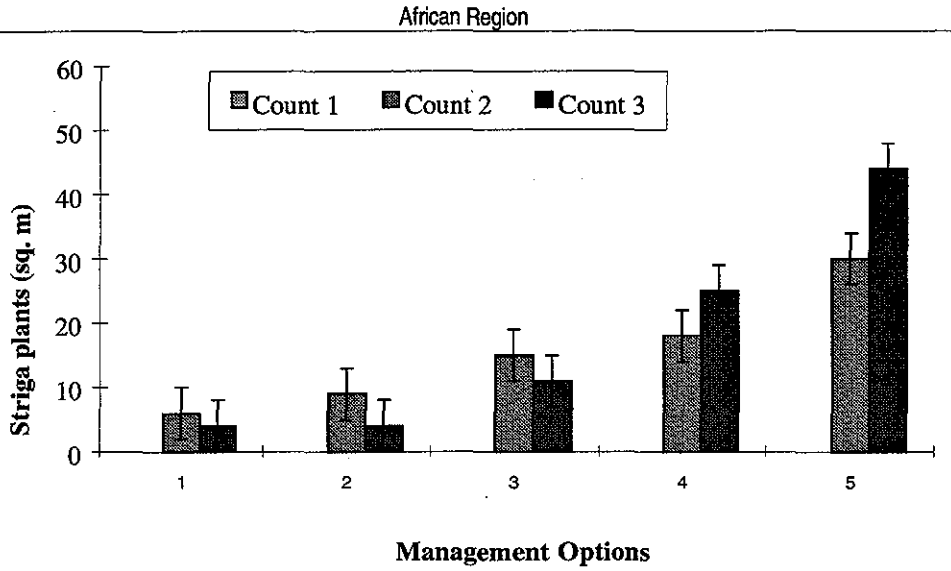

Figure 1. Effect of management on *Striga* emergence through season (First rains 1998)

Impact

The use of inorganic fertilizer combined with interplanting with *Celosia argentea* appears to reduce the effect of *Striga* on sorghum crop growth. When hand weeding is done twice, reduction on *Striga* emergence is obtained. An integrated strategy based on application of inorganic fertilizer in combination with interplanting with the *Striga* Chaser and hand weeding twice appears to be effective in *Striga* management. Due to very poor crop establishment in planted to Dobbs, statistical comparisons between treatments was not possible. Observations based on *Striga* emergence trends indicate the usefulness of a second hand weeding. Steps have been instituted to ensure quality of seed and the trial will be repeated in the second rains of 1998.

2. Innovative Complementary Approaches to Striga Management: Lab Research at Virginia Tech

Research Objectives

To develop through laboratory and greenhouse testing, innovative and improved strategies for *Striga* control in sorghum, involving crop lines with resistance/tolerance to *Striga* in combination with selected, safe herbicides applied as (a) seed treatments, (b) timely low-dosage foliar sprays, or (c) both.

IPM Constraints

The problem, devastating losses caused by the root parasitic weed, *Striga*, in sorghum production, demands the application of all "BMPs" (best management practices). Current integration strategies, e.g. involving nitrogen fertilization, water management, dates of planting, varieties, hand weeding, etc. have thus far proved inadequate. The greatest hope of success with the *Striga* problem seems to lie with crop lines having either natural or genetically engineered resistance/tolerance to *Striga* attack and/or selected herbicides, used in combination with low dosages of safe "environmentally friendly" herbicides.

Research Methods

Eight *Striga* – resistant lines, P9401, P9402, P9403, P9404, P9405, P9406, P9407, and P9408, were obtained from Dr. Gebisa Ejeta of Purdue University via Dr. Brhane Gebrekidan. All experiments were conducted under greenhouse conditions at Virginia Tech, Blacksburg, VA. Sorghum plants were grown in 15-cm diameter pots containing ProMix Bx in all experiments.

Response of Sorghum to Herbicides Applied Postemergence

All sorghum lines were used and plants were fertilized with Peters 20-20-20 All Purpose Fertilizer at 4 g/L (150 ml per pot) 3 weeks after planting. Herbicides and rates tested were: 2,4-D amine at 70, 140, and 280 g ai/ha; dicamba at 70, 140, 280, and 560 g ai/ha; halosulfuron at 9.0, 17.9, 35.8, and 71.7 g ai/ha; and prosulfuron at 7.6, 15.1, 30.2, and 60.5 g ai/ha. The surfactant, X-77 at 0.25% (v/v) was included with halosulfuron and prosulfuron. Treatments were applied in 187 L/ha of water using a CO_2-charged, moving belt laboratory sprayer equipped with a single 8001E flat fan nozzle delivering 172 kPa pressure. Treatments were applied 42 DAP (days after planting) when sorghum plants

were 18 to 38 cm tall. Each pot contained 1 to 3 plants. Percent crop injury (yellowing, collapsing of plants) and plant height measurements were recorded 13 and 27 days after treatment (DAT).

Response of Sorghum to Herbicides Applied as a Soil Drench

All sorghum lines were used and Osmocote 14-14-14 fertilizer (3 g/pot) was applied at planting. Herbicides and rates tested were: 2,4-D amine at 140, 280, and 560 g ai/ha; dicamba at 140, 280, 560, and 1120 g ai/ha; halosulfuron at 17.9, 35.8, 71.7, and 143.4 g ai/ha; and prosulfuron at 15.1, 30.2, 60.5, and 121.0 g ai/ha. Treatments were applied as a soil drench (150 ml per pot) 41 DAP when sorghum plants were up to 39 cm tall. Each pot contained 1 or 2 plants. Percent crop injury (yellowing, collapsing of plants) and plant height measurements were recorded 15 and 30 DAT.

Response of Sorghum to Herbicide Seed Treatment

Sorghum lines P9401 and P9407 were used in this experiment. Osmocote 14-14-14 fertilizer (3 g/pot) was applied at planting. Treatments were as follows: 2,4-D and dicamba, each at 10.0, 1.0, 0.1, 0.01, 0.001, and 0.0% (w/v), and halosulfuron and prosulfuron, each at 1.0, 0.1, 0.01, 0.001, 0.0001, and 0.0% (w/v). Treatments were prepared using distilled water. One set contained the adjuvants, Agrimax 3 (International Specialty Products) at 0.2% (v/v). Thirty-five seeds of each lines were soaked for 5 min in 10 ml of the solution, allowed to dry at room temperature overnight, and 10 seeds per pot were planted. Treatments were replicated three times. Plant stand counts and height measurements were recorded 18 and 33 DAP.

Results

Response of Sorghum to Herbicides Applied Postemergence (Tables 1 and 2)

Germination of seeds of most lines was poor, providing only enough plants for one or two replications of the treatments. Germination of lines P9401 and P9407 was best and allowed for three replications. Results reported in Table 1 and 2 are for these two lines. Crop injury (yellowing, collapsing, and stunting of plants) was minor overall except for the highest rates of 2,4-D (a recommended rate) or dicamba (twice the recommended rate) on several lines as indicated by injury ratings and plant heights 27 DAT.

Table 1. Effect of herbicides applied postemergence on injury and height of sorghum.[a]

		Line No. P9401			
		Injury		Plant height	
Treatment Rate		13 DAT	27 DAT	13 DAT	27 DAT
	(g ai/ha)	%		% of control	
Control	-	0.0	0.0	100	100
2,4-amine	70.0	4.3	2.7	96	93
	140.0	13.3	20.0	91	81
	280.0	16.7	21.7	83	79
Dicamba	70.0	1.7	1.7	100	100
	140.0	0.5	1.7	104	105
	280.0	0.0	0.0	100	103
	560.0	3.0	11.3	98	100
Halosulfuron	9.0	0.0	4.0	102	100
	17.9	1.7	10.0	100	95
	35.8	0.0	3.3	104	105
	71.7	0.7	0.0	104	103
Prosulfuron	7.6	0.0	0.0	107	103
	15.1	1.7	3.3	98	105
	30.2	1.7	8.3	104	100
	60.5	0.0	1.7	109	116

[a]Data are averages of 3 replications.

In some instances, plants were less vigorous with a lower rate than with higher rates of the same herbicide. The recommended rate for halosulfuron in sorghum in Virginia is 35.8 g/ha and prosulfuron is recommended at 30 to 40 g/ha. All lines showed good tolerance to halosulfuron at the recommended rate (or below) and most showed good tolerance to twice the recommended rate. Results were similar with prosulfuron at rates recommended or lower except with line P9403.

Table 2. Effect of herbicides applied postemergence on injury and height of sorghum.[a]

Treatment	Rate	Line No. P9407 Injury 13 DAT	Injury 27 DAT	Plant height 13 DAT	Plant height 27 DAT
	(g ai/ha)	%		% of control	
Control	-	0.0	0.0	100	100
2,4-amine	70.0	0.0	8.3	103	96
	140.0	3.3	16.7	88	79
	280.0	4.0	18.3	85	72
Dicamba	70.0	0.0	4.0	103	100
	140.0	0.0	0.7	100	108
	280.0	4.3	8.3	80	89
	560.0	7.7	33.3	78	62
Halosulfuron	9.0	5.0	8.3	93	100
	17.9	3.3	9.0	98	89
	35.8	3.3	23.3	90	77
	71.7	0.0	3.3	100	96
Prosulfuron	7.6	0.0	0.7	103	109
	15.1	6.7	16.7	90	74
	30.2	1.7	6.7	90	87
	60.5	0.7	6.7	105	102

[a]Data are averages of 3 replications.

Response of Sorghum to Herbicides Applied as a Soil Drench (Tables 3 and 4)

Germination of seeds was poor except for lines P9401 and P9407. Overall, lines P9403 and P9404 were less tolerant to the herbicide treatments than did the other lines. Severe injury and death of some plants of line P9403 occurred. Severe injury to P9404 occurred with some treatments; however, no plants were killed. As indicated by injury ratings and plant heights 30 DAT, tolerance of the other lines to most herbicide treatments was good. Prosulfuron at 60.5 and 121.0 g/ha reduced plant heights of a few lines compared to lower rates of the herbicide.

Table 3. Effect of herbicides applied as a soil drench on injury and height of sorghum.[a]

Treatment	Rate	Line No. P9401 Injury 15 DAT	Injury 30 DAT	Plant height 15 DAT	Plant height 30 DAT
	(g ai/ha)	%		% of control	
Control	-	0.0	0.0	100	100
2,4-amine	140.0	11.7	16.7	85	88
	280.0	18.3	8.3	91	94
	560.0	21.6	15.0	91	92
Dicamba	140.0	1.7	0.0	104	118
	280.0	21.7	23.3	83	88
	560.0	11.8	15.0	90	92
	1120.0	28.3	11.7	79	90
Halosulfuron	17.9	16.7	1.7	101	104
	35.8	3.3	5.0	105	102
	71.7	3.3	0.0	94	104
	143.4	3.3	1.7	95	103
Prosulfuron	15.1	5.0	0.0	104	106
	30.2	13.9	15.0	85	92
	60.5	0.0	1.7	104	95
	121.0	10.0	8.3	99	91

[a]Data are averages of 3 replications.

Table 4. Effect of herbicides applied as a soil drench on injury and height of sorghum.[a]

Treatment	Rate	Line No. P9407			
		Injury		Plant height	
		15 DAT	30 DAT	15 DAT	30 DAT
	(g ai/ha)	%		% of control	
Control	-	0.0	0.0	100	100
2,4-amine	140.0	6.7	3.3	98	106
	280.0	16.7	13.3	91	94
	560.0	11.7	13.3	88	89
Dicamba	140.0	18.3	30.0	93	90
	280.0	3.3	0.0	113	113
	560.0	11.7	16.7	96	95
	1120.0	8.3	11.7	95	100
Halosulfuron	17.9	8.3	10.0	111	110
	35.8	6.7	5.0	105	103
	71.7	1.7	1.7	100	102
	143.4	28.3	30.0	82	78
Prosulfuron	15.1	21.7	18.3	89	94
	30.2	20.0	21.7	93	86
	60.5	23.3	30.0	86	78
	121.0	21.7	25.0	88	86

[a]Data are averages of 3 replications.

Response of Sorghum to Herbicide Seed Treatment (Tables 5-12).

Both lines showed acceptable tolerance to 2,4-D at 0.001% (with or without adjuvant). Compared to no treatment, germination of P9401 was reduced and plants were shorter with 2,4-D at 0.01 and 0.1% without adjuvant. 2,4-D at 1.0 and 10.0% prevented germination. When applied with the adjuvant, 2,4-D at 0.1, 1.0, and 10.0% prevented germination of P9401; germination was reduced and plants were shorter with 2,4-D at 0.01%. 2,4-D at 0.1% and above, with or without adjuvant, prevented germination of P9407; germination and plant heights were reduced at 0.01%. Dicamba at 1.0 and 10.0% (with or without adjuvant) prevented germination of seeds of both lines. Dicamba at 0.1% with adjuvant prevented germination of P9407. Germination of P9401 was slightly reduced with dicamba at 0.001, 0.01, and 0.1% (without adjuvant), but growth of plants was normal compared to no treatment. However, with adjuvant, dicamba at 0.1% reduced germination and plant height. Acceptable concentrations for P9407 appeared to be 0.001 and 0.01%. Halosulfuron, with or without adjuvant, did not prevent germination of seeds of either line. Acceptable concentrations for plant growth appeared to be 0.0001, 0.001, and 0.01%. Halosulfuron at 0.1 and 1.0% caused reductions in plant height compared to no treatment.

Table 5. Effect of 2,4-D (with and without adjuvant) seed treatment of sorghum on stand and height.[a]

Concentration of 2,4-D	Adjuvant[b]	Line No. P9401			
		Plants per pot		Plant height	
		18 DAP	33 DAP	18 DAP	33 DAP
	%, w/v	%		cm	
10.0	-	0.0	0.0	0.0	0.0
1.0	-	0.0	0.0	0.0	0.0
0.1	-	0.7	0.7	3.7	21.0
0.01	-	0.3	0.3	2.3	10.3
0.001	-	7.0	7.0	25.3	49.0
0.0	-	7.0	7.0	25.7	52.3
10.0	+	0.0	0.0	0.0	0.0
1.0	+	0.0	0.0	0.0	0.0
0.1	+	0.0	0.0	0.0	0.0
0.01	+	1.3	1.7	9.0	19.0
0.001	+	5.3	5.7	23.3	49.7
0.0	+	3.3	3.3	21.3	55.7

[a]Data are averages of 3 replications. [b]Agrimax 3 at 0.2% (v/v).

Table 6. Effect of 2,4-D (with and without adjuvant) seed treatment of sorghum on stand and height.[a]

Concentration of 2,4-D	Adjuvant[b]	Line No. P9407			
		Plants per pot		Plant height	
		18 DAP	33 DAP	18 DAP	33 DAP
	%, w/v	%		cm	
10.0	-	0.0	0.0	0.0	0.0
1.0	-	0.0	0.0	0.0	0.0
0.1	-	0.0	0.0	0.0	0.0
0.01	-	1.7	1.7	6.3	21.0
0.001	-	4.3	4.3	21.3	51.0
0.0	-	6.7	6.3	18.7	48.0
10.0	+	0.0	0.0	0.0	0.0
1.0	+	0.0	0.0	0.0	0.0
0.1	+	0.0	0.0	0.0	0.0
0.01	+	0.3	0.3	4.3	18.0
0.001	+	5.7	5.7	18.0	42.0
0.0	+	4.3	4.3	21.7	55.0

[a]Data are averages of 3 replications. [b]Agrimax 3 at 0.2% (v/v).

Table 7. Effect of dicamba (with and without adjuvant) seed treatment of sorghum on stand and height.[a]

Concentration of dicamba	Adjuvant[b]	Line No. P9401 Plants per pot 18 DAP	33 DAP	Plant height 18 DAP	33 DAP
	%, w/v	—%—		—cm—	
10.0	-	0.0	0.0	0.0	0.0
1.0	-	0.0	0.0	0.0	0.0
0.1	-	4.0	4.0	21.3	50.3
0.01	-	4.0	3.7	18.3	37.0
0.001	-	4.7	4.7	22.0	47.7
0.0	-	7.3	7.3	22.0	44.7
10.0	+	0.0	0.0	0.0	0.0
1.0	+	0.0	0.0	0.0	0.0
0.1	+	0.7	0.7	6.3	16.3
0.01	+	4.7	4.7	17.3	44.3
0.001	+	2.7	2.3	14.0	50.7
0.0	+	4.0	4.3	24.3	54.3

[a]Data are averages of 3 replications. [b]Agrimax 3 at 0.2% (v/v).

Table 8. Effect of dicamba (with and without adjuvant) seed treatment of sorghum on stand and height.[a]

Concentration of dicamba	Adjuvant[b]	Line No. P9407 Plants per pot 18 DAP	33 DAP	Plant height 18 DAP	33 DAP
	%, w/v	—%—		—cm—	
10.0	-	0.0	0.0	0.0	0.0
1.0	-	0.0	0.0	0.0	0.0
0.1	-	0.3	0.3	6.3	17.0
0.01	-	4.0	4.0	19.7	50.7
0.001	-	7.3	6.7	24.7	49.7
0.0	-	7.0	7.0	22.0	52.7
10.0	+	0.0	0.0	0.0	0.0
1.0	+	0.0	0.0	0.0	0.0
0.1	+	0.0	0.0	0.0	0.0
0.01	+	2.7	3.0	18.0	47.0
0.001	+	4.3	4.0	18.0	52.0
0.0	+	3.0	3.0	20.0	55.3

[a]Data are averages of 3 replications. [b]Agrimax 3 at 0.2% (v/v).

Table 9. Effect of halosulfuron (with and without adjuvant) seed treatment of sorghum on stand and height.[a]

Concentration of halosulfuron	Adjuvant[b]	Line No. P9401 Plants per pot 18 DAP	33 DAP	Plant height 18 DAP	33 DAP
	%, w/v	—%—		—cm—	
1.0	-	5.3	5.7	7.8	23.6
0.1	-	6.7	6.7	11.7	29.3
0.01	-	6.3	6.3	19.0	38.0
0.001	-	7.7	7.7	24.0	46.7
0.0001	-	6.7	6.7	21.7	41.3
0.0	-	8.3	8.3	22.3	46.0
1.0	+	4.3	3.7	8.0	28.7
0.1	+	6.3	6.3	13.3	36.3
0.01	+	6.0	6.3	19.0	44.0
0.001	+	6.0	6.0	23.3	51.0
0.0001	+	4.0	4.0	20.3	49.0
0.0	+	7.3	7.3	22.7	47.0

[a]Data are averages of 3 replications. [b]Agrimax 3 at 0.2% (v/v).

Table 10. Effect of halosulfuron (with and without adjuvant) seed treatment of sorghum on stand and height.[a]

Concentration of halosulfuron	Adjuvant[b]	Line No. P9407 Plants per pot 18 DAP	33 DAP	Plant height 18 DAP	33 DAP
	%, w/v	—%—		—cm—	
1.0	-	3.0	3.3	6.0	16.7
0.1	-	4.7	4.7	6.7	20.3
0.01	-	7.0	7.0	18.0	44.3
0.001	-	6.0	6.0	21.0	50.7
0.0001	-	6.3	6.3	21.3	49.0
0.0	-	5.0	5.7	18.3	42.7
1.0	+	4.3	4.7	5.7	14.0
0.1	+	5.0	5.0	10.7	22.3
0.01	+	5.0	4.7	16.7	42.7
0.001	+	4.7	4.7	17.0	42.3
0.0001	+	5.3	5.7	25.0	47.7
0.0	+	3.3	3.3	18.7	49.7

[a]Data are averages of 3 replications. [b]Agrimax 3 at 2% (v/v).

Table 11. Effect of prosulfuron (with and without adjuvant) seed treatment of sorghum on stand and height.[a]

Concentration of prosulfuron	Adjuvant[b]	Line No. P9401 Plants per pot 18 DAP	33 DAP	Plant height 18 DAP	33 DAP
	%, w/v	—%—		—cm—	
1.0	-	7.7	7.7	15.7	41.0
0.1	-	8.0	8.0	21.3	48.0
0.01	-	7.3	7.3	23.7	47.7
0.001	-	7.0	7.0	26.7	49.0
0.0001	-	8.0	8.3	28.0	50.0
0.0	-	6.3	5.3	24.0	52.7
1.0	+	4.3	4.3	9.7	31.3
0.1	+	4.7	4.7	22.0	52.3
0.01	+	6.0	6.0	24.0	48.7
0.001	+	6.3	6.3	23.0	51.0
0.0001	+	6.0	6.0	22.3	51.0
0.0	+	5.0	5.0	23.0	54.0

[a]Data are averages of 3 replications. [b]Agrimax 3 at 2% (v/v).

Table 12. Effect of prosulfuron (with and without adjuvant) seed treatment of sorghum on stand and height.[a]

Concentration of prosulfuron	Adjuvant[b]	Line No. P9407 Plants per pot 18 DAP	33 DAP	Plant height 18 DAP	33 DAP
	%, w/v	—%—		—cm—	
1.0	-	7.0	6.7	16.3	42.3
0.1	-	7.0	7.0	21.7	47.6
0.01	-	9.0	8.7	22.3	47.0
0.001	-	7.7	7.3	20.0	50.0
0.0001	-	7.0	7.0	22.0	48.7
0.0	-	5.3	5.3	18.0	42.3
1.0	+	3.7	3.7	11.3	35.0
0.1	+	6.3	6.3	19.3	49.7
0.01	+	3.7	3.7	22.0	53.3
0.001	+	5.0	5.0	23.7	50.0
0.0001	+	5.3	5.3	24.0	52.0
0.0	+	7.3	7.3	22.0	55.3

[a]Data are averages of 3 replications. [b]Agrimax 3 at 2% (v/v).

Prosulfuron, with or without adjuvant, did not prevent germination of seeds of either line and plant growth was good with the majority of treatments. The addition of the adjuvant to prosulfuron at 1% reduced plant heights compared to no herbicide treatment.

Impact

Using a combination of *Striga*-resistant lines and low doses of safe "environmentally friendly" herbicides (e.g. sulfonylureas) either as seed dressings or as timely foliar sprays could provide effective *Striga* control, both safely to the user and without adverse environmental impacts. Seed treatment would be an especially cost-effective method of application since it would reduce the level of active ingredient required for control and eliminate the need for application equipment. Application of low dosage foliar sprays is only slightly less appealing, involving only the use of an easily calibrated, hand-held sprayer. These approaches should not exclude, but rather complement, other valid IPM practices such as N fertilization, intercropping with legumes, and so forth.

Networking Activities

Participated in portions of the IPM CRSP Symposium, Planning Meeting, and Technical Committee Meeting during the period May 15-18, 1998, especially Symposium Session II – Research Reports: Weeds on Friday morning, May 15th.

Interacted with Dr. Joseph Oryokot regarding research plans in progress during the above mentioned meeting at Virginia Tech.

Supplied a copy of the fifth year sub-project annual report to the following: Dr. Oryokot, Collaborating Scientist; Dr. Gebrekidan, Program Director, IPM CRSP; Dr. DeDatta, Principal Investigator, IPM CRSP; and Dr. Erbaugh, Africa Site Chair.

Requested a transfer of $4,800 of the funds approved for expenditure under TA Proposal #11-AF2 to Dr. Oryokot for his use in Uganda.

Follow-up studies are proposed to test the most promising leads from the greenhouse experiments under field conditions in Uganda. Initially, we propose to use the unspent portion of funds already allocated under the approved Year 5 work plan for this subproject. Additional funds may be requested later as justified.

Training Output

Employed graduate student, Greg Armel, a US citizen, on an hourly-wage basis to assist with greenhouse studies.

Project Highlight

Results of these studies suggest that 2,4-D, dicamba, halosulfuron, and prosulfuron can be applied as foliar sprays at recommended (or below) rates to these *Striga*-resistant lines. Not all of the lines tolerated soil drenches. Safe doses of the herbicides for seed treatments were indicated for two lines. The most promising of these treatments should now be further investigated on the most *Striga*-resistant sorghum lines available under representative field conditions at several sites in Uganda.

Comparative Performance of cv *Igola-1* and Other Local Groundnut Cultivars for the Control of Rosette Disease

Investigators: Adipala, E.[1], H.L. Warren[2], Epieru, G.[3], Takan, J.P.[3], Kyamanywa, S.[1], and H. Willson[4]

Abstract

In Uganda, as in many other countries of sub-Saharan Africa, groundnut rosette is widespread, and especially destructive on late planted crops. Rosette is a virus disease spread by aphid vectors *Aphis craccivora* Koch. To reduce losses due to this disease, scientists in Uganda have developed the cultivar '*Igola-1*'; it is resistant to rosette and high yielding. Other technologies related to the control of the disease such as use of high plant density, timely planting and insecticide sprays are also available, and except for insecticide sprays, others are largely unknown to farmers. Through farmer-participatory research, we have mounted on-farm trials to expose farmers to

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these technologies have been mounted. Last season, we compared *Igola-1* to two popular local cultivars *Erudurudu* and *Etesot* at high (45x15 cm) and low (60x30 cm) plant densities. Although the three cultivars supported similar levels of aphids, there was markedly low rosette on *Igola-1*, and it yielded almost twice as much as the two local cultivars. High plant density did not significantly affect severities of rosette but it reduced significantly aphid infestation. The trials are being repeated, in first rains of 1998.

Introduction

After beans (*Phaseolus vulgaris* L.), peanut or groundnut (*Arachis hypogaea* L.) is the second most important legume food crop in sub-Saharan Africa. In Uganda, it is grown throughout the country, largely under subsistence farm conditions. Yield vary substantially ranging from between 500-1000 kgs/ha to 1000-1700-2200 kgs/ha (Unshelled nuts) in poor and rich soils, respectively. The area under ground nuts has also declined in the last ten years due to shortage of good planting material and widespread rossete epidemics. Due to ravages of diseases, especially groundnut rosette and cercospora leaf spots *(Cercosporidium personatum* and *Cercospora arachidicola)*, total crop failure are not uncommon (Emechebe, 1975).

Rosette is generally considered the most important constraint to groundnut production in sub-Saharan Africa (Reddy *et al.*, 1990), and is generally restricted to the African continent (Subrahmanyan, 1990). The disease is transmitted by aphids *Aphis craccivora* Koch (Homotera: Aphididae) in a persistent manner (Hull and Adams, 1968). The virus causes yellowing, mottling, stuntedness and under severe infection pegs (pods) are not formed. In cowpea and other legumes,growing of aphid resistant cutivars offers one of the simplest and most convinient methods of control (Dent, 1991).

In recognition of the importance of this disease, the Uganda National Agricultural Research Organisation (NARO), in collaboration with Makerere University and other agencies notably ICRISAT has mounted research to reduce losses by this disease. Research has focussed on identification and development of sources of resistance. After many years of selection, the variety *Igola-1* was developed. It is known to be tolerant to rosette and high yielding. Other plausible control measures include use of high plant populations which reduce aphid infestation (Ogenga-Latigo *et al.*, 1992; Edema *et al.*, 1997), and early planting so that groundnuts develop resistance before massive aphid infestation (Emechebe, 1975).

Although these technologies are available at research stations in Uganda, they are largely unknown to Ugandan farmers. Unfortunately, rosette pressure seem to be on the increase in recent years making many farmers to resort to indiscriminate use of foliar insecticides to control the disease (Erbaugh & Kyamanywa, unpubl.). Under the IPM/CRSP programme we have mounted on-farm research to expose farmers to some of the improved technologies for managing groundnut rosette.

Objectives

- compare the performance of *Igola-1*, an improved groundnut cultivar with resistance to rosette against local farmer cultivars under farmer-managed field trials.
- compare the effect of plant density on incidence of groundnut Rosette.

Research Methods

Three groundnut cultivars were evaluated. *Igola-1* is an improved erect and early maturing cultivar, that was developed by Serere Agricultural Research Institute for resistance to rosette. It was compared against two popular local cultivars, *Erududuru (Kabbonge omumyufu)* (spreading with 120 day maturity period) and *Etesot* (erect, 110-120 day maturity period). They were grown at farmers' low density (60 x 30 cm, approximately 6 plants/m^2) and high density (45 x 15 cm, approximately 15 plants /m^2). The experiment was laid out as a RCBD with 3 replications. The plot sizes were relatively large, 10 x 10m, for purposes of yield assessment, and to ensure farmers get reasonable yield from the experiment. Farmers in the trial sites had already adopted row planting of groundnut but they generally use wide spacing (60 x 30 cm) (Erbaugh & Kyamanywa, unpubl.). The trial was conducted in two sites, Ikulwe and Kumi, approximately 150 km apart. The season was characterised by late arrival of rains. At Ikulwe, the groundnut was planted on 20 December, 1997 and on 5 December, 1997 in Kumi, which in normal seasons are harvesting times. At both sites, there were two weedings corresponding to farmer assessment of weed infestation.

Data collection commenced two weeks post germination, and continued weekly for eight weeks. At each sampling date, a quadrat of 2x2 m was laid randomly in each experimental unit and the total number of plants counted. The number of plants with foliar deformation and those stunted were also recorded. Likewise, the number of plants with aphid infestation were recorded. Rosette severity was assessed on 10 plants using a scale of 1-5, where 1 = no rosette seen, 2 = 10-20% of plants showing rosette, 3 = >20-50% rosetted, 4 = > 50 - 80% rosetted, and 5 = plant completely stunted by rosette. At maturity all plants in each plot were uprooted, pods removed, dried and weighed.

Data collected are subjected to analysis of variance (ANOVA) using the General Linear Model Procedure of SAS. Aphid incidences and rosette virus disease indices are also related using correlation analysis.

Results

Etesot had poor plant stand at Ikulwe and hence, data for this variety are not considered for Ikulwe. Under low density, both

the farmer cultivar *(Erududuru)* and the improved cultivar *(Igola-1)* supported aphid infestation. In fact there were more aphids on the improved culivar than the local check. But, under high density, *Igola-1* supported relatively lower aphid infestation than the farmer cultivar. However, it is worth noting that planting the local cultivar at high plant population reduced considerably the aphid infestation. No aphids were detected during the first two weeks post germination, with most aphids being encountered during weeks 3-5, and thereafter, there was a decline in aphid infestation. It is also of interest to note that although aphids were not detected early in the season, rosette-like symptoms were apparent.

Damage by rosette usually causes foliar deformation and stuntedness. These indices were assessed in this study. Overall, there was markedly less foliar deformation in *Igola-1* than *Erududuru*. Planting density, however, showed no significant effect on the degree of foliar deformation. Similarly, there was markedly reduced stuntedness in *Igola 1* than *Erududuru* resulting in significantly reduced rosette severity in Igola 1 than *Erududuru*. In both cases, however, no effect of plant population was detected. In virtually all cases, deformation increased with crop growth.

Table 1 shows that there was no strong relationship between aphid incidence and foliar deformation, stuntedness and rosette severity. However, stuntedness and foliar deformation were strongly related (r = 0.528, P =0.001), as were stuntedness and rosette severity (r = 0.815, P = 0.001). At Kumi, *Igola-1* had significantly (P=0.01) fewer stunted plants than *Erududuru* but not *Etesot* (Table 2), and it yielded twice as much as *Erududuru*, a popular variety in the area.

Table 1. Correlation among indices used to assess rosette disease on a groundnut crop planted at Ikulwe, Uganda in December 1997.

Indices	aphid incidence (%)	(%) foliar deformation	Stuntedness (%)
Foliar deformation (%)	0.291NS		
Stutendness (%)	0.03NS	0.528**	
Rosette severity	0.112NS	0.222NS	0.815***

, * Significant at P=0.05 and 0.005, respectively; NS = Not significant at P=0.05

Table 2. Effect of Rosette virus on yield of three groundnut cultivars in Kumi during the late season of 1997

Cultivar	Mean no. of stunted plants/m^2	Yield (kg/plot)
Igola 1	0.16 b	9.10 a
Erududuru	5.03 a	4.48 b
Etesot	1.50 b	6.07 b
cv %	28.6	23.3

*Yield data for Ikulwe not yet available

Discussion

Our preliminary results clearly indicate that the newly released cultivar *"Igola-1"* greatly reduced foliar deformation, stuntedness and groundnut rosette severity in comparision to the farmers' local cultivars. However, resistance/tolerance seem to be directed at the virus rather than the aphid vectors since in some cases *Igola-1* supported higher aphid infestation than the farmer's cultivars. And, except for aphid infestation, higher plant population did not reduce rosette severity. We attribute this lack of effectiveness to the heavy *El-Nino* rainfall which adversely affected germination of *Igola-1*, and masked the plant density effect. Other authors (e.g. Emechebe, 1975) have indicated that high plant populations greatly reduced rosette incidence, as a result of reduced aphid vector activity.

Our results also indicate that aphid infestation were highest 3-5 weeks post germination. The practical implication is that when heavy aphid infestation are anticipated, farmers should apply insecticides, possibly 2-3 weeks post germination. It is also clear from our results that farmers can almost double their yields by growing the improved rosette resistant cultivar *Igola-1*. The on-farm trials have already led to high demand for *Igola 1* in the study areas. Currently, 1 bag of *Igola-1* seed in-shell costs 40,000-50,000 Ug. Sh. (US $35-43) as compared to other varieties which fetch 20,000-30,0000 Ug. Sh. (US $ 17-26).

Although we failed to demonstrate the effectiveness of high plant population density on reducing rosette severities at farm level, we will persue this further since the effectiveness of high plant population has been shown to suppress many aphid-virus transmitted diseases (Ogenga-Latigo *et al.*, 1992; Edema *et al.*, 1997). One problem though with high groundnut plant population is that it favours build-up of Cercospora leaf spot diseases. We will also assess the occurrence and severities of Cercospora leaf spots in future trials. We are also still to evaluate the effects of time of planting on rosette epidemics. Our investigations will continue to focus on Farmer Participatory Research so as to encourage adoption of IDM packages envisaged.

Impact

The farmers are demanding for Igola-1 seeds. Farmers participating in the groundnut trials are selling Igola-1 to other farmers at a cost of US 35-43 per bag of shell groundnuts, as com pared to other varieties fetching US $ 20-30 per bag.

Networking

NARO, Makerere University and Extension organised an open day to allow other farmers see the groundnut trials.

Project Highlights

- Igola-1 an improved variety had significantly lower incedence of groundnut rosette com pared to the local varieties, Erudurudu and Etesot.
- Igola-1 significantly out yielded the local varieties.
- High groundnut plant density reduced aphid incidence.

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Management of Insect Pests on Millet and Sorghum

Investigators: Gamby Kadiatou Touré[1], John S. Caldwell[2], and C. Richard Edwards[3]

Collaborating Scientists: Sissoko Haoua Traoré[1] and Diakité Mariam Diarra[1]

Abstract

Results from on-farm research on the management of insect pests of pearl millet *(Pennisetum americum)* were analyzed from the 1997 cropping season (July-November 1997), and on-farm trials were installed in the 1998 cropping season (July-November 1997, in four villages in north central Mali. In the 1997 research, light traps were used for assessment of insect pest populations, installed in millet and fallow fields and illuminated each night from 5 August to 14 October 1997. The blister beetles *Psalydolytta* spp. and *Mylabris* spp. reached their highest numbers in late August and early September, the same time period as in 1996. The insect pest captured in greatest numbers was the scarab beetle *Ryinyptia infuscata.* Neem decreased blister beetle counts on millet heads by 75-76% and increased yield by 86% (391 kg ha^{-1}) over the farmer control. *Bacillus thuringiensis* decreased blister beetle counts on millet heads by 52-57% and increased yield by 56% (256 kg ha^{-1}) over the control. Mean blister beetle counts were 12.3 beetles/ head in 1997, compared with 1.5, 3.4, and 7.7 beetles / head in 1996, 1995, and 1994, respectively. Millet grown in association with sorghum had fewer beetles / head and higher yield, compared with millet grown in pure stand. Two varieties with tolerance to blister beetles, 'GRP1' and 'M2D2', had higher yields than the local control. Blister beetles were 3.4 times greater in number and millet yields higher in fields without light traps compared to counts taken 5 m from traps, and an effect was seen out to 50 m from the trap. Pheromone traps reduced stem boring by *Acigona ignefusalis* and increased millet yield increased out to 50m, and yield was 50% higher at

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5m from the traps compared with fields without traps.

Objectives

1. To study the population dynamics of blister beetles *Psalydolytta* spp. and *Mylabris* spp., the scarab beetle *Rhinyptia infuscata*, and other pest insects in millet and fallow fields.

2. To evaluate the effectiveness of *Bacillus thuringiensis* in comparison with neem extract for control of blister beetles on millet;

3. To evaluate the effectiveness of sorghum as an intercrop in providing associational resistance for reduction of blister beetles on millet;

4. To evaluate the tolerance of introduced millet varieties to blister beetles under on-farm conditions in two zones;

5. To quantify the extent of the reduction by light traps of blister beetle populations observed by farmers, and assess potential of light traps as a control method for blister beetles;

6. To assess the effectiveness of pheromone traps to reduce stem boring in millet by *Acigona ignefusalis*.

IPM Constraints

Blister beetles (Coleoptera: Cantharidae) are the most important insect pest of pearl millet *(Pennisetum americum)*, the principal cereal crop of the Sahelian region of West Africa. Gahukar (1991) reviewed reports on the collection of 97 species of blister beetles in West Africa and concluded that *Psalydolytta fusca* and *P. vestita* were the most important blister beetle species attacking millet in Chad, the Gambia, Mali, Mauritania, Niger, and Senegal. In assessing various control methods, Gahukar pointed out the impracticability and danger of conventional insecticides under Sahelian environmental and socio-economic conditions. He recommended use of safe insecticides in ultra-low volume formulations.

Since 1994, the IPM CRSP has worked in north central Mali to carry out participatory on-farm research on pest problems of Sahelian agriculture. Millet grown in association with cowpea is the principal crop of farmers in this region. Both the Participatory Assessment of 1994 (Caldwell *et al.*, 1994) and a farmer evaluation of IPM on-farm research in 1996 (Erbaugh *et al.*, 1996) indicated that blister beetles were among the three most serious pests of millet/cowpea association in this region. Since its inception in 1994, the research program has tested multiple approaches to blister beetle control. One approach has been the use of oil from the seed of the neem tree (*Azadirachta indica*), an introduced tree widely grown in West Africa today. Oil from its seed contains more than 50 triterpenoid substances. The biologically active substance azadirachtin, a tetranortriperpenoid, a mixture of many isomers, has insecticidal properties.

Several other approaches have potential for blister beetle control. One is use of *Bacillus thuringiensis* tenebrionis, which is specific to coleopteran insects. Another is the use of millet varieties with tolerance to blister beetles, able to maintain acceptable yield levels in the presence of infestations that cause large yield losses in farmer varieties. Station research in Niger and Mali has identified several varieties of millet with such tolerance to blister beetles. A third approach is the use of associational resistance (Altieri and Letourneau, 1982), through a mixture of millet and sorghum. In contrast with millet, sorghum is unattractive to blister beetles. The presence of sorghum in association with millet can confuse blister beetles and prevent their colonization on millet heads. A fourth approach is the use of light traps as a control method. This was proposed by farmers after the 1996 cropping season. We have used these traps as a monitoring tool in IPM CRSP on-farm research since 1995; farmers stated that their informal observations suggested that the light traps reduced blister beetle infestation on the millet crop in the vicinity of the trap.

Other important insect pests of millet include the scarab beetle *Rhyniptia infuscata*, the head miner *Heliocheilus albipunctella* (widely-used synonym from older taxonomy: *Rhaguva albipunctella*), and the stem borer *Acigona ignefusalis* (widely- used synonym from older taxonomy: *Coniesta ignefusalis*). *R. infuscata* has entered Mali from Niger, and monitoring in 1995 and 1996 showed its increasing prevalence. Adults feed on millet heads, impeding grain formation and resulting in as much as 80% loss of yield (UCTR/PV, N.d.). *H. albipunctella* is found in all West African countries (UCTR/PV, N.d.), and it was ranked second in severity by male farmers in one of the four villages in the 1994 PA (Caldwell *et al.*, 1994). It was also one of three pests ranked equally in severity by farmers after the principal pests of blister beetles and *Striga* spp. parasitic weed in the 1996 farmer evaluation (Erbaugh *et al.*, 1996). *A. ignefusalis* may damage 50 to 100% of millet stems under Sahelian conditions (UCTR/PV, N.d.).

Research Methods

Insect monitoring and on-farm experimentation were conducted in four villages in two zones in north central Mali: Koïra and Douabougou in the semi-arid, more northern zone of the Mourdiah *arrondissement* (sub-county) (between the 400 and 500 mm isohyets); and Koroma and Dontiéribougou in the semi-humid, more southern zone of the Sirakorola *arrondissement* (~600 mm isohyet) (Traoré and Monnier, 1980).

We report here on the following results:

- the third year of results of monitoring of the population dynamics of key pest insects;

- the first year of comparison of the effects of a botanical control method, village-prepared neem oil applied in Ultra Low Volume (ULV), and a biological control method, *Bacillus thuringiensis* tenebrionis ('M-Trak'), on blister beetle populations, damage and millet yield;
- the second year of assessment of the effects on insect pest populations and yields of millet of millet varieties tolerant to blister beetle infestation, and the of planting millet in association with sorghum;
- the first year of assessment of the use of light traps as a control measure for blister beetles and the use of pheromone traps as a control measure for *A. ignefusalis.*

This research was carried out in the field from June 1997 to January 1998 (overlapping IPM CRSP years 4 and 5), and data entry and analysis were done from February to May 1997.

Field research during this cropping season (June 1998-January 99, overlapping IPM CRSP years 5 and 6) is currently underway, and a progress report on this research is provided after the discussion of results from the 1997-98 cropping season.

Population dynamics of insect pests: Light traps were placed in one millet field and one fallow field per village, for a total of eight traps. Each trap consisted of a round metal container supported by a tripod. Water and detergent were placed in the container. The container was open to the air but covered by a conical roof mounted on poles above it. A kerosene lamp was hung from the center of the cone, below the cone but above the top of the container. The lamp was lit each night at sundown (~ 17:00) and extinguished the following morning (~ 7:00). During the night, insects were attracted by the light of the lamp, but when they got too close to the lamp, they were stunned by the heat and fell into the water in the container below. Insects were collected and counted daily from 5 August to 21 October 1997. Daily counts were summed over weekly intervals.

Botanical and biological agents: Treatments were applied on the millet fields of 12 farmers in four villages. Each field was divided into four plots of 625 m^2 and one of three treatments was assigned to each plot: (1) farmer control; (2) locally-prepared neem oil at the rate of 2 l ha^{-1}; (3) *Bacillus thuringiensis* tenebrionis ('M-Trak') at the rate of 3.7 l ha^{-1}. This was the first year to include treatment (3), while treatment (2) used the same rate as in 1995 and 1996 trials, but with a different application method, Ultra Low Volume (ULV).

Neem oil was prepared locally in each village according to the procedures of Gamby *et al.* (1998). Both neem oil and *B.t.* were applied 2 times, once at heading and once at flowering. Neem oil was applied using an Ultra Low Volume sprayer, rather than by a conventional sprayer in which the neem oil was mixed with kerosene, as in 1995 and 1996.

All data were taken from five 25 m^2 sampling squares per treatment. The number of blister beetles on 10 heads per square (50 heads total per treatment) was counted 24 h before and 24 h and 48 h after treatment application. At harvest, the numbers of heads with damage from blister beetles (*Psalydolytta* spp. and *Mylabris* spp.), head miners (*Heliocheilus albipunctella),* grasshoppers, and birds were counted using the same 10 heads. Millet heads were harvested, threshed, and weighed from each sample, and data pooled to determine yield per treatment. Farms were treated as replications within villages. Results are reported for 11 farms with usable data.

Millet/sorghum association: In the second year of this trial, three treatments were established on 12 farmers' fields in the four villages. (1) millet in pure stand (2) millet in alternating rows with sorghum; (3) sorghum in pure stand. Each treatment was applied to a 20 m^2 plot, and replicated across farms in a randomized complete block design. Numbers of blister beetles were counted at heading and flowering, and yields determined at harvest. Results are reported for nine farms with usable data.

Insect-tolerant millet varieties: In the second year of this trial, six treatments were applied on the millet fields of 12 farmers in the four villages. The same five improved varieties found to have tolerance to insect pests in on-station research used in the first year in 1996 were compared with the farmer local variety of millet, *souna.* The improved varieties were: 'M2D2,' 'Toroniou C1,' and 'Pool6' (from Mali), and 'GRP1' and 'Zatib' (from Niger). The number of blister beetles of both species were counted on 10 heads three times from mid-September to early October. The number of heads damaged by head miners *H. albipunctella* was counted. Days to flowering, number of suckers, and head characteristics were also recorded. Results are reported for nine farms with usable data.

Use of light and pheromone traps: A transect design was used in the first year of this trial in 1997 to test the effects of light and pheromone traps. Light traps of the design of Gamby were placed in a millet field of six farmers in Sirakorola. Counts of the number of infested heads at heading out, flowering, and milky stages were made at sampling stations 5, 10, and 50 m from the trap. The percentage of damaged heads and yields were also measured at the same stations. Similar counts were also made in the center of an adjacent millet field without a light trap. Pheromone traps were placed in a millet field of three farmers in Sirakorola. Observations were made at stations 5, 10, and 50 m from the trap and in an adjacent field without a pheromone trap, as with the light traps.

Research Results

Population dynamics of insect pests: In the two drier, more northern villages of Mourdiah, blister beetles *Psalydolytta* spp. and *Mylabris* spp. reached their highest numbers in early September, the same time period as in 1996. Counts were 6.8 times greater at the peak in 1997 (230) compared to 1996 (34). A second peak in early August with populations nearly as great (221) as in early September also appeared in 1997 (Figure 1). In the wetter, more southern villages of Sirakorola, blister beetle populations were much lower (1/20 of Mourdiah at the peak). Overall, blister beetles were present in higher numbers in 1997 than in 1996, but 40% lower at the peak (21 beetles). The late August peak came at the same time in both years (Figure 2).

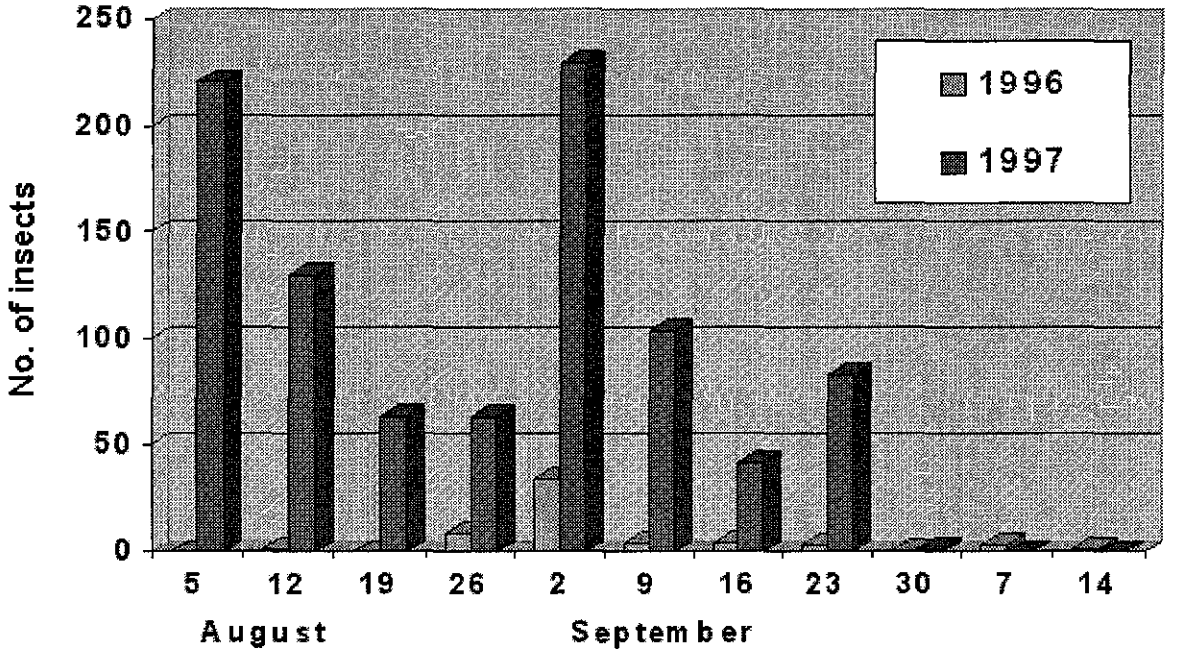

Figure 1. Numbers of Blister Beetles, Mouridah, 1996-1997

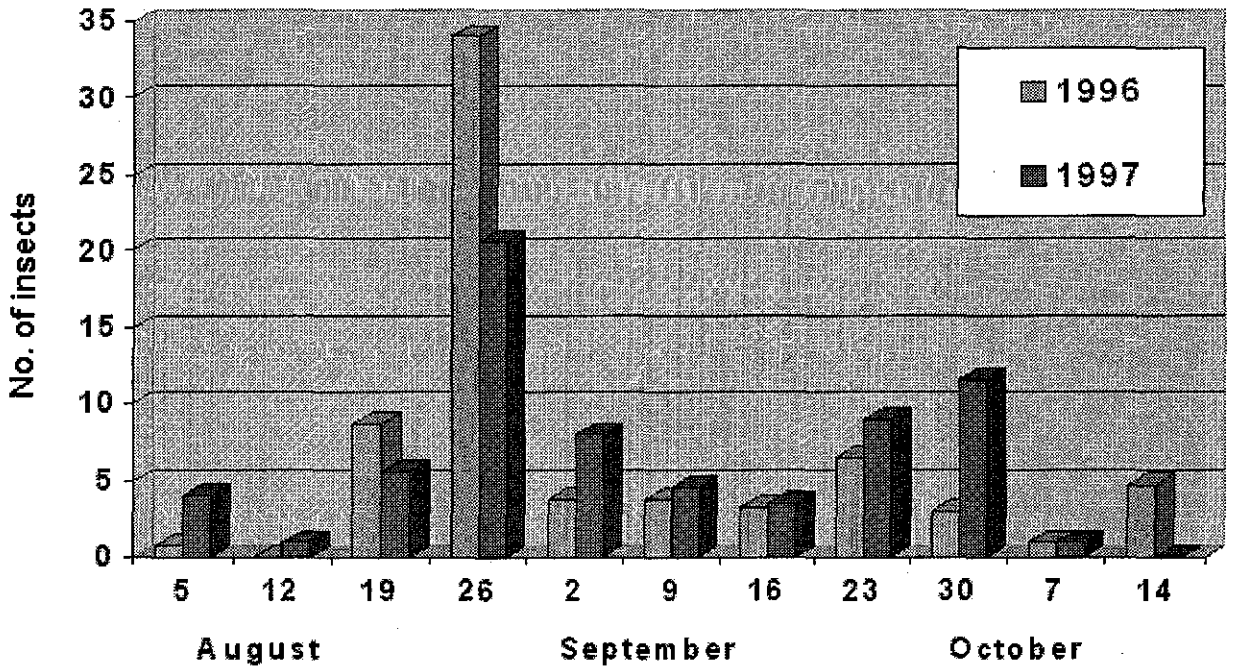

Figure 2. Numbers of Blister Beetles, Sirakola, 1996-1997

The most important insect pest captured in the traps in Moudiah was the scarab beetle *Rhinyptia infuscata*. Numbers were much higher in 1997 than in 1996. There were two population peaks (late August - early September

and late September) (Figure 3). Numbers of *R. infuscata* were much lower in Sirakorola in 1997 than in 1996, and lower than at Mourdiah in 1997. Their peak was in mid-August (Figure 4).

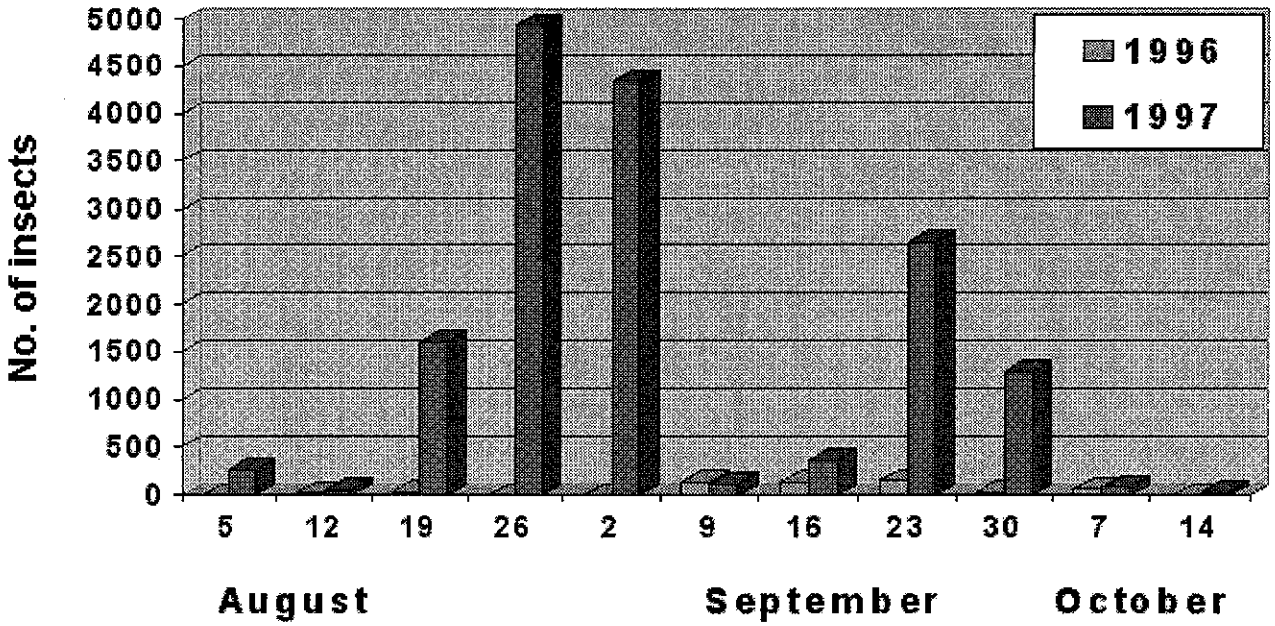

Figure 3. Numbers of *R. infuscata*, Mourdiah, 1996-1997

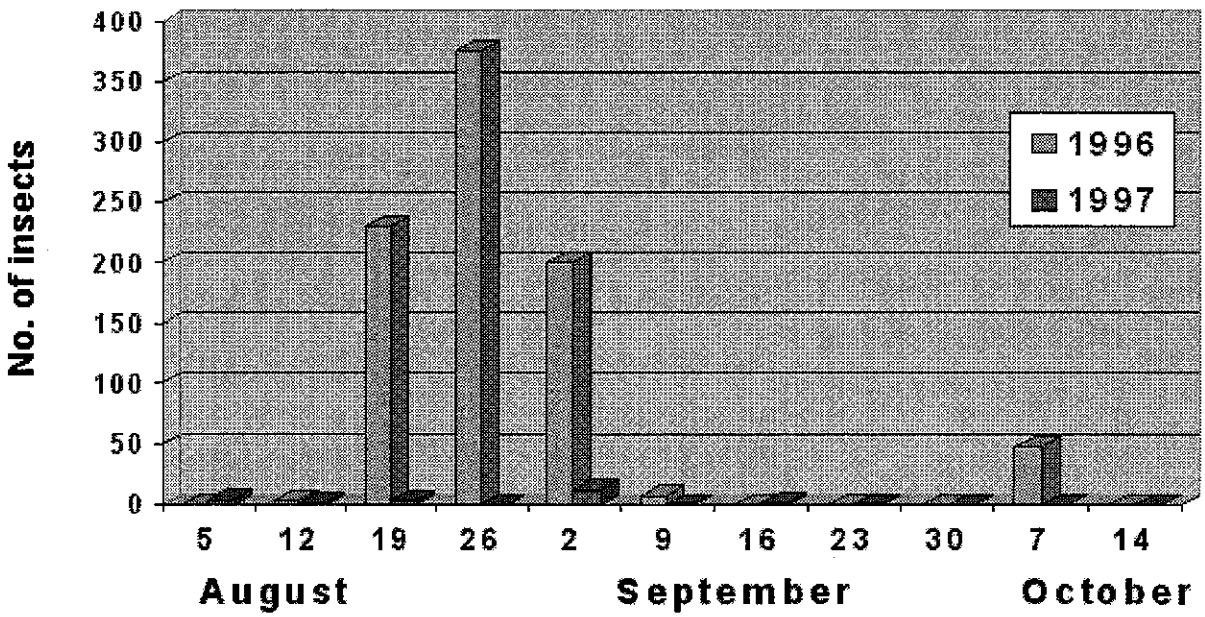

Figure 4. Numbers of *R. infuscata*, Sirakorola, 1996-1997

Counts of *Heliocheilus albipunctella* were 11 times higher at Mourdiah than at Sirakorola in 1997. There were three peaks in Mourdiah in 1997, early August, late August, and late September. Peaks similarly occurred in late August and late September in Sirakorola (Figures 5-6).

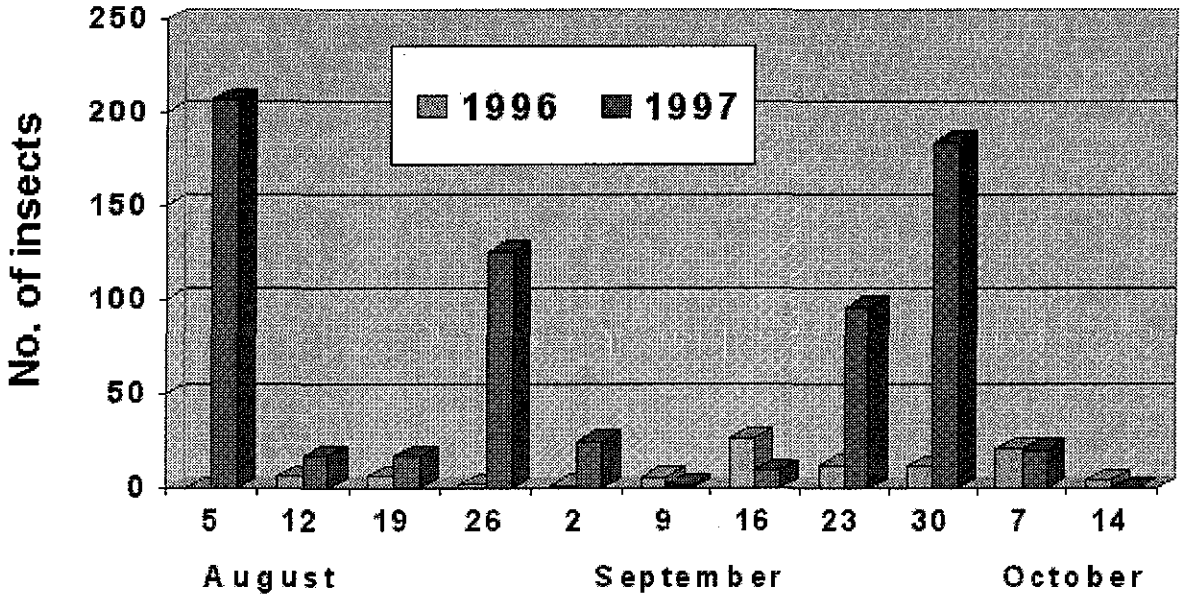

Figure 5. Numbers of *H. albipunctella*, Mourdiah, 1996-1997

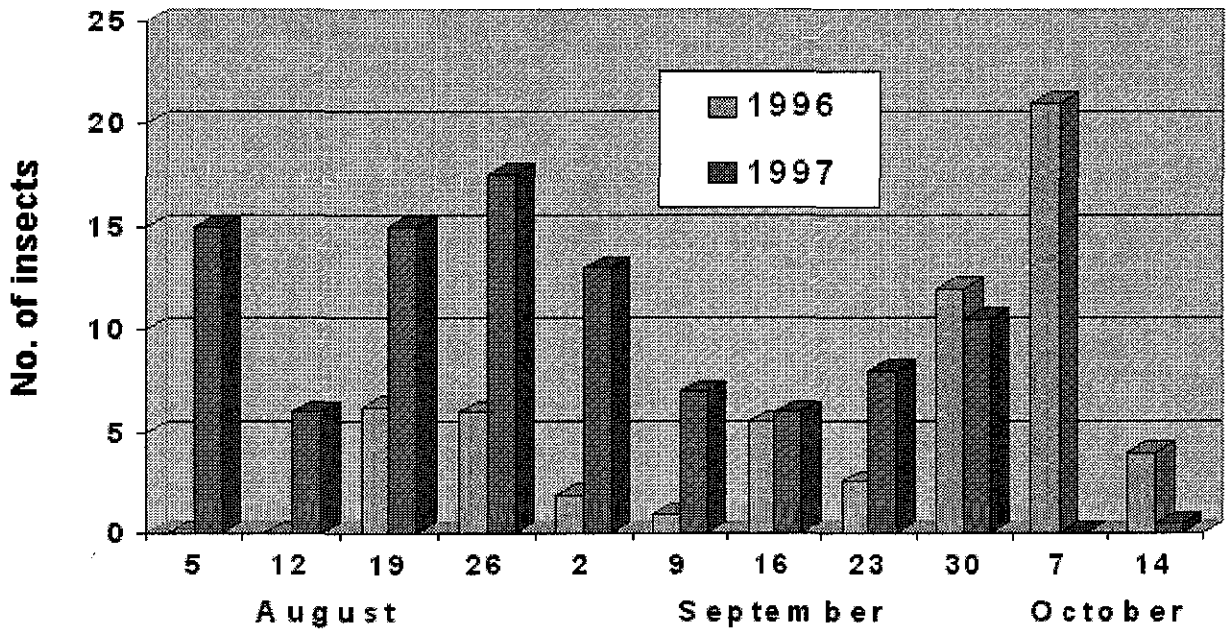

Figure 6. Numbers of *H. albipunctella*, Sirakorola, 1996-1997

Botanical and biological agents: Across all villages, *B.t.* and locally-pressed neem oil decreased the number of blister beetles 24 and 48 hours after application. Neem reduced beetles by 75-76%, compared to 52-57% with *B.t.* Differences in counts among treatments were highly significant at both 24 h and 48 h after application. Repeated measures analysis for the 3 counts showed that the decrease over time was highly significant for the difference in counts between the farmer practice (absence of control measures, for which insect counts shown in figure 7 were similar across all three times of counts) and the introduced practices (neem oil and *B.t.*, for which insect counts decreased after application of neem oil and *B.t.*).

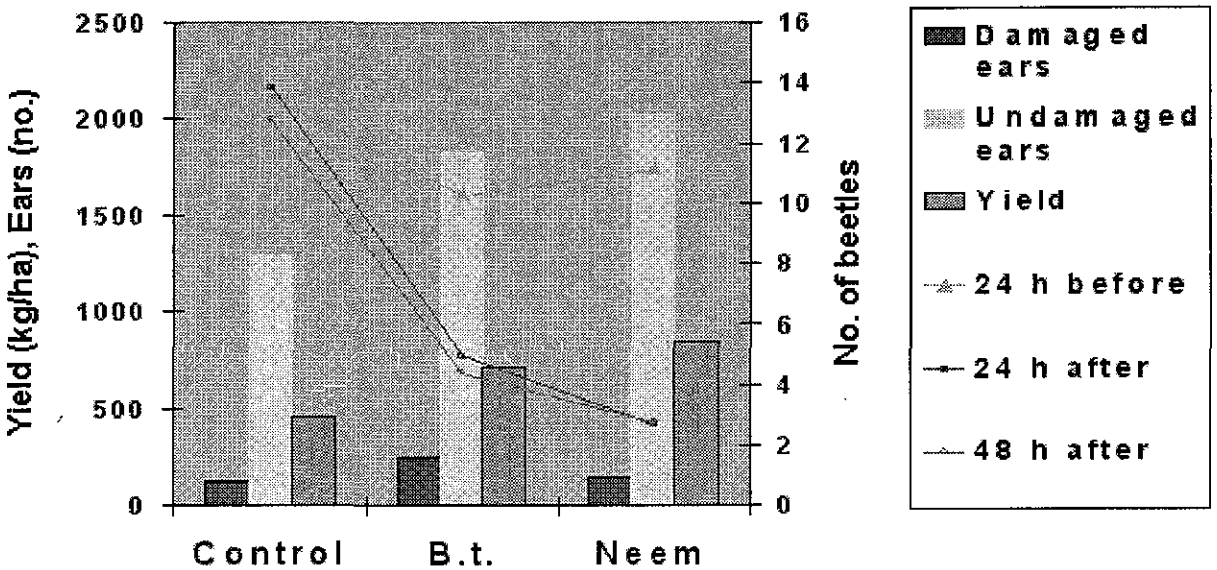

Figure 7. Effect of Neem and *B.t.* on Millet Ear Damage, Yield, and Blister Beetle Counts, Mali, 1997

The effect of time on the difference in counts between neem oil and *B.t.* was highly significant at 24 h after application, but not at 48 h after application (Table 1).

Table 1. Repeated measures analysis of variance using single-degree of freedom contrasts for effects of time after application on blister beetle counts after application of neem oil, *Bacillus thuringiensis*, and absence of control measures on millet under semi-arid (Mourdiah zone) and semi-humid (Sirakorola zone) conditions in Mali.

Source of variation	24 hours after vs. 24 hours before		48 hours after vs. 24 hours before	
	F-values	Probability of significant differences	F-values	Probability of significant differences[z]
zones	0.03	0.8740	0.36	0.5648
villages within Mourdiah	4.49	0.0719 +	0.11	0.7544
villages within Sirakorola	2.43	0.1630	0.01	0.9432
farms within villages	2.42	0.0759 +	3.29	0.0276 *
farmer practice vs. introduced measures	44.76	0.0001**	21.20	0.0004**
neem oil vs. *Bacillus thuringensis*	13.33	0.0026**	0.02	0.8991

z = +, *, ** Differences in counts with trend at p < 0.10, significant at p< 0.05, or highly significant at p< 0.01.

Decreased insect pressure at the critical time of risk to the crop was reflected in both ear quality and yield. Numbers of damaged ears were similar across treatments, but numbers of undamaged ears were increased by both protective treatments, *B.t.* and neem oil. As a result of this increase in undamaged ears, total yield in plots with *B.t.* (711 kg · ha^{-1}) was increased 56%, and total yield in plots with neem (846 kg · ha^{-1}) was increased by 86%, over the control (455 kg · ha^{-1}). Both the difference between the introduced measures and the control, and the difference between neem and *B.t.*, were highly significant.

The direction of these results was the same across both zones, and there were no significant interactions between zones and treatments or villages within zones and treatments. However, the size of the effects was significantly different between the semi-arid Mourdiah zone and the semi-humid Sirakorola zone, reflecting significant differences between the zones. Insect pressure was higher in Mourdiah (17 beetles / head) than in Sirakorola (6 beetles / head). As a result, the magnitude of the yield increase was greater in Mourdiah (421 kg · ha^{-1}) than in Sirakorola (362 kg · ha^{-1}). However, farmer control yield levels were higher in Mourdiah (584.2 kg · ha^{-1}) than in Sirakorola (325.3 kg · ha^{-1}). Thus, the effect of *B.t.* and neem on yield increase was proportionally greater in the Sirakorola villages (70-111%) than in the Mourdiah villages (49-72%) (Table 2).

Table 2. Analysis of variance using single-degree of freedom contrasts for effects of neem oil, *Bacillus thuringiensis*, and absence of control measures on yield of millet under semi-arid (Mourdiah zone) and semi-humid (Sirakorola zone) conditions in Mali.

Source of variation	F-value	Probability of significant differences[z]
zones	8.55	0.0222 *
villages within Mourdiah	14.72	0.0064**
villages within Sirakorola	0.08	0.7798
farms within villages	10.54	0.0001**
farmer practice vs. introduced control measures	94.40	0.0001**
neem oil vs. *Bacillus thuringensis*	12.30	0.0035**

z = *, ** Diferences in counts significant at p≤ 0.05 or or highly significant at p<0.01.

In 1994, blister beetles populations (7.7 beetles / head) were well above the threshold of 2 beetles / head, and the use of the commercial neem product 'Azatin' resulted in a 53% increase in season millet yield. In 1996, under lower overall blister beetle pressure (3.4 beetles / head), there were no significant differences in yield. Blister beetle populations were even lower in 1996 (1.5 insects / head), and again yield differences were not significant, despite apparent increases of 11% and 23% with 'azatin' and local 'neem.' In 1997, blister beetle populations were the highest of the four years (12.3 beetles / head). In addition, application was done using an Ultra Low Volume (ULV) sprayer, whereas application had been done in the previous three years using a conventional sprayer in which neem oil was mixed with water or kerosene (Figure 8). Neem oil and water have poor miscibility, and their use in conventional sprayers can result in uneven neem oil coverage within plots and greater heterogeneity among farmers. As a result, neem had more effect, and significant yield increases were obtained.

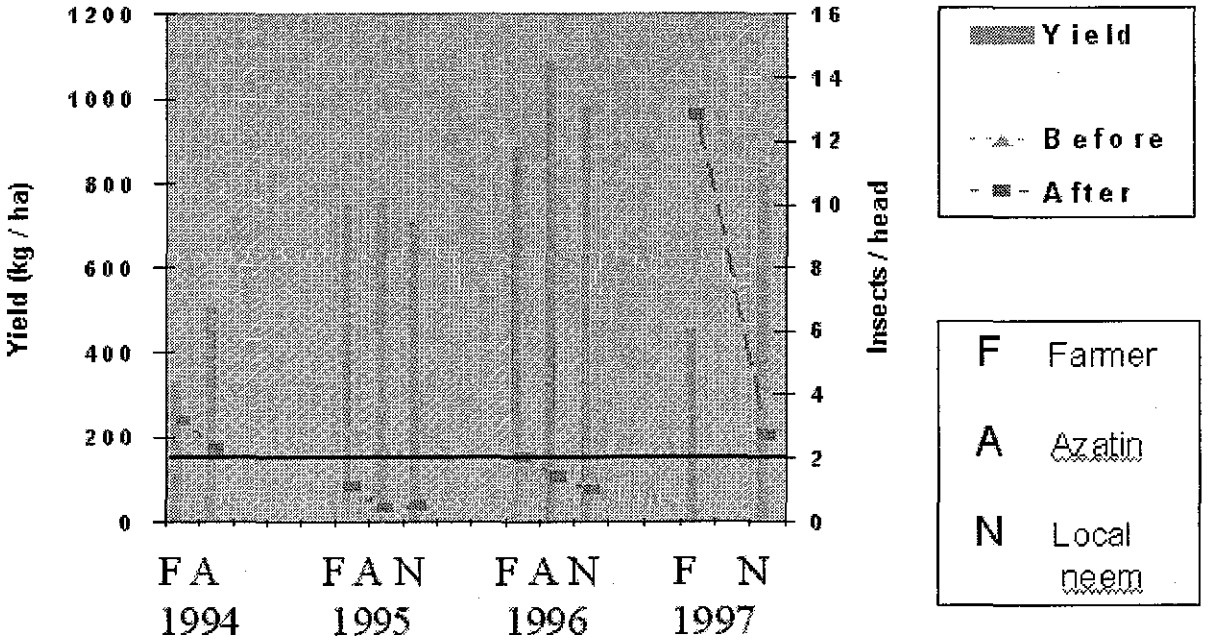

Figure 8. Effect of Neem on Millet Yield and Blister Beetle Counts, Mali, 1994-1997

Millet/sorghum association: The number of blister beetles on millet at heading and flowering stage were less when millet was grown in association with sorghum in Dontiéribougou in the Sirakorola zone, compared to when it was grown as a sole crop. Differences were significative at the flowering and heading stage, and well as for yield (Figure 9). These effects were reflected in yields, which were increased by 114% (321 kg · ha^{-1}) in the Sirakorola zone. These results are consistent with results obtained in the 1996 millet/sorghum association trial (Gamby *et al.*, 1998) (Table 3).

Table 3. Analysis of variance for effect of asssociation of sorghum with millet on insect counts and yield of millet under semi-humid conditions, Sirakorola zone, Mali.

Variable	F-value	Probability of significant differences[z]
Insects at heading stage	20.46	0.0106 *
Insects at flowering stage	10.94	0.0297 *
Insects at milky stage	6.13	0.0686 +
Yield (kg / ha)	16.13	0.0159 *

z = +: Differences in counts with trend at $p < 0.10$ or significant at $p < 0.05$.

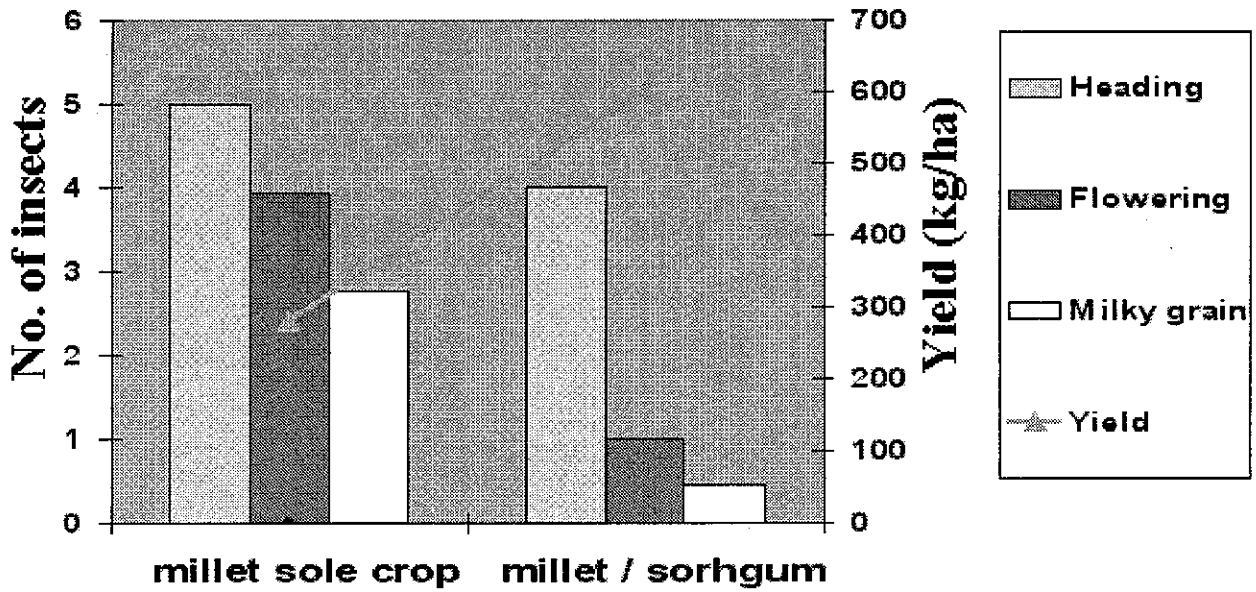

Figure 9. Effect of Sorghum Association on Millet Yield and Beetle Counts, Sirakorola, Mali, 1997

Insect-tolerant millet varieties: The performance of the six varieties varied depending on zone, but the patterns in 1997 were similar to those in 1996. In Mourdiah, 'GRP1' had the highest yield in 1997, as in 1996, despite its also having the highest percentage of damaged heads (Figure 10). A positive correlation (r = + 0.60) between yield and percentage of damaged heads was not significant. In Sirakorola, 'M2D2' had the highest yield in both years Figure 11). Yield was negatively correlated with the percentage of heads attacked (r = -0.87). The differences in the percentage of heads attacked and yield in 1997 were statistically significant in Koroma, but not in Dontiéribougou, where overall yield levels were low (492 kg· ha^{-1}, compared to 1,271 kg · ha^{-1} in Koroma) (Table 4).

Table 4. Analysis of variance for effect of millet variety on insect counts and yield of millet under semi-humid conditions, Koroma, Sirakorola zone, Mali.

Variable	F-value	Probability of significant differences[z]
Insects at heading stage	1.19	0.3814
Insects at flowering stage	1.10	0.4186
Insects at milky stage	0.93	0.4988
Number of heads attacked	8.64	0.0021**
Yield (kg / ha)	3.74	0.0361 *

z = *, ** Differences in counts significant at p< 0.05 or highly significant at p<0.01.

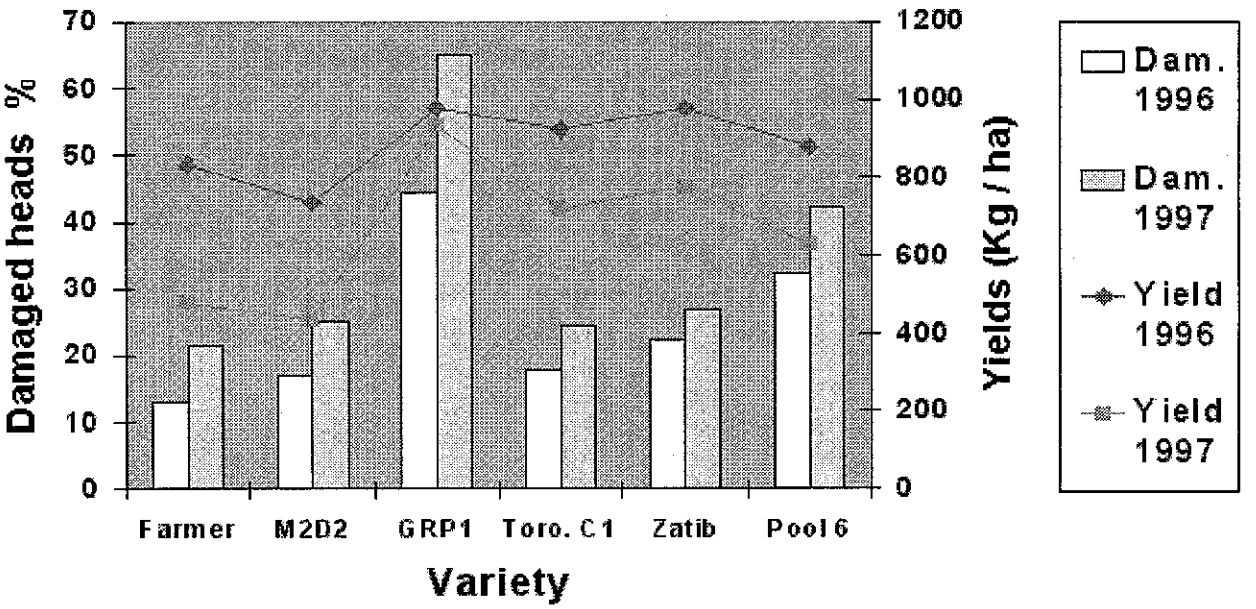

Figure 10. Effect of 6 Varieties on Millet Yield and Blister Beetle Damage, Mourdiah, 1996-1997

Use of light and pheromone traps: Similar patterns in the effects distance from light traps on blister beetle counts and yield were seen in both Sirakorola villages, Koroma and Dontiéribougou. The increase in numbers of blister beetles / head was greatest at heading, with 3.4 times as many beetles in the field with no trap and 1.9-2.3 times as many at 50 m, than at 5 m from the trap. There were significant linear effects for all 3 counts at Koroma, and for counts at the milky stage at Dontiéribougou. There was a significant correlation (r = +0.82) between the number of damaged heads and infestation, but the negative correlations between yield and infestation (r = -0.40) and yield and number of damaged heads (r = -0.13) were non-significant. Yields showed a significant linear effect, decreasing with distance from the trap, and lowest in the field without traps in both villages. The percentage of stems with holes bored by the stem borer *A. ignefusalis* increased at all three stages (tillering, heading, and maturation) as a function of distance from the pheromone trap. At each stage, the increases were significantly linear. The increase was greatest at tillering, with percentages 4.6 times greater in the field with no trap and 2.8 times greater at 50 m, than at 5 m from the trap. However, there was no significant correlation between percentage of stems with boreholes and yield (r = -0.13). Yield was 50% higher at 5 m from the trap, compared to the field without the trap. However, yield differences between 5 m and 50 m from the trap were small (<3%), and overall the linear effect of distance on yield was not significant (Figures 12,13, 14, and Tables 5 and 6).

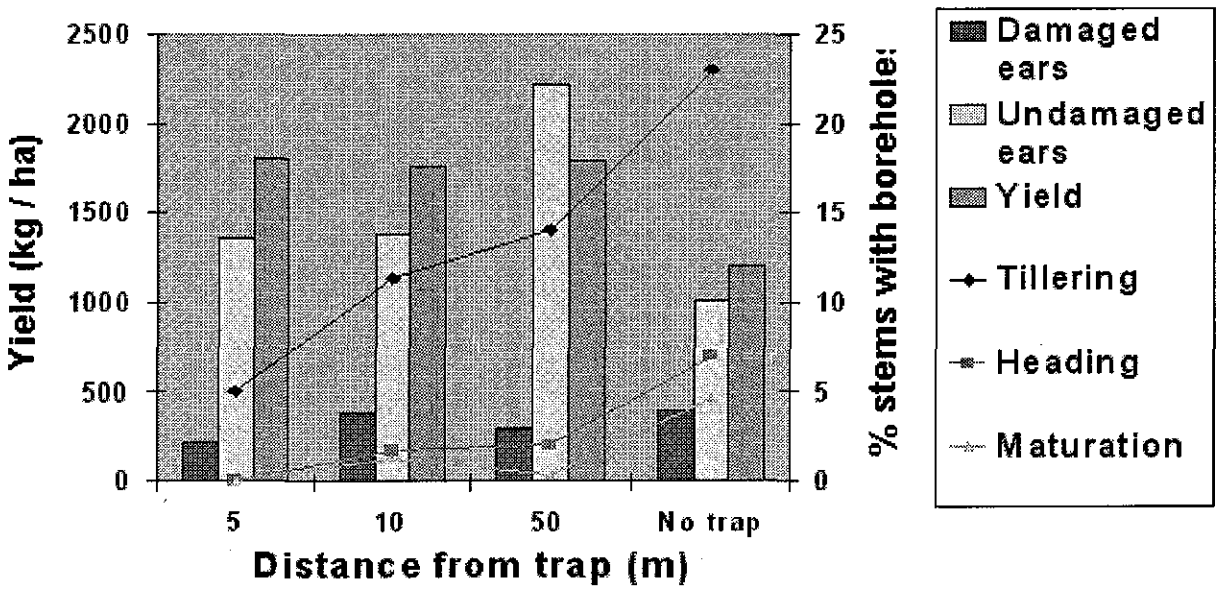

Figure 12. Effect of Distance from Pheromone Trap on Millet Damage and Yield and Stem Borer Counts, Dontieribougou, 1997

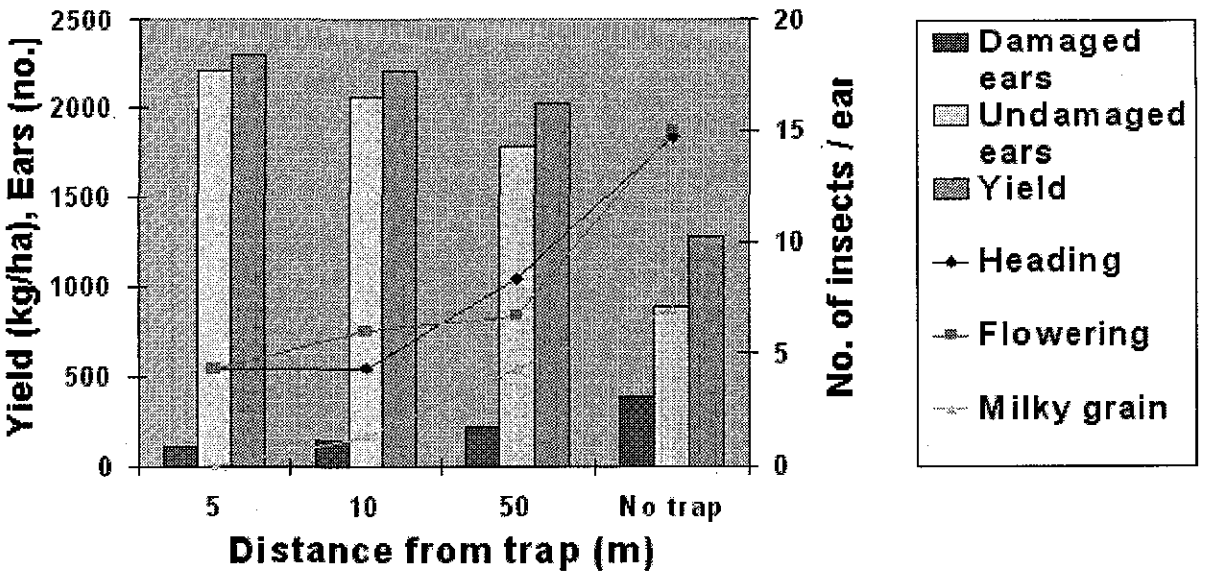

Figure 13. Effect of Distance from Light Trap on Millet Damage and Yield and Blister Beetle Counts, Koroma, 1997

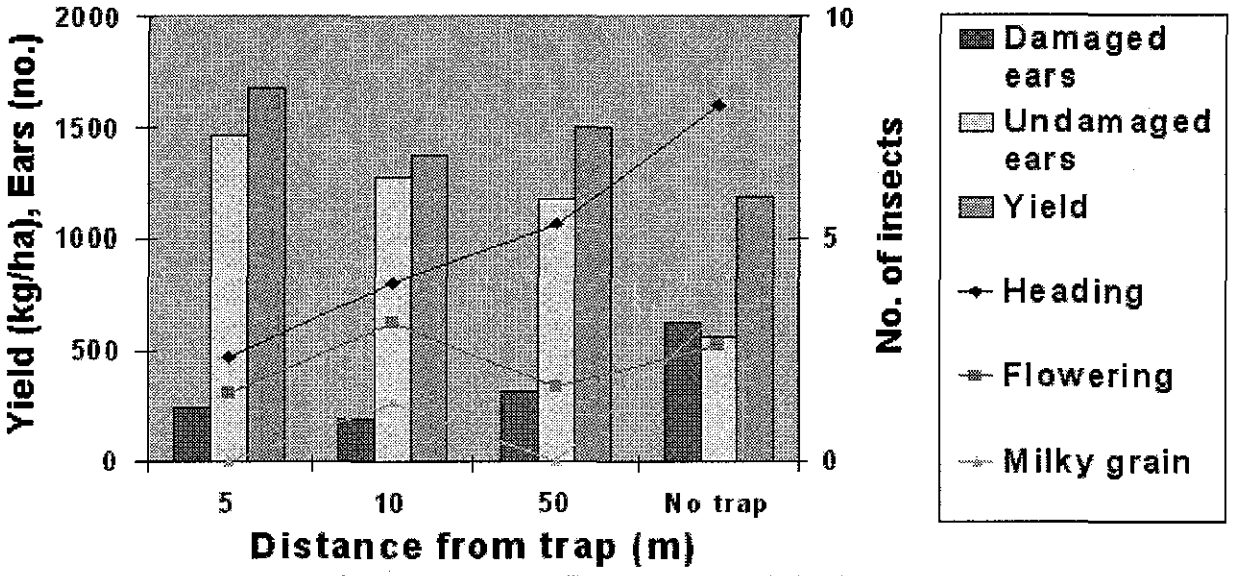

Figure 14. Effect of Distance from Light Trap on Millet Damage and Yield and Blister Beetle Counts, Dontieribougou, 1997

Table 5. Analysis of variance for linear effect[z] of distance from light trap on blister beetlecounts and yield of millet under semi-humid (Sirakorola zone) conditions in Mali.

Variable	Koroma		Dontiéribougou	
	F-values	Probability of significant differences	F-values	Probability of significant differences[y]
blister beetle counts at heading	31.53	0.0014**	5.17	0.0634 +
blister beetle counts at flowering	7.83	0.0312 *	1.09	0.3376
blister beetle counts at milky stage	10.72	0.0169 *	7.20	0.0364 *
yield	5.30	0.0001**	3.85	0.0973**

[z] = Quadratic and cubic terms also tested in the model were not significant for all variables in both villages.

[y] +,*,** = Differences in counts with trend at p< 0.10, significant at p< 0.05, or highly significant at p< 0.01.

Table 6. Analysis of variance for linear effect[z] of distance from pheromone trap on counts of the stem borer *Acigona ignefusalis* and yield of millet under semi-humid (Sirakorola zone) conditions in Mali.

Variable	F-values	Probability of significant differences[y]
blister beetle counts at tillering	22.97	0.0030**
blister beetle counts at heading	38.65	0.0008**
blister beetle counts at maturation	9.89	0.0199 *
yield	5.98	0.0500 +

[z] = Quadratic and cubic terms also tested in the model were not significant for all variables in both villages.

[y] +,*,** = Differences in counts with trend at p < 0.10, significant at p< 0.05, or highly significant at p< 0.01.

Progress Report on Year 5 Trials (1998-1999 Agricultural Season): IPM CRSP Year 5 trials combine results of trials for the management of insect pests and *Striga* spp. parasitic weeds in integrated comparisons. These trials are underway in the 1997-1998 agricultural season, which will end in January 1998. The number of farmers and the dates of installation (seeding and where necessary due to poor stand, reseeding), are shown in Table 7 below.

Table 7. Dates of seeding of 1997-98 agricultural season integrated insect-weed-disease management research trials

Zone and Village	Number of farmers		Dates of trial installation	
	Seeded	Reseeded	Seeding	Reseeding
Sirakorola				
Dontiéribougou	5	1	8/1-8/7	8/16
Koroma	5	2	7/27-31	8/11
Mourdiah				
Koïra	5	1	7/26-8/2	8/15
Douabougou	5	0	7/25-8/10	-----
Total	20	4		

Impact

Population dynamics of insect pests: Monitoring confirmed that the peak period of blister beetle appearance is relatively stable even though populations may fluctuate nearly seven-fold from one year to another, as was observed in 1997 compared to 1996. This provides farmers with the

knowledge of the period when they should plan to have neem or *B.t.* available as a control measure.

Botanical and biological agents: The results obtained in 1997 confirmed the hypothesis that neem applied as ULV would be more effective than *B.t.* bioinsecticide in the first year of application. These results also show the importance of multiple year assessment of control measures. Populations of blister beetles are highly variable from year to year, and over four years, the effectiveness of the use of neem has depended on the level of infestation. In 1995 and 1996, at levels of 4 beetles or less per head, reductions of beetle numbers were small and yields were affected less. At the higher levels of infestation, 7 beetles / head or more, observed this year, 1997, as well as in 1994, effects on yield are more substantial. Farmers thus need to monitor beetle levels to make a decision about the use of neem. These results suggest that only in about half of the years would neem application be justified.

These results also confirm the validity working in both of the two zones, semi-arid and semi-humid. Performance is not the same in the two zones, so extrapolation from one zone to another provides a less accurate indication of the potential impact of control measures.

Millet/sorghum association: These results show that associational resistance offers farmers another control technique. In general, the yield of a given crop decreases when it is grown in association, in comparison to its yield as a sole crop. These results are an exception to that rule, but they have been observed for two years. In measurement of field areas in eight villages in 1988 and 1989, millet / sorghum association was found in the largest proportion (22%) in Kominta, a village like the Sirakorola villages located in the sorghum - millet transition area (Jensen, 1989). In this area, it is too risky for farmers to rely solely on sorghum, yet in many years sorghum will outyield millet. In this zone, sorghum / millet association could be more widely promoted. Discussion with farmers in the village where it predominated in that study would also be valuable to determine to what extent farmers there are aware of the pest management advantages of this association.

Insect-tolerant millet varieties: These results in 1997 confirmed the results obtained in 1996. They show that the best choice of variety depends on zone. 'GRP1' should be promoted in semi-arid areas like Mourdiah, and 'M2D2' in semi-humid areas like Sirakorola. At the same time, these results also show the limitations of varietal resistance as a control strategy. What has been observed in these results is a form of tolerance rather than true resistance. This was evidenced by the lack of correlation between yields and infestation levels. The mechanisms of this tolerance need to be determined. While varietal resistance alone may not be a fully adequate strategy, it may be useful in combination with neem application.

Use of light and pheromone traps: The effectiveness of light traps confirmed an informal observation made by farmers in 1996. The research team applied scientific methods to assess this. This shows how participatory research can effectively combine both farmer and formal scientific knowledge.

Light traps have serious practical drawbacks, however, despite their positive effects on insect numbers and yield. Farmers grow millet as a semi-subsistence crop, and sales are dependent on first having met the subsistence needs of the household. In the absence of other cash crops, farmers are reluctant to depend on the market for purchase of the household's basic grains. Moreover, most households are in a food-deficit situation (Volet OHV, 1990). Analysis of the economic benefits of the increased millet yield needs to consider household food needs, to determine if the increased yield would generate enough additional revenue after the food deficit is first met, to pay for the cost of the kerosene used in the trap. Also, the fact that the light traps must be turned off and on each day is likely to be an impediment to long-term use. Theft of the lamps, valuable in the rural areas for lighting, could also be a concern.

Overall and future directions: In the PA and farmer evaluation described in the introduction, farmers indicated that they had no control measures for blister beetles. After four years of research, the above results show that IPM CRSP research has generated several control measures that can give farmers new options for control of this key insect pest. The broadening of the research program, and the development of on-farm IPM research skills, shows that collaborative research has an another benefit in addition to the development of answers to IPM constraints. It is also an effective mechanism for strengthening institutions. In 1998, capstone trials are underway combining neem use and varietal resistance with other techniques tested during phase I for control of mildew and *Striga* parasitic weed. The objective is to be able to offer rainfed cereal / legume farmers a package of proven IPM techniques for their most important insect, disease, and weed pests.

Networking Activities

Research Information Exchange

We report here on two companion research efforts carried out by members of the Mali IPM CRSP site team: cowpea insect pest management at Cinzana, and disease management using natural products in the site villages of the insect management trials of the workplan.

Companion research on cowpea insect pest management: IER carried out four other companion IPM experiments on cowpea at the Cinzana research station approximately 200 km northeast of Bamako, and at the Koporo substation. Although not formally part of the year 5 workplan, all of these experiments applied methods and technologies developed by IPM CRSP research. In effect, this research

represents an extension of IPM CRSP research into the Cinzana zone, as recommended by the February 1994 stakeholders' meeting that developed the overall research plan for phase I of the IPM CRSP in Mali. This research is a product of the commitment of IER to contributing to IPM CRSP research bringing additional resources into this collaborative effort.

Stimulated by observation of the use of yellow vaseline traps for thrips control in Guatemala, Dr. Gamby K. Touré, IPM CRSP research coordinator and principal collaborator for entomology, incorporated this technique into an experiment carried out with cowpea at Cinzana and Koporo. Cowpea is a cash crop in the Cinzana region, and insecticides are more widely used than when cowpea is planted in low density as a primarily subsistence intercrop with millet. Four treatments were installed in 10 m x 10 m plots, each replicated four times in a randomized complete block design. Yellow traps were installed at 1 m above ground every 3 m in the crop row at 20 days after planting and changed every 15 days hence. Decis at 2 l · ha^{-1} and neem at 3 kg · ha^{-1} were applied 4 times over the season (seedling, tillering, flower bud, and pod formation). Counts of thrips were taken at 24 h before and 48 h after each insecticide or neem application. Results at Cinzana showed that yellow vaseline traps decreased thrips infestation and increased yield (430 kg · ha^{-1}) relative to the control (240 kg · ha^{-1}), although the yield increase was inferior to that obtained with use of the insecticide Decis (890 kg· ha^{-1}). Similar results were obtained at Koporo (Figure 15).

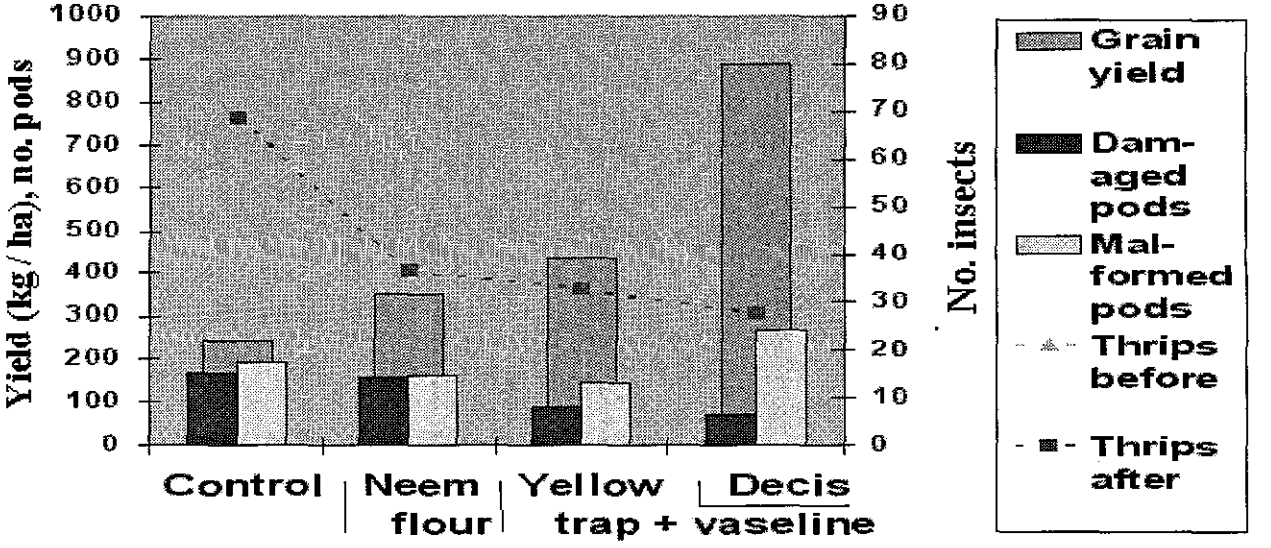

Figure 15. Traps and Insecticide on Thrip Infestation and Cowpea Yield, Cinzana, 1997

In a second companion experiment, neem flour was compared with neem extract; two local products, soap and potassium powder; and a control. Treatments were installed in 10 m x 10 m plots and replicated four times in a randomized complete block design. Each product was applied 4 times (seedling, tillering, flower bud, and pod formation); water was applied at the same time in the control treatment. Counts of thrips and pod worms were taken at 24 h before and 48 h after each application. At Cinzana, total thrip and worm infestation was reduced by 31-53% in plots where a natural product was used, but the differences were not significant. Neem extract, soap, and potassium increased yields by 58-74%, but neem flour was not effective in increasing yields (Figure 16).

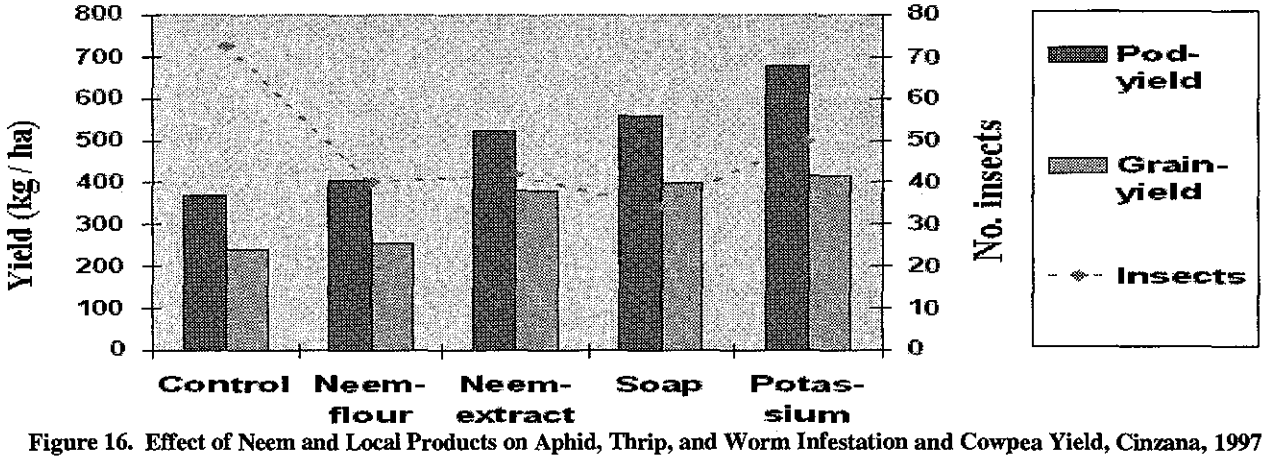

Figure 16. Effect of Neem and Local Products on Aphid, Thrip, and Worm Infestation and Cowpea Yield, Cinzana, 1997

Research was also carried out at Cinzana and Koporo with the objective of determining if the number of insecticide applications on cowpea could be reduced. Plot size was 10 m x 10 m per treatment, with treatments replicated 4 times in a randomized complete block design. Decis was applied at 2 l · ha^{-1} 1-4 times: flower bud stage only (1 application); flower bud and flowering stages (2 applications); seedling, tillering, flowering, and pod formation (4 applications). Counts of aphids, thrips, and worms were taken 24 h and 48 ha after each application. No significant differences were found between 1, 2, 3, and 4 applications, with yields over 800 kg· ha^{-1} for all treatments with 2-4 applications, compared with 272 kg· ha^{-1} for the control with no insecticide. Similar results were obtained at Koporo (Figure 17).

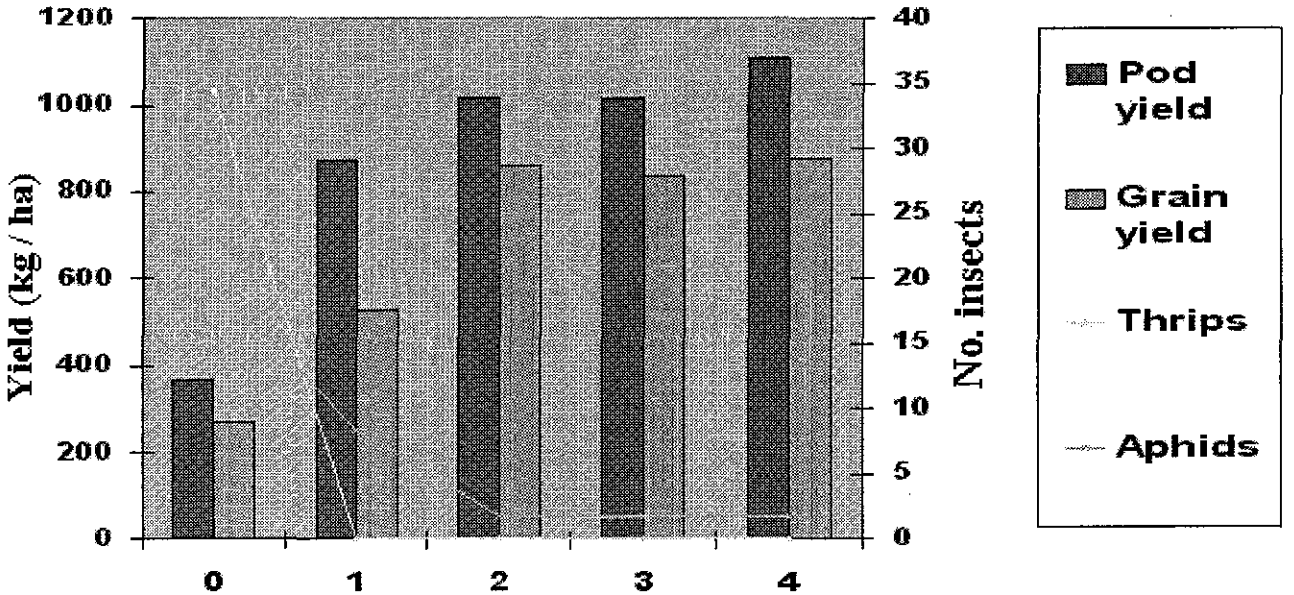

Figure 17. Effect of Number of Insecticide Applications on Thrip and Aphid Infestation and Cowpea Yield, Cinzana, 1997

The fourth experiment evaluated 14 cowpea varieties for tolerance to aphid infestation. Plot size was 10 m x 10 m per treatment, with 4 replications in a randomized complete block design. Counts were taken of aphids, thrips, and worms. The variety IT93KD-692-1 had the highest aphid infestation, over 3 times the average of the 14 varieties. Three varieties ('Wango 1'; 'IT89KD-374'; 'Amary shô') were completely free of aphid infestation. However, the highest yields were obtained from three other varieties ('IT93KD-692-1'; 'IT90KD-372-1-2'; 'IT89KD-245') which showed tolerance to rates of aphid infestation equal or greater than the average rate of infestation (61 aphids). Aphid infestation was low at Koporo (11 of the 14 varieties had aphid counts of 2 or less), and yields were depressed by heavy *Striga* spp. parasitic weed infestation (Figure 18).

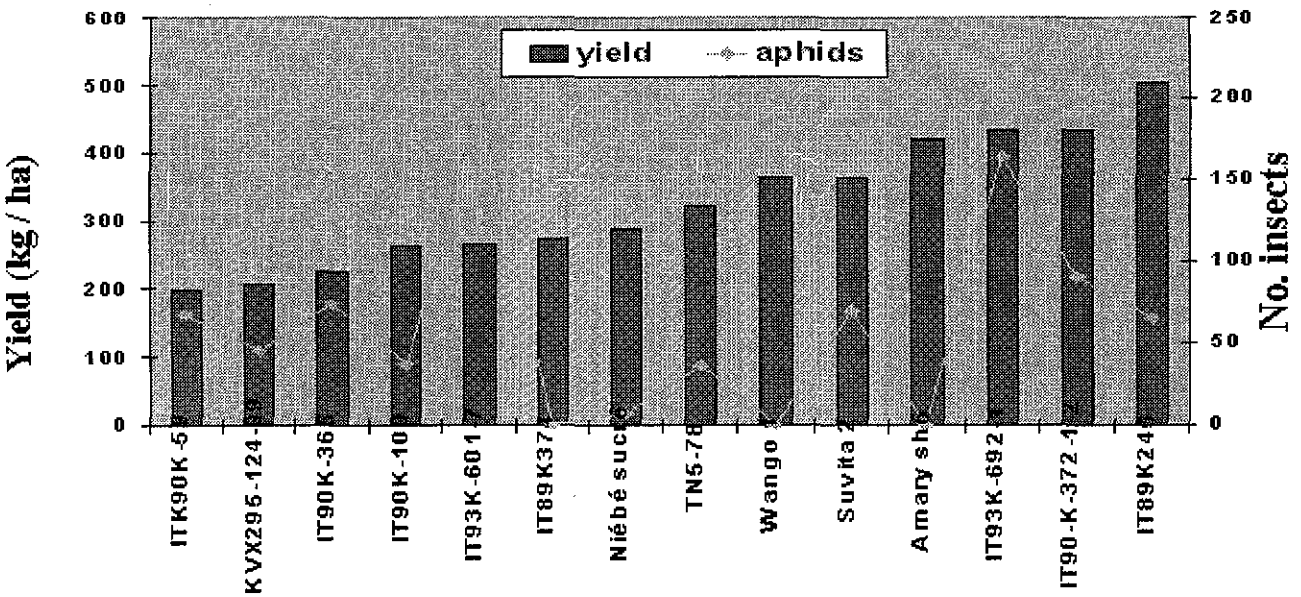

Figure 18. Effect of Variety on Aphid, Thrip, and Worm Infestation and Cowpea Yield, Cinzana, 1997

Companion research on disease management: A companion trial for control of mildew (*Sclerospora graminicola*) of millet was carried out in 1997 in the four research villages. Four treatments were applied in plots of 25 m^2:

1. Fungicide 'Apron plus 50Ds' at the rate of 10g / kg of seed (research control);

2. Powder from the fruit of the local plant *Nguo* (*Canavalia ensiformis*), at the rate of 10g / kg of seed;

3. Powder from roots of the local plant *Diro* (*Securidaca longipedonculata*), at the rate of 10g / kg of seed;

4. No treatment.

Treatments were replicated 4 times in the field of each farmer. Data were taken on the incidence of mildew and grain weight from the inner 3 rows in each treatment parcel. Results for Koïra showed that the incidence and severity of mildew were reduced by both natural products relative to the farmer control, although not as much as use of fungicide. The differences in both incidence and severity between the farmer control and the other treatments, and between fungicide and the natural products, were highly significant, but there were no significant differences between the two natural products.

Publications and Presentations

Gamby K.T., J. Caldwell, R. Edwards, and Mme. Sissoko H.T. 1998. Approaches to blister beetle control on millet: botanical and biological agents, varietal resistance, associational resistance, and light and pheromone traps. Proceedings of the IPM CRSP Symposium, May 15-18, 1998, Blacksburg, Virginia (in press).

Traoré, Mme. Sissoko H., J.S. Caldwell, and Y.S. Traoré. 1998. Suivi agronomique des tests de lutte intégrée contre les nuisibles des cultures dans le cadre de IPM/CRSP au Mali [Agronomique monitoring of integrated crop pest management trials of the IPM CRSP in Mali.]. Institut d'Economie Rurale, Bamako, Mali, 17 pp. (This study, in French, presents the results of agronomic monitoring of the 1997 IPM CRSP trials, covering field slope, soil drainage and texture, crop rotations and fertilization in the two years preceding the trial, planting dates, and observation of pests other than the pest focused on by the trial).

Project Highlight

In 1997, under higher insect pressure (12 beetles / head) than past years, locally-pressed neem oil applied directly in Low Volume Application decreased the number of blister beetles by 75% at 48 hours after application, resulting in 82% greater yield (846 kg · ha^{-1}) compared to the farmer practice without any control measures (455 kg · ha^{-1}).

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Formulation and Commercialization of Malian Village-Produced Neem Kernel Extract

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Collaborating Scientists: David Jenkins[1], L. Joseph Sears[1], Matthew McClelland[2] and Jane Crites[2]

Abstract

In Year 5 we accomplished: 1) a broad objective integrating research results with community economic development and 2) a specific objective in which we tested the hypothesis that village-produced neem kernel extract could be formulated in the village for preharvest use without petroleum products and still overcome the water immiscibility problem. As Year 5 began, it was clear that neem kernel extract was preferred by farmers for preharvest and postharvest application based on their own field trials. It was also clear that although presses villagers borrowed from Institut D'Economie Rurale (IER) to make the extract were locally available, they were not economically affordable. In Year 5 we developed a flow diagram for how profit could be obtained from the use of the press. The development of this profit model included discovery 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. Interviews with Mali-based non-governmental organizations (NGOs) and our villagers indicated these value-added products could be sold as a source of cooking oil, of light and energy to run small engines, and as the active ingredient in antimicrobial soap. Since these villages are not yet electrified and dermal conditions/direct contact diseases are prevalent, the prospect of these new, inexpensive products was considered very favorable. The problem remained of who should "loan" the first press to the first villager entrepreneur and how should repayment from the profits be guaranteed. We then developed a flow diagram summarizing a loan-credit-replacement process in which village groups would collaborate with a Malian NGO, Groupe de Recherches et d'Applications Techniques (GRAT), and a Malian (Bamako) branch of a Washington, D.C. based NGO, Appropriate Technologies, Inc. (ATI). US AID-Bamako was identified as a funding source to start the process. Plans for a market analysis/feasibility study by GRAT, ATI, and the IER scientists/economists were made. The result was a method to integrate the byproduct of an IPM program into the economic base of the community and have a broader effect than only in pest management.

To circumvent use of petroleum-based products to solve immiscibility problems with neem kernel extract in preharvest application, we tested village-produced soap and a commercial detergent in a model real scale system. Our data analysis established that at concentrations similar to those used in the field (750 microliters 25% neem kernel extract per 20 g dry wt cowpeas), the addition of reasonable amounts of soap (10 and 55 mg) or commercial detergent significantly increased mean no. of eggs laid per adult female *Callosobruchus maculatus* and did not improve application homogeneity using a water-based formulation in a conventional backpack sprayer. In the same model, real-scale system, we then tested application patterns, using ultra-low-volume (ULV) application without a diluent/surfactant to solve immiscibility problems. The result was a homogeneous application with neem kernel extract.

Objectives

To develop a bioassay to test the efficacy of village-produced soap as a surfactant in the neem kernel extract insecticidal formulation for use in preharvest (sorghum, millet, cowpea crops as well as for periurban uses) and in postharvest systems. Because in Year 4 we had undesirable variability in miscibility trials with the neem kernel extract, in Year 5 we had the following objectives: 1) Conduct the full scale bioassay in the laboratory (MSU) with the surfactant; 2) Conduct a larger scale test at IER-Sotuba; 3) If the 2 sets of laboratory trials showed promising results, introduce the soap-surfactant alternative to the farmers; and 4) Make available a manual press in each of the four IPM CRSP villages.

IPM constraints

1. The Neem tree, *Azadirachta indica* A. Juss, thrives in several regions of West Africa, particularly Mali. The neem kernel may be crushed to extract an oil, neem kernel extract, which can be used as a preharvest pesticide and whose

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processing byproduct (neem cake or tortou) is preferred as a postharvest pesticide by farmers in our collaborating villages. Neem kernel extract has been evaluated for its effectiveness to control a variety of insects. Neem kernel extract is accessible to villagers, but the extraction process yields small amounts, so they must conserve it or find new methods of application. The main problem is that neem kernel extract is immiscible in water. Because of the lack of miscibility in water, use of water as a dilutent for this village-produced extract causes a non-homogeneous cover of crops preharvest and commodities postharvest.

2. To dilute neem kernel extract and solve the miscibility problem villagers have most commonly been using petroleum-based products. These "inert" compounds, however, have been found to be hazardous to several species (Dunkel and Richards 1998; Kumar *et al.* In review). Use of the current surfactants, kerosene or gasoline, with neem kernel extract preharvest is costly and hazardous to nontarget organisms and to humans, particularly children.

3. Due to this risk, a series of miscibility trials has been performed using village-produced soap and a commercial detergent. Since neem kernel extract floats on water even after agitation, a common problem was uneven application of the active ingredients. This was due to the delivery mechanism on the sprayer which pulls fluid from the bottom of the spray container. The deposition of neem extract was higher near the end of the run. If soap would have improved miscibility of neem kernel extract in water this uneven deposition would not have occurred. At field concentrations of neem kernel extract (25% or higher) the addition of reasonable amounts of soap or detergent did not improve miscibility of neem kernel extract in water. Therefore, instead of conquering the miscibility problem with a surfactant, an ultra-low-volume applicator, was tested to produce a homogenous field application without a diluent while still conserving neem kernel extract.

4. Neem kernels are available within most villages in the Sahelian and near-Sahelian areas of Mali, and villagers in the 4 villages where we focused our research found preparation of the kernel and the pressing of the kernels to produce the oil a simple process, but access (due to cost) to a cold, manual press presented problems for the farmers/villagers.

Research Methods

Selection of Materials and Equipment: Neem kernel extract was produced at Institut D'Economie Rurale in Sotuba from kernels collected on-farm in Mali. Two separate evaluations were conducted with this extract to test our hypothesis. First, we conducted a high performance liquid chromatography analysis to determine the relationship between neem kernel extract volume and azadirachtin A content. Ninety percent pure azadirachtin A (5.4 mg) was dissolved into 5 ml of HPLC-grade methanol. Ten microliters of this solution were injected into the column using a 25 microliter syringe. An isocratic 50:35:15 H_2O:MeOH:Acetonitrile (AcN) mobile phase was used for analysis and pure AcN was used for 20 min to clean the column between runs, according to the methods of Hull *et al.* (1993). The HPLC instrument used was a Shimadzu LC-6A with a Spectroflow 757 absorbance detector and a Chromatopac C-R68 integrator (Shimadzu, Kyoto, Japan). The runs were repeated 5 times to ensure that the chromatograms were typical. The flow rate was set at 1 ml/min; UV absorbance = 214 nm. Anisole was used as an internal standard to quantify azadirachtin A content (Thejavathi *et al.* 1995). Neem kernel extract from Malian villages (0.5 ml) was mixed with 5 ml of HPLC grade methanol and placed on an Bakerbond octadecyl (c-18) solid phase extraction (SPE) column, equilibrated with 5 ml of methanol. No pressure was used to extract the neem kernel extract. The filtrate was collected for analysis and run on the HPLC according to the settings for the pure azadirachtin run. Ten microliters of 90% pure azadirachtin A were spiked in each neem kernel extract to see when azadirachtin A eluted. All HPLC runs were repeated 5 times to ensure that the chromatograms were typical.

Selection of Model Oil for Application/Formulation Studies: In order to conserve village-produced neem kernel extract (since transport from Mali to the USA was problematic), we compared the deposition of neem kernel extract with the deposition of a vegetable oil. Studies reported used vegetable oil as a model. According to Brown *et al.* (1994) viscosity can be measured by timing how long it takes a certain amount of liquid to flow through a thin tube under gravitational force. Water and five oils were used in comparing viscosity (including glycerol, motor oil, neem oil, mineral oil, and blended oil (soybean/canola)). Nine mL of each substance were measured in separate graduated cylinders. The temperature of each substance was recorded. The funnel was filled with one of the oils or water with the end of its stem blocked. The block was removed and flow rate of the substance was recorded. Flow rate determinations were replicated 3 times with each of the substances. Between the determination of each substance, glassware was cleaned with hot water and Simple Green^R (Sunshine Makers Inc.,Huntington Beach, CA USA) rinsed 3 times with water at 80^0C.

Testing Malian Village-prepared Soap as a Surfactant to Improve the Miscibility of Neem Kernel Extract in Water Formulation for use with a Handheld Conventional Sprayer in Preharvest Applications

Testing of Model Oil with Surfactant. A calibrated sprayer was mounted on a mechanized rack and used to measure differences in deposition of the model oil mixed with water and the effects of surfactants on this deposition pattern. The model oil used to substitute for neem kernel extract was sprayed using an apparatus that moved at a standard rate and heighth above glass watch glasses arranged in a grid (3 X 3 watch glasses [9cm diameter]). Each watch-glass in a row was separated from its neighbor by 3 cm. Each row of watch-glasses was separated by 18.5 cm. A velocity of 0.95 km/h

was used in each spraying. This velocity, the slowest velocity on the mechanized sprayer, was selected because it allowed maximum deposition of fluid and thereby allowed us to be more accurate in determining spray volumes. Treatments consisted of: 150 ml water only spray (control); 35 ml neem kernel extract and 115 ml water mixture; 35 ml neem kernel extract and 115 ml water mixture plus 3.5 g powdered Malian soap; 35 ml neem kernel extract and 115 ml water mixture with 0.25% by volume of X-77, a commercial surfactant. The amounts of Malian soap used were previously determined in the lab to be reasonable amounts for farmers to allot to crop protection. The amount of X-77 used was the rate recommended by the manufacturer. Oil was collected from watch glasses and quantified using a 50 microliter syringe. The oil deposition pattern was then compared with the pattern created by spraying water combined with 0.35 g of Malian soap, in powder form, which was added to a 25% Neem kernel extract mixture and this mixture was sprayed. A solution containing a commercial detergent (X-77; 0.25% in deionized water) was used to dilute Neem kernel extract to 25%. This mixture was sprayed and the oil was collected and quantified. Spray patterns for each fluid (water; water and neem kernel extract; water, neem kernel extract and Malian soap; water, neem kernel extract and commercial detergent) were compared. Treatments were replicated 5 times and differences in deposition, volumes along rows and along columns were analyzed using ANOVA (SAS 1988).

Model for Testing Improvement of Homogeneity in Field Application of Neem Kernel Extract using a Handheld Ultra-Low-Volume Sprayer

Nine pieces of 6"x 6" disposable papers, each with four glass weights, were weighed. Each set was labeled A through I and their weight was recorded. Using forceps each set was placed on a 3x3 grid, separating each column by 18.5 cm and each row by 3.5 cm. Glass weights were moved, using forceps, into the corners of the disposable papers to anchor them from the air current produced by the sprayer when it passed. The Micron Ulvafan MK2 ULV (ultra-low-volume) sprayer was attached to a support bar which was mounted adjacent to the spray cabinet. The sprayer was then lined up with the hood sprayer and tilted so that its head was parallel to the ground. The cabinet sprayer was positioned to the lowest speed to allow maximum deposition with the ULV sprayer. A 500 mL bottle was filled with blended oil (Canola/Soybean) and attached to the ULV Sprayer. The ULV sprayer was moved across the test area for a total of six passes, mimicking the speed of the hood sprayer. Each set (Treatment=position) was then weighed and recorded. Forceps were used to move the sets so not to disturb the oil deposition. A difference was calculated and recorded. Each paper used was disposed of and each glass weight was cleaned with an absorbent tissue. Applications on the treatment positions were repeated 10 times.

Statistical Analyses Used in Formulation Studies

Differences in deposition, volumes along rows and columns were analyzed using 1-way and 2-way Analysis of Variance (ANOVA) (SAS 1988) and a Scheffe comparison of means (SAS 1988). A multiple regressiion analysis was used to generate the response surfaces presented in Figures 2-5.

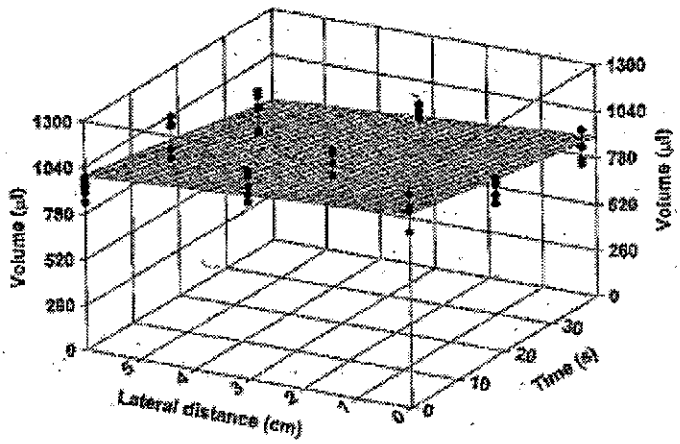

Figure 2. Spray pattern of water alone. Plane created by equation: volume = 1103 +- 5.2 (time) + -18.2 (lateral distance).

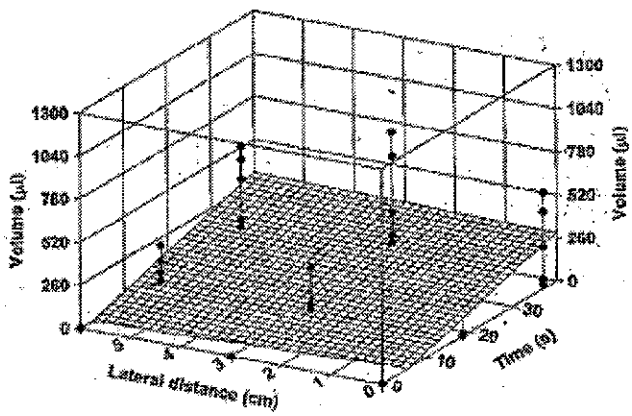

Figure 3. Spray pattern of water and neem kernel extract. Plane created by equation: volume = -74 + 11.3 (time) + 1.8 (lateral distance).

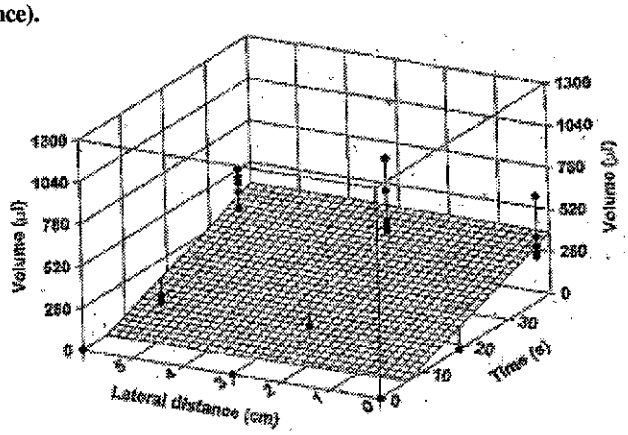

Figure 4. Spray pattern of water and oil model of neem kernel extract with 3.5 g of village-prepared soap. Plane created by the equation: volume=-51+8.6(time)+4.4(lateral distance).

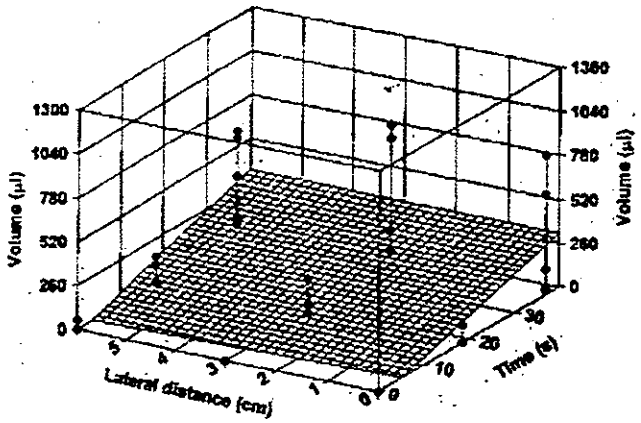

Figure 5. Spray pattern of water (0.25% X-77 surfactant) and oil model of neem kernel extract. Plane created by the equation: volume = -49.9+9.3 (time) + 2.7 (lateral distance)

Obtaining Data to Make Available a Manual Press to Produce Neem Kernel Extract in each of the Four IPM CRSP Villages

In Year 5 we consolidated all comments received from our collaborating villagers regarding the use of the press and related products. We also conducted a series of extensive interviews with several NGO units, Groupe de Recherches et d'Applications Techniques [GRAT] and both the directors of the Malian (Bamako) branch and the Washington, D.C. headquarters of Appropriate Technologies, Inc. [ATI]. We also interviewed one of the project officers at USAID-Bamako who informed us that US-AID Bamako could provide funding were an acceptable request transmitted. 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 to summarize a plan for beginning the process of developing small businesses in the Malian villages using the purchased press.

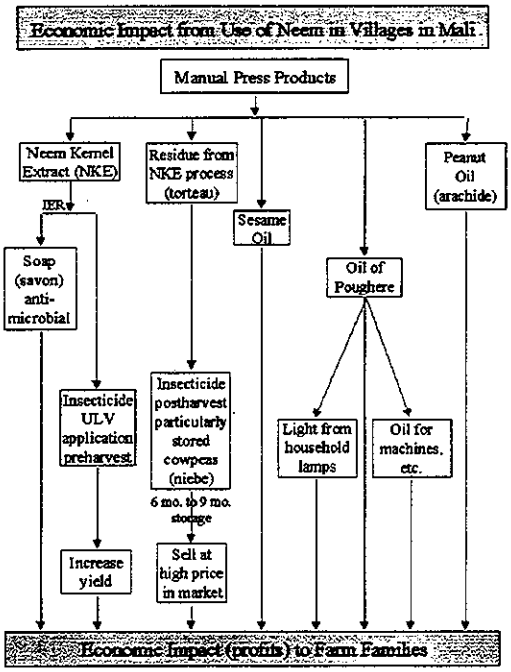

Figure 6. Economic impact from use of neem in villages in Mali.

Research Results

Testing Malian Village-prepared Soap as a Surfactant to Improve the Miscibility of Neem Kernel Extract in Water for Preharvest Application.

Selection of a model oil for further application/formulation studies. The mean, standard deviation, and Student-Neuman-Keuls Comparison of Means of the flow rate of each substance was calculated for three replicate trials of water and five different oils (Table 1). Temperatures of the substances during testing were 22.2 $\pm$ 1.1 ^{0}C. Flow rates and standard deviations obtained were as follows: water at 1.6 sec.; neem kernel extract was 9.6 sec.; Blended Oil (Shurfine^R Canola/Soybean) was 16.3 sec; motor oil was 46 sec.; and glycerol was 185 sec. From viscosity tests we concluded that the viscosity and therefore the deposition of neem kernel extract by a sprayer would be most similar to that of the blended oil. It is important, however, to note that the viscosity, as measured by flow rate for neem kernel extract was significantly lower than that of the Blended Oil (Canola/Soybean).

Table 1. Comparison of viscosity (flow rate) of village-produced, Malian neem kernel extract and various substances, including other oils. Trials run at 22.2 ± 1.1 °C.

Substance	1st Trial (seconds)	2nd Trial (seconds)	3rd Trial (seconds)	Mean of Trials ± standard deviation (seconds)[1]
Water	1.5	1.5	1.8	1.6 ± 0.2e
Blended Oil (Shurfine[R]) (canola/soybean)	17	16	16	16.3± 0.6c
Mineral Oil	45	40	44	43 ± 2.6b
Glycerol	189	180	181	185 ± 5.3a
Motor Oil	46	46	45	45.6 ± 0.6b
Neem Kernel Extract (Malian village roduced)	10	9	10	9.6 ± 0.6d

[1] ANOVA (SAS Institute 1988) with Student-Neuman-Kuels Comparison of means. $R^2 = 0.999$, $P < 0.0001$.

Testing of Model Oil with Surfactant. HPLC demonstrated a linear relationship between neem kernel extract volume and azadirachtin A content, indicating homogeneity of azadirachtin A in our neem kernel extract samples (Figure 1a,b). Adding surfactants, i.e., Malian village-prepared soap and a commercial product X-77, failed to improve the miscibility of Neem kernel extract in water (Figures 2-5). Spray patterns of all oil and water treatments had similar slopes for time (95% CI: 5.4, 13.9) but were significantly different from the water-only spray pattern (95% CI for slope of time: -6.9, -3.5). The main difference was the higher levels of oil deposition toward the end of the spray run in the oil trials (Figures 3-5). The water-only spray pattern was relatively even, demonstrating no trend similar to the oil and water spray patterns (Figure 2). Lateral distance on the grid showed no significant variation (r^2=12) in any of the treatments but time was a significant factor in all oil treatments (r^2=0.80; $p<0.05$).

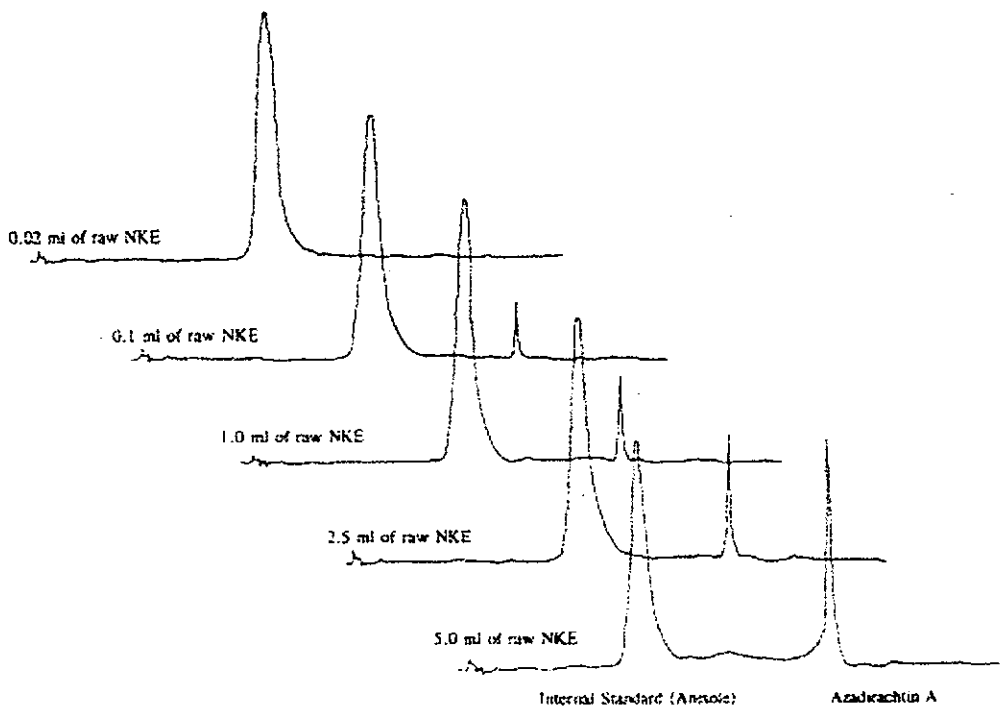

Figure 1. (a) Chromatograms (HPLC) demonstrate correlation of NKE volume to azadirachtin A. Ratio of peak areas (anisole:azadirachtin A) were used to quantify azadirachtin content.

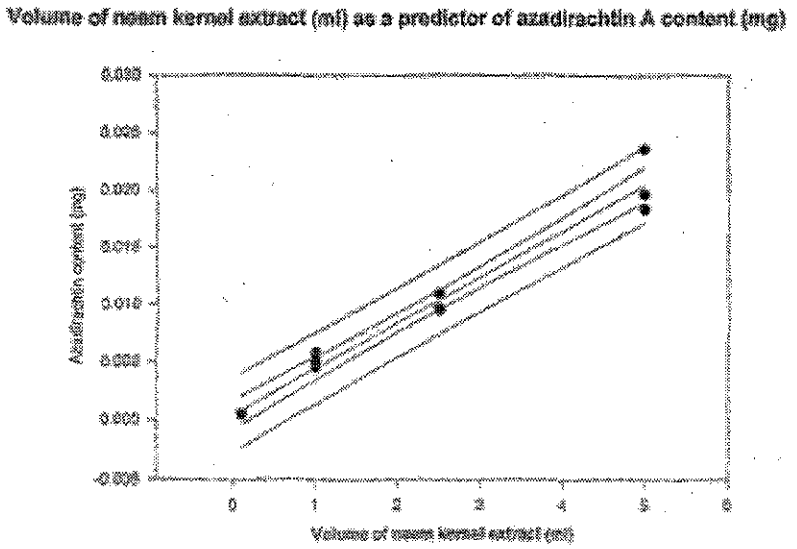

Figure 1. (b) Linear regression of neem kernel extract volume and azadirachtin A content. This regression demonstrates the homogeneity of azadirachtin A in our extract. The regression is defined by the equation: mg of azadirachtin = 0+0.004 (volume of neem kernel extract). (r^2=0.972)

The addition of various concentrations of Malian soap did not reduce the variability of treatments (Dunkel and Gamby Year 4 Ann. Rept. p.281, Table 3), although when the solutions were prepared, all of them appeared to be homogenized (uniform color). The soap also had no apparent effect on the oviposition decisions of females at low concentrations but increased oviposition significantly at the highest concentration tested (Dunkel and Gamby Year 4 Ann. Rept. p.281, Table 3). The spray table experiment also revealed that the addition of feasible amounts of Malian soap or X-77 does not homogenize neem kernel extract in water (95% CI of the slope of spray pattern when only water is sprayed is between -6.9 and -3.5: 95% CI for the slopes of all other mixtures is between 5.4 and 13.9). (See Figures 2-5.) The main difference is the higher levels of oil deposition toward the end of the spray run in the oil trials. The water-only spray pattern is relatively even, demonstrating no trend similar to the oil-and- water spray patterns. Distance within rows showed no correlation with oil deposition (r^2 = 0.12) in any of the treatments, but distance between rows was a significant factor in all oil treatments (r^2 = 0.80, $p < 0.05$).

Testing the use of Ultra-Low-Volume Application as a way to Circumvent Problems with the Miscibility of Neem Kernel Extract in Water for Preharvest Application.

This study demonstrated, in 2 separate experiments with 10 replicates each, that an even dispersal was obtained with the model oil when applied with an ultra-low-volume apparatus when not considering the center row positions within the spray area. Although the first trial was notably different from the following nine, the standard deviation of trials two through ten was 0.002. When comparing trials two through ten with the first trial, the minimum significant difference was 0.0323. When comparing homogeneity and position it was found that the back row (positions C,F,I) had a higher deposition value than the first row (positions A,D,G) (Table 1b). We attribute this to the "backsplash" of the fine mist made by the ultra-low-volume applicator, a problem that would not occur in an open field. There was consistence in volume dispersal using the ultra-low-volume applicator throughout the trials within row.

Obtaining Data to Make Available a Manual Press to Produce Neem Kernel Extract in each of the Four IPM CRSP Villages

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 (Dunkel and Gamby Year 4 Annual on Postharvest Monitoring and Pest Management; Gamby *et al.* Year 5 Assessment of Introduced and Natural Measures for (preharvest) Management of Insect Pests of Millet and Sorghum). These 2 materials were the neem kernel extract and the residue from neem kernel extraction. Producers in the 4 focus 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). Presses, we found, were being manufactured in 2 locations in Mali, Bamako and Mopti. Further discussion with 2 NGOs in Bamako (GRAT and ATI) revealed that these presses have already been introduced in parts of Mali for the production of botanical cooking oils, namely peanut oil and sesame oil. Both of these seeds are produced in our focus 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 (Figure 6). In addition to the use of neem kernel extract for the farmers' own fields and the use of neem kernel extract to make antimicrobial soaps within the home for sale in the local market as another value-added product, there is peanut oil, sesame oil, fuel oil for household lamps and machine oil for lubrication. These commercial products, therefore, could be viewed as a result of the development of IPM techniques in the Sahelian and near-Sahelian areas. A major roadblock to this commercial venture was access to the press.

Many suggestions for obtaining a press were offered to us as a way to involve villager entrepeneurs who wished to participate in this commercialization process involving the manual press. Gifts, grants, and loan systems were not considered advisable. We developed the following plan (Figure 7) after 1.5 year of discussion with: USAID-Bamako; IPM CRSP / IER Scientists / Economists; NGOs (Groupe de Recherches et d'Applications Techniques [GRAT] and the Malian (Bamako) branch of the Washington, D.C.-based Appropriate Technologies, Inc. [ATI]).

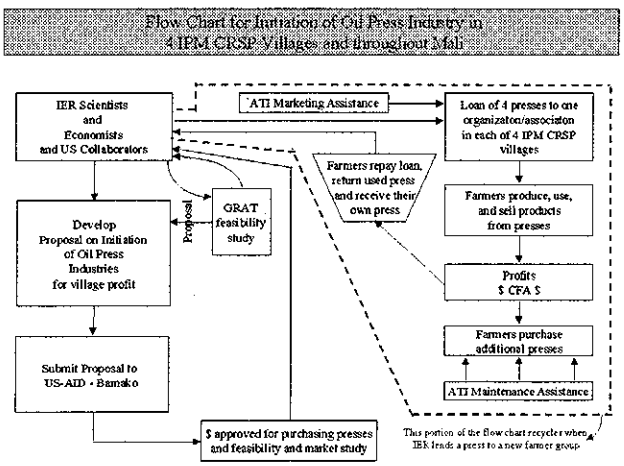

Figure 7. Flow chart for initiation of oil press industry in our 4 IPM CRSP villages and throughout Mali.

First, USAID-Bamako informed us that they could provide a source of funds that could be requested. USAID-Bamako was particularly interested in our plan because it was a good example of their own mandate to develop the private sector in Mali. It was the role of the IPM CRSP team to show USAID how this commercialization would be initiated in this specific agricultural system. It was decided that the next step that we will take is to develop economic impact figures of how much profit will be realized by the farm families. The NGOs (GRAT and ATI) suggested a loan-credit-replacement process. GRAT agreed to conduct in collaboration with IER scientists and economists, a market feasibility study of the potential level of market saturation for profit of each of these products. ATI agreed to give an initial demonstration of the press in each village and to make routine maintenance visits to each of the groups that obtain a press and respond to requests for repairs. If the market feasibility study conducted by GRAT was favorable, IER would purchase the 4 presses from the Bamako manufacturer. IER would then loan one press to an organization or association in each of the 4 villages. With a small down payment and a designated period of time to make subsequent payments, the association would then proceed to purchase the press from a portion of their profits. The association would receive a new press and the initial press would be loaned to another village. IER scientists proposed that even without a loan-reimbursement system in place, that villagers will on their own initiative set up a mechanism to purchase the press.

Discussion

Neem kernel extract floats on water, even after agitation, i.e., neem kernel extract is immiscible with water. The mechanism used in the spray-table experiment reported here is similar to a typical backpack sprayer in that both of the delivery mechanisms pulls fluid from the bottom of the spray container. This explains the increased deposition of the oil at the end of the spray run and indicated what occurs when a backpack sprayer is used to disperse a neem kernel extract-water formulation. If the surfactants we evaluated would have improved the miscibility of the neem kernel extract in water, we would not have seen this increased oil deposition at the end of a spray run when a surfactant was added. More surfactant may have improved miscibility a significant amount, but this would have required unreasonable amounts of soap to be sent from the villagers. If this was successful in the lab, it would have required unreasonable amounts of soap to be used in the field to solve this formulation problem. We, therefore, recommend that farmers do not dilute their neem kernel extract when treating their fields and instead apply 100% neem kernel extract with an ultra-low-volume apparatus. An ultra-low-volume apparatus is available in many villages.

The Ulvafan MK2 ultra low volume sprayer used in our laboratory experiments is similar to those used in Mali. When using this sprayer the stream is guided vertically along the entire plant and not from above in a constant straight line. When designing the sprayer support bar the angle of the spray was not considered to be a changing variable. We theorized that the spray head had to be parallel with the ground. Unfortunately, this was the incorrect angle. This explains why the data did not show a homogeneous spray. Because the sprayer was at the wrong angle the back row (C,F,I) had a higher deposition rate than the front (Table 2). The amounts sprayed on each trial were not significantly different, hence, it is believed that if the angle were to be changed, a homogenous application would be present. Although homogeneity was not displayed by position it was displayed by volume. Trials two through ten showed no significant difference between one another in the volumes dispersed. Unfortunately trial one was significantly lower than the others. According to the general linear models of SNK (Student-Neuman-Keuls), Tukey Studentized Range (HSD) & Bonferroni (Dunn), when the first

trial was removed, there is no significant difference between the dispersal rate of the nine other trials. This data suggests that trial one is an outlier. This data could be attributed to that fact that it was the first trial. Additionally, the incorrect angle of the sprayer may have affected this trial. Commonly when conducting an experiment such as this, several practice runs are made. Because these trial runs are performed for preparation it is necessary to take data collection after they are finished to avoid outlying data.

Table 2. Mean[1] deposition of model oil (oil chosed based on similarity in viscosity to neem kernel extract) when applied with a hand held, ultra-low-volume applicator, making 2 passes, one from left and one from the right (n=10).

(Experiment run 17 July 1998).

Location of collection station (parallel to path of ULV sprayer)	Edge of horizontal column perpendicular to spray path	Center of horizontal column perpendicular to spray path	Edge of horizontal column perpendicular to spray path
row against back of cabinet	0.089cb	0.11a	0.095ab
center row	0.08cb	0.087cb	0.083cb
row nearest to sprayer path	0.057d	0.066cd	0.069cd

[1] ANOVA (SAS Institute 1988) with Student-Neuman-Kuels Comparison of Means. R^2=0.184, P<0.03. R^2=0.437, P<0.0001.

(Experiment run 28 August 1998)

Location of collection station (parallel to path of ULV sprayer	Edge column perpendicular to spray path	Center column perpendicular to spray path	Edge column perpendicular to spray path
row against back of cabinet	0.07	0.068b	0.071ab
center row	0.07	0.066b	0.075ab
row nearest to spray path	0.08	0.076ab	0.097a

[1] ANOVA (SAS Institute 1988) with Student-Neuman-Kuels Comparison of Means. R^2=0.184, P<0.03.

In the past 4 years, we have 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 general, an individual or organization (an "association") in the Sahel or near-Sahelian areas would not have the cash reserves to buy a press.

Conclusion

At effective field concentrations of neem kernel extract (25% or higher), the addition of reasonable amounts of soap or detergent does not improve the miscibility of neem kernel extract in water. For preharvest insect pest protection, we suggest that Malian farmers apply 100% neem kernel extract in ultra-low-volume applications. This not only provides a homogenous application but also conserves the limited amounts of neem kernel extract. Therefore, because the conclusion of our laboratory surfactant studies were to abandon the village soap possibility and to use ultra-low-volume application, we did not conduct surfactant trials at IER-Sotuba nor did we introduce the idea to Malian farmers. Since field trials using ultra-low-volume application have already been conducted by Dr. Gamby with locally produced neem kernel extract minus any dilutent, we are simply forwarding our recommendation regarding the use of neem kernel extract to the farmers at this point. The main constraint emerging now is how will the individual farmer gain access to the hand-held, battery operated, ultra-low-volume applicator at the time when it needs to be used.

Therefore, 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 the availability of equipment to prepare the neem kernel extract, the press, for use by the farmers. Or, at least, this plan, 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.

Impacts

- As a result of our simulated backpack sprayer studies in a controlled application room, we do not advise the use of water and Malian soap as a formulation for neem kernel extract in preharvest locations.

- As a result of additonal nontarget studies with inert materials (surfactants plus petroleum-based solvents) registered in the USA for use with neem kernel extract, it is clear that these inert materials would have a harmful effect if used near aquatic ecosystems.

- As a result of our ultralow volume application studies, it seems that Malian farmers can use this application equipment to provide a homogeneous cover on their crops without the use of water or petroleum-based solvents.

(Our analysis of results will be completed by mid-November 1998 to confirm this recommendation.)

- Many times in IPM projects, we stop here with collection and interpretation of field data and we forget to follow the practice through adoption and trace the actual economic impact of the IPM technique. In this case, adoption of neem kernel extract was dependant on the availability of a press. This situation, immediately moves 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 the interviews we conducted, we have demonstrated that this IPM technique can be moved into a commercial arena. We view this summary as a model that may work in West Africa and elsewhere in Africa.

Networking Activities

Workshops

- Ethnopharmacology group (undergraduate students) from the University of Montana, Missoula. IPM CRSP graduate students assisted in the presentation at Montana State University. David Jenkins and Carin Miller assisted Dr. Dunkel in the role-playing presentation of participatory assessment of the use of botanicals in pest management in a Malian village. Anuj Kumar and David Jenkins presented results of their research using Mexican marigolds, *Tagetes minuta,* and neem, *Azadirachta indica,* in an integrated system. Dr. Dunkel presented techniques in "Participatory ethno-entomology and ethno-botany." 1 November 1997.

- Workshop to explore other insecticidal crops, e.g. *Tagetes minuta*, using the development of the neem tree as a model. Made presentations and facilitated group meetings at Virginia Tech October 1997 and May 1998. Departments of Horticulture, Plant Pathology, Soil Science, and Agricultural Economics.

Research Investigator Exchanges

Exchanged recently published literature with and met with Dr. Ali Shaaya and his colleagues, Volcani Institute, Israel. Dr. Shaaya is an entomologist working with volatile terpenoids, such as linalool, the main active compound in *Ocimum canum,* one of the botanicals used in the on-farm IPM CRSP trials with stored cowpeas in Mali.

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.

Assistance given to collaborating scientists

- Assisted in laboratory testing the ULV application of neem kernel extract.

- Assisted in the laboratory testing of the miscibility resulting from village-produced surfactants.

- Assisted in journal-requested revisions following refereed review of neem temperature effects with postharvest cowpeas article.

- Drafted manuscript on neem kernel extract and surfactants.

- Assisted in preparing poster for presentation at national meetings of the Entomological Society of America and at the IPM CRSP International Symposium at Virginia Tech.

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.

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). Returned from Environmental Entomology for minor revisions

Kumar, A., F.V. Dunkel, and M.J. Broughton. Effect of root extracts of the Mexican marigold, *Tagetes minuta* (Asterales: Asteraceae) on six nontarget aquatic macroinvertebrates. In MSU review prior to submission to Environmental Entomology. (This paper also presents a large set of data on the effect of "inert," petroleum-based solvents/surfactants on nontarget organisms in the environment. 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.

Published Proceedings Articles

Dunkel, F.V. K.T. Gamby, M. Diakete, A. Konate, K. Toure, and D.A. Jenkins. 1998. Integrating local natural products into pest management systems / local economic base of Sahelian and near-Sahelian Mali. Third International Symposium of the IPM CRSP. May 15, 1998. Virginia Tech. Blacksburg VA

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).

Presentations

Jenkins, D.A., F. V. Dunkel, and M. McClelland. 1997. Semi-subsistence technology and crop protection in Mali, West Africa. Presentation at the National Meetings of the Entomological Society of America in Nashville, Tennessee. December 1997.

Dunkel, F.V. 1998. Overcoming cultural and linguistic barriers to doing business. International Business Course presentation. Montana State University-Bozeman. March 1998.

Dunkel, F.V. 1998. Integrating local natural products into IPM systems. Seminar presented at the Agricultural Experiment Station, Virginia State University. Petersburgh VA. May 20, 1998.

Jenkins, David A. 1998. Sustainable use of neem in Malian villages: "The little tree that could...and couldn't." Department of Entomology Seminar. Thesis defense. 24 March 1998.

McClelland, M. 1998. Appropriately solving technological problems posed by the use of neem kernel extract for IPM systems in Mali, West Africa. Presented at the Montana State University Undergraduate Scholars Symposium. April 23, 1998. Bozeman, Montana.

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

Thesis Completed

Jenkins, David A. 1998. Sustainable use of neem in Malian villages. Thesis submitted in partial fulfillment of the requirements for the degree M.S. in Entomology. Montana State University-Bozeman. 57pp.

Training Output

Djibode, F. (Ph.D. candidate) IITA, Cotonou, Benin

Kumar, A. (M.S. candidate) Hyderabad, India

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

McClelland, M. (Completed 1 year of research as an Undergraduate Scholar EpsCOR funded by NSF), Appleton, Wisconsin

Crites, J. (Undergraduate Scholar EpsCOR funding from NSF), Springfield, Illinois

Project Highlights

- Ultralow volume application of village-produced neem kernel extract is probably the best method of covering a field plot uniformly.

- 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.

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Kumar, A., F.V. Dunkel, and M.J.Broughton. Effect of root extracts of the Mexican marigold, *Tagetes minuta* (Asterales: Asteraceae) on six nontarget aquatic macroinvertebrates. In MSU review prior to submission to Environmental Entomology.

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Integrated Management of *Striga* Parasitic Weed for Sorghum, Millet, and Cowpea

Investigators: Bouréma Dembélé[1], Amadou Diarra[1], and John S. Caldwell[2]

Abstract

Two approaches to control of *Striga hermonthica*, a critical weed pest in Mali, were tested in on-farm trials in two zones in north central Mali. The first approach combined cowpea varietal resistance with modifications in methods of intercropping millet and cowpea, conducted on 12 farms in two zones (semi-arid Mourdiah and less arid Sirakorola). *Striga* counts were reduced with both alternate row (interrow) and alternate hills (intrarow) arrangements using the *Striga* resistant cowpea cv. IT 89KD 245 in one of two villages in each zone, but yields were increased in only one of the four villages. *Striga* infestation was low, <2.5 plant / m^2, compared with 12 plants/ m^2 in 1996 and 58 plants / m^2 in 1997, when greater yield differences were observed. The second approach compared three introduced *Striga* tolerant sorghum varieties and the local farmer variety on 10 farms in the Sirakorola zone only. *Striga* infestation was higher in 1997 than in 1996 and 1995, but no yield response was seen. Infestation was 1.8-2.2 higher in plots with cv. Séguétana than in plots with other varieties, but yields of all four varieties were equivalent, indicating that 'Séguétana' was tolerant of increased *Striga* infestation.

Objectives

1. To assess the potential for control of the parasitic weed *Striga hermonthica* on millet grown in association with cowpea, through integrated combinations of intercropping method and resistance.

2. To evaluate the resistance to *Striga* under on-farm conditions of three varieties of sorghum that have performed well in on-station trials.

IPM Constraints

Since 1995, the IPM CRSP has carried out participatory on-farm IPM research on *Striga* in two zones in north central Mali: the semi-arid, more northern zone of the Mourdiah *arrondissement* (sub-county) (between the 400 and 500 mm isohyets); and the semi-humid, more southern zone of the Sirakorola *arrondissement* (~600 mm isohyet, Traoré and Monnier, 1980). In the 1994 Participatory Assessment (PA) carried out in these zones, *Striga* was ranked third by farmers (Caldwell *et al.*, 1994). It was ranked first in a farmer evaluation of IPM CRSP research conducted in 1996 (Erbaugh *et al.*, 1996).

Striga hermonthica is a critical weed pest in Mali as well as Africa as a whole, causing substantial losses to both millet and sorghum. Average millet yield loss due to *Striga* in the *Cercle* of Nara [the administrative district in which the Mourdiah *arrondissement* is located] was 36% in 1992 (Webb and Smith, 1992). Konate (1989) reported yield losses of millet and sorghum of up to 100% due to *Striga* infestation in Malian fields. Mboob (1989) estimates that annual cereal yields in Africa are reduced by 40% due to *Striga*.

IPM CRSP research has focused on two approaches to *Striga* control. Millet / cowpea association predominates in the Mourdiah zone but is also important in the Sirakorola zone. The first approach has combined cowpea varietal resistance with modifications in methods of intercropping millet and cowpea. Sorghum requires more water than cowpea, and so is only an important crop in the Sirakorola zone. The second approach has focused on assessing the adaptability of *Striga* tolerant sorghum varieties in that zone.

The cowpea variety IT 89KD 245 has been developed with resistance to *Striga*. Use of a resistant cowpea variety can reduce *Striga* infestation in the field. This cowpea variety has a maturity of 75 to 85 days, with a grain yield potential of 1.5 t/ha and a forage yield potential of 2 t/ha. It is adapted to semi-arid conditions of 400 to 800 mm annual rainfall. IPM CRSP research conducted in 1995 showed that use of

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this *Striga*-resistant cowpea variety in alternate rows in association with the farmer's millet variety increased millet yield 23% over the farmer practice (Dembélé and Caldwell, 1996). In 1996, use of 'IT 89KD 245' in both alternate rows ("interrow" arrangement) and alternate hills ("intrarow" arrangement) with millet reduced *Striga* counts by 61-80% compared to millet in pure stand, but the "intrarow" arrangement had 20-30% higher yield than the control (Dembélé *et al.*, 1998).

Two varieties of sorghum, 'Malisor 84-1' and 'Malisor 92-1,' have been developed with tolerance to *Striga* as an objective. Selection from local varieties has identified the variety Séguétana as also having *Striga* tolerance. In 1996, 'Séguétana' had 69% higher yield than the mean yield of the Malisor varieties and the farmer control under conditions of increasing *Striga* infestation over the season practice (Dembélé and Caldwell, 1996). In 1997, under lower *Striga* infestation, effects of *Striga* tolerant sorghum varieties on *Striga* counts and sorghum yields were inconsistent between villages, but 'Malisor 92-1' had yield equivalent to the farmer variety under 2.4-3.5 times higher *Striga* infestation in one of two villages (Dembélé *et al.*, 1998).

Research Methods

We report here on the results of the third year of trials on Striga spp. management, conducted with farmers in four villages in two zones of north central Mali during the 1997/1998 growing season. This was the third year of on-farm research on integration of control measures derived from research station. Two sets of experiments were conducted in four villages in the two zones [Koroma and Dontiéribougou (Sirakorola zone); Koïra and Douabougou (Mourdiah zone)]:

- Effects of improved intercropping practices for millet / cowpea association and cowpea varietal resistance on the incidence of *Striga hermonthica* and the yield of millet;
- Verification on farmers' fields of resistance to *Striga hermonthica* of new sorghum varieties bred and selected for resistance to *Striga* spp.

Both trials were conducted on the fields of ten farmers per village. Each farmer was considered as a replicate for the treatments within a village. Data for each village were analysed using a randomized complete block design.

Improved millet/cowpea intercropping: This trial was conducted on the fields of 12 farmers, six each in Mourdiah and Sirakorola. Three treatments were established on farmers' fields:

1. Control: millet as a pure crop;
2. Interrow arrangement: millet and cowpea cv. IT 89KD 245 planted in alternate rows;
3. Intrarow arrangement: millet and cowpea cv. IT 89KD 245 planted in alternate hills in the same rows.

Seeding was done between 20 June and 1 July on Mourdiah farms, and between 22 July and 1 August on Sirakorola farms. Each treatment was established in a 36 m^2 plot. Striga counts were taken from 1 m^2 sampling squares at 70 and 90 days after seeding, and at harvest. Each farm was considered as a replication within its zone, and data were analysed using a randomized complete block design for each zone.

Sorghum varietal resistance: This trial was conducted on the fields of 10 farmers in the Sirakorola zone. Four treatments were established on farmers' fields:

1. Control: local farmer sorghum variety;
2. 'Séguétana';
3. 'Malisor 84-1';
4. 'Malisor 92-1.'

Each treatment was established in a 200 m^2 plot. Seeding was done between 4 July and 22 July. Striga counts were taken from 1 m^2 sampling squares at 70 and 90 days after seeding, and at harvest. Each farm was considered as a replication, and data were analysed using a randomized complete block design for the zone.

Research Results

Improved millet/cowpea intercropping. Fig. 1 shows that the effect of intercropping systems varied considerably across villages. In one village in each zone (Koroma in Sirakorola and Koïra in Mourdiah), striga counts were reduced with both alternate row (interrow) and alternate hills (intrarow) arrangements, but this effect was not observed in the other two villages. However, overall *Striga* infestation was low, with the highest *Striga* counts (in Douabougou) less than 2.5 plant / m^2. Only in Koïra did both the interrow and intrarow arrangements have higher yields than the farmer control.

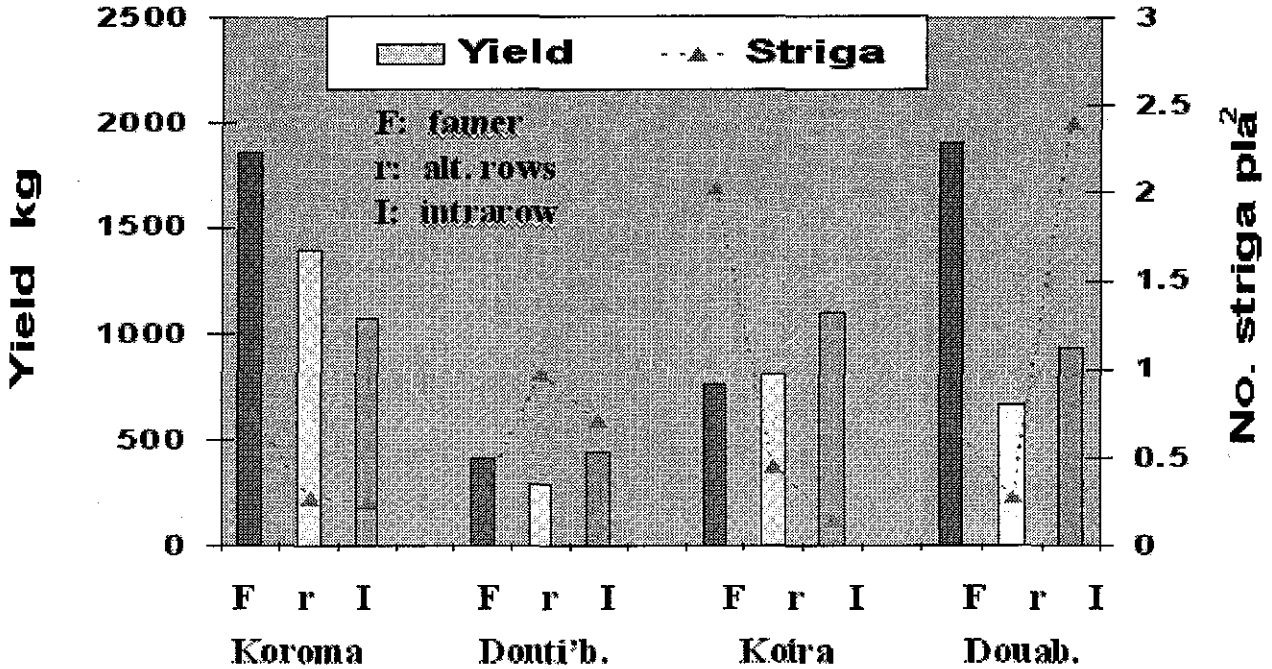

Figure 1. Effect of Striga Management on Millet Yield and *Striga* Count, Mali, 1997

Table 1. Analysis of variance using single-degree of freedom contrasts for effects of zone, village, cowpea varietal resistance, and intercropping method on number of *Striga* spp. plants / m^2 at 90 d after seeding and yield of millet under semi-arid (Mourdiah zone) and semi-humid (Sirakorola zone) conditions in Mali.

Source of variation[z]	Striga plants (no · m^2)		Yield (kg · ha)	
	F-values	Probability of significant differences	F-values	Probability of significant differences
zones	0.33	0.5820	0.01	0.9190
villages within Mourdiah	0.02	0.8892	0.59	0.4652
villages within Sirakorola	0.07	0.8039	6.04	0.0394 *
farms within villages	6.39	0.0008**	6.18	0.0010**
farmer vs.improved	5.68	0.0300 *	12.69	0.0026**
interrow vs. intrarow	0.12	0.7320	0.37	0.5498
village x treatment	3.62	0.0184 *	4.44	0.0079**
zones x F vs rI	4.45	0.0510 +	0.48	0.4991
Mourdiah villages x F vs rI	8.96	0.0086**	18.12	0.0006**
Mourdiah villages x r vs I	3.64	0.0745 +	0.01	0.9398
Sirakorola villges x F vs rI	3.90	0.0659 +	4.12	0.0593 +

notes:
[z]F, farmer: local cowpea variety mixed with millet
rI, improved: Striga-resistant cowpea cv. IT 89KD 245 in alternate rows or hills
r: alternate rows (interrow) arrangement
I: alternate hills (intrarow) arrangement
all other interactions of zone or village with treatments other than those in table non-significant for both variables

Village x treatment interactions were significant overall for both *Striga* counts 90 days after seeding and for yield, with the difference in response to improved intercropping between the Mourdiah villages (Koïra vs. Douabougou) the primary contributing interaction (Table 1). There were no significant differences in Striga counts at 70 days after seeding (data not shown).

Sorghum varietal resistance. *Striga* infestation in the trial fields with *Striga*-tolerant sorghum varieties was higher in 1997 than in 1996 and 1995, but no yield response was seen. Infestation was 1.8-2.2 higher in plots with 'Séguétana' than in other plots, including the farmer control (Fig. 2). The fact that 'Séguétana' maintained yields at the same level as the other varieties despite this higher infestation confirms its tolerance of *Striga*. However, this also suggests that the use of 'Séguétana' may lead to a buildup of *Striga* in the field.

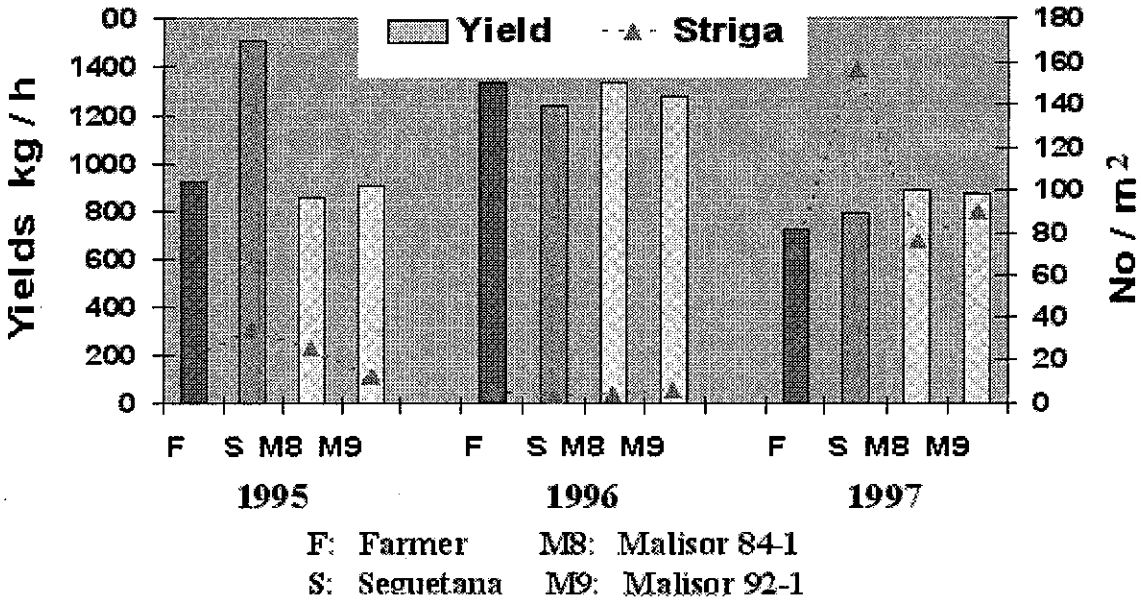

Figure 2. Effect of Variety on Sorghum Yield and *Striga* Counts, 1995-1997

Progress Report on Year 5 Trials (1998-1999 Agricultural Season). IPM CRSP Year 5 trials test integrated combinations of weed, insect, and disease management techniques, based on results of the past three years of on-farm IPM research on management of *Striga* spp. parasitic weeds, management of insect pests, and use of local products for disease control. These trials are underway in the 1997-1998 agricultural season, which will end in January 1998. The number of farmers and the dates of installation (seeding and where necessary due to poor stand, reseeding), are shown in Table 2 below.

Table 2. Dates of seeding of 1997-98 agricultural season integrated insect weed-disease management research trials

Zone and Village	Number of farmers		Dates of trial installation	
	Seeded	Reseeded	Seeding	Reseeding
Sirakorola				
Dontiéribougou	5	1	8/1-8/7	8/16
Koroma	5	2	7/27-31	8/11
Mourdiah				
Koïra	5	1	7/26-8/2	8/15
Douabougou	5	0	7/25-8/10	-----
Total	20	4		

Impact

Improved millet/cowpea intercropping: The results for 1997 contrast with 1995 and 1996 in several ways. Fig. 3 shows that the overall level of *Striga* infestation was much lower in 1997 than in the previous two years. In 1997, there were no significant differences in overall *Striga* counts, which were <1 plant / m^2. Under conditions of low infestation, the farmer practice was superior to the introduced arrangements, with 56% higher yield than the interrow arrangement, and 39% higher yield than the intrarow arrrangement (see Table 3 for explanation of treatment codes in Fig. 3). In contrast, the intrarow arrangement had 21% higher yield in 1996. In that year, *Striga* counts were reduced 75%, from 12 plants / m^2 in the farmer control to 3 plants / m^2, in both introduced arrangements. In 1995, *Striga* counts were even higher, with 58 / plants m^2 in the farmer control, and reductions of 18-53% in *Striga* counts in treatments with *Striga* resistant cowpea 'IT 89KD 245' planted in alternate rows. Yields were increased in all treatments with 'IT 89KD 245' planted in alternate rows.

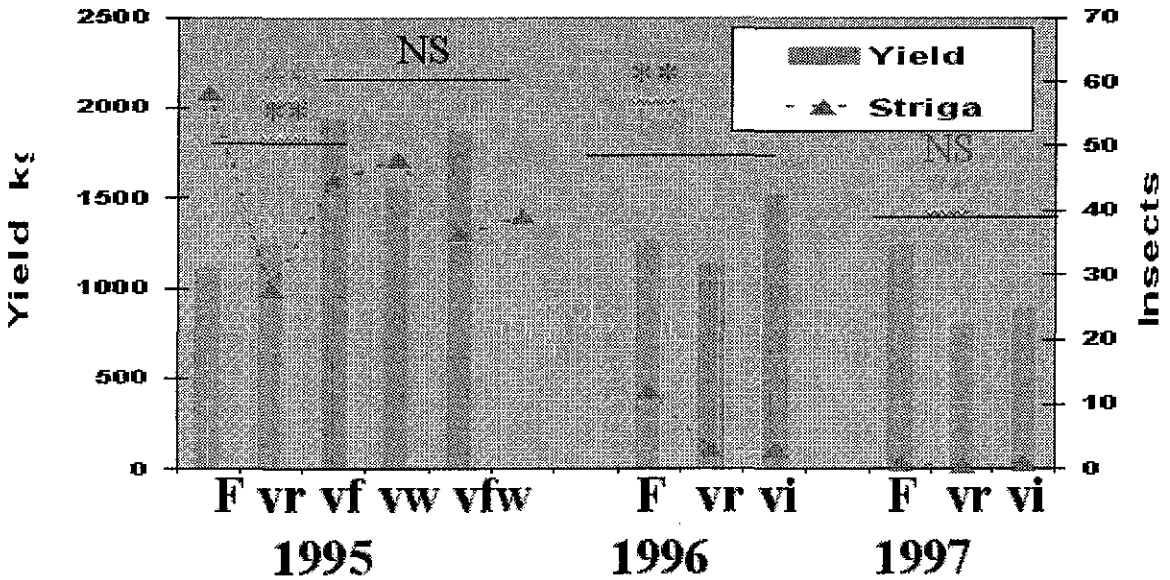

Figure 3. Effect of *Striga* Management on Millet Yield and *Striga* Count, Mali, 1995-1997

Table 3. Treatments used in integrated *Striga* management research (refer to Fig. 3).

Code used in Fig. 3	Treatment	Component			
		Cowpea variety	Intercropping method	Fert.	Late weeding
F	Farmer control	Local	mixed intercropping	no	no
vr	Variety + row intercropping	IT 89KD 245	"interrow": alternate row intercropping	no	no
vf	Variety + fertilization	IT 89KD 245	"interrow": alternate row intercropping	yes	no
vw	Variety + weeding	IT 89KD 245	"interrow": alternate row intercropping	no	yes
vfw	Variety + fertilization + weeding	IT 89KD 245	"interrow": alternate row intercropping	yes	yes
vi	Variety + alternate hills	IT 89KD 245	"intrarow": alternate hill intercropping	no	no

These results over a three year period suggest that response to improved intercropping arrangements depends on the level of *Striga* infestation. The farmer practice of planting a low density of cowpea by mixing a little cowpea seed in the same planting gourd as the millet seed has the objective of maximizing millet yield under normal conditions. Cowpea is considered to be a bonus crop, that may spread and produce more if millet does poorly, but it is not an essential crop. However, under conditions of higher *Striga* infestation, having the *Striga* resistant cowpea in the association also aids millet, by reducing *Striga* infestation. The improved intercropping arrangements are necessary to accomodate its more compact growth habit, compared to local varieties of cowpea which have a spreading growth habit.

These results also present an interesting comparison with measures that the IPM CRSP Mali site have tested over four years for control of blister beetles. In that research, the use of neem had significant effects in reducing beetle infestation on millet heads and increasing millet yields in two out of four years. Both years when neem was effective were years when beetle populations were high, well above the threshold for their control (Gamby *et al.*, 1998). IPM control measures can be effective under the right conditions, but may pose the risk of increased cost and / or reduced benefits in years when those conditions are not met. These results would suggest a level of risk for improved intercropping for control of Striga parasitic weed of 33%.

Under conditions of higher *Striga* infestation, improved intercropping with *Striga* resistant cowpea 'IT 89KD 245' can help to reduce *Striga* and increase yield. However, this effect is not always consistent. Moreover, under conditions of low *Striga* infestation, traditional mixed intercropping of millet and cowpea may be superior. In 1998, we have combined improved intercropping with fertilization, use of neem for control of insect pests on both millet and cowpea, and mildew disease control using the local botanical materials *diro* and *n'go* . This trial will provide more data on the response of millet / cowpea association to these techniques of *Striga* management. This trial, to be carried out over two years as the capstone of IPM CRSP research for millet / cowpea association, has as its objective to be able to offer farmers a package of proven IPM techniques for management of *Striga*, blister beetles, and mildew. This will respond to farmer-identified needs, as these three pests are the weed, insect, and disease pests that farmers have identified through IPM CRSP participatory research to be their priority pest management constraints for millet / cowpea association.

Sorghum varietal resistance. The sorghum variety Séguétana has been made available to the extension organization in 1998. However, 'Séguétana' should be used only in situations where *Striga* infestation is already high. Its use in fields with less *Striga* infestation runs the risk of contributing to long-term buildup of *Striga* in the field.

Publications and Presentations

Dembélé, B., A. Diarra, J.S.Caldwell, and Mme. Sissoko H. Traoré. 1998. Integrated management of *Striga* parasitic weed in millet / cowpea association and adaptabiity of *Striga*-tolerant sorghum varieties under farmer conditions in Mali. Proceedings of the IPM CRSP Symposium, May 15-18, 1998, Blacksburg, Virginia (in press).

Project Highlight

Yield of sorghum cv.Séguétana was equivalent to that of three other varieties despite infestation 1.8-2.2 higher in plots with 'Séguétana' than in plots with the other varieties.

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Long-Run *Striga* Control by Subsistence Farmers in Mali

Investigator: Jeffrey D. Mullen[1]

Collaborating Scientists: Demba Kebe[2], Daniel B. Taylor[1], and John Caldwell[1]

Abstract

The IPM-CRSP/Mali project has developed a bio-economic model for evaluating the economic and nutritional returns to millet production practices aimed at controlling the parasitic weed *Striga*, and the relevance of *Striga* seed movement in the adoption decisions of subsistence farmers. The model is comprised of two components: a biological component reflecting the effects of various production practices on the development and reproductive capacity of *Striga*, and an economic component reflecting the input and output prices and production constraints faced by subsistence farmers. The model has been specified for the Mourdiah and Sirakorola zones of Mali.

Results from the specification of the biological component indicate: (1) *Striga* germination is a negative function of nitrogen application rates; (2) the relationship between nitrogen and *Striga* emergence is best described as quadratic – increasing at low application rates and eventually decreasing; (3) the optimal rate of nitrogen application is dependent on the density at which millet is planted and the proliferation of *Striga* seeds in the soil; (4) *Striga* germination is a positive function of millet planting density; (5) planting millet in association with cowpea does not significantly affect *Striga* population dynamics or millet production; (6) planting millet in association with groundnut reduces *Striga* germination rates but also has a negative effect on millet production; (7) a person can hand-pull approximately 2,500 emerged *Striga* per day; and (8) hand-pulling emerged *Striga* can significantly reduce the number of new seeds that are introduced into the soil.

Preliminary results indicate that the following: (1) in the absence of *Striga*, optimal millet density is 3.5 hills/m^2 in both zones; (2) at average levels of *Striga* infestation the optimal millet density is 0.5 hills/m^2 in Mourdiah and 3.5 hills/m^2 in Sirakorola; (3) relevant production constraints include the farmer's access to weeding labor and the availability of cash to purchase seed and fertilizer; (4) returns to hiring labor to hand-pull *Striga* are negative at high infestation levels but positive at low infestation levels; (5) the relevance of the seed externality is dependent on the level of *Striga* infestation and the farmer's level of investment in *Striga* control measures – the relevance increases as infestation and investment increase; (6) conventional millet production practices are not optimal; and (7) the millet-cowpea and millet-groundnut associations are superior to conventional practices both in terms of net returns and their ability to meet the nutritional needs of the production unit.

Objectives

- To specify the biological component of the model.
- To specify the economic component of the model.
- To write and validate the computer program to solve the model.
- To generate preliminary results.

IPM Constraints

- Impact of labor constraints on *Striga* control.
- Impact of cash constraints on *Striga* control.
- Influence of the production decisions of one's neighbors on one's own production decisions.
- Access to labor markets.
- Price of urea fertilizer.

Research Methods

A dynamic, non-linear programming model was developed to evaluate the financial and nutritional returns to *Striga* control measures. The model is comprised of a biological component accounting for the influence of control measures on *Striga* population dynamics, and an economic component reflecting the price parameters and production constraints farmers face. The program was written and solved in

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GAMS. The biological component divides the *Striga* life-cycle into eight distinct stages, with the ability of a seed to reach each successive stage contingent on a transition probability. Using secondary data, the effects of control measures on the transition probabilities were estimated.

Equation (1) represents the hypothesized relationship between urea and the probability a *Striga* seed will germinate. Equation (2) represents the hypothesized relationship between nitrogen and the probability a *Striga* parasite will emerge. Both of these equations were estimated by non-linear least squares in SAS.

(1) $Y = \beta_0 * \exp\{\beta_1 * \text{Urea}\}$
Where Urea = kg urea/ha
Y = probability a *Striga* seed will germinate

(2) $Z = \exp\{\beta_1 * N + \beta_2 * N^2\}$
Where N = kg nitrogen/ha
Z = probability a *Striga* parasite will emerge

Data from the IPM-CRSP/Mali Socio-Economic Baseline survey were used to classify production units (UP) into different sizes and determine the land and labor endowment of each UP in each zone. Information provided by the Institut d'Economie Rurale was used to estimate the discount rate of farmers in Mali and input and output prices relevant to the model. The results of a survey designed and administered by the IPM-CRSP/Mali team were used to estimate the length of the planning horizon of subsistence farmers in each zone.

Research Results and Discussion

The estimated parameters from Equations (1) and (2) are presented in Tables 1 and 2, respectively. All of the parameters are significantly different than zero.

Table 1. Estimation of Equation (1)

Descriptive Statistics:	R^2 = .9207		Adjusted R^2 = .9128
Independent Variable	Estimate	Approximate Std. Err.	Approximate P-value
β_0	0.878	0.063	0.0001
β_1	-0.003	0.0004	0.0001

Because the model is nonlinear, standard errors of the estimates, T-ratios, and p-values are only approximate (SAS Institute, Inc., 1993).

Table 2. Estimation of Equation (2)

Descriptive Statistics:	R^2 = .5941		Adjusted R^2 = .5784
Independent Variable	Estimate	Approximate Std. Err.	Approximate P-value
β_1	0.07111	0.00951	0.0001
β_2	-0.00068	0.00014	0.0001

The results of Equation (1) indicate that *Striga* germination rates decrease as a function of the rate of urea application. In other words, as the application rate of urea increases, the proportion of *Striga* seeds that germinate decreases. The results of Equation (2), however, indicate that low rates of nitrogen application facilitate the emergence of *Striga* parasites, while high rates impede *Striga* emergence. The net effect has significant implications for *Striga* population dynamics.

Even though fewer seeds germinate compared to no urea, at low rates of urea application the number of *Striga* parasites that emerge is higher. This leads to a greater number of *Striga* setting seed and more seeds introduced into the field. As a result, the density of *Striga* seed – and potential for significant millet yield reductions – is increasing faster at low rates of urea/nitrogen application than it would when not applying urea/nitrogen. The nitrogen-emergence relationship is, however, quadratic. So, eventually, at a high enough application rate nitrogen does reduce both *Striga* germination and emergence. The exact application rate at which this occurs depends on the planting density of millet and the density of *Striga* seeds in the soil. For example, at a millet density of 3.5/m2 and Striga seed density of 40,000/m2 (average for Mourdiah), nitrogen does not become a profitable input until application rates exceed 130 kg/ha are not profitable; at a millet planting density of 0.5/m2 and 40,000 Striga seeds/m2 nitrogen application rates above 114 kg/ha are profitable.

The land and labor endowments for each UP size in each zone are presented in Tables 3 and 4, respectively. The length of the UP's planning horizon was estimated to be 3 years in Mourdiah and 4 years in Sirakorola.

Preliminary results from the model indicate that the order in which the various production constraints become binding is dependent on the level of *Striga* infestation and the zone. In the absence of *Striga*, production is constrained first by the availability of labor to perform a mid-season weeding and then by the availability of cash to purchase fertilizer and seed. In the presence of *Striga* the cash constraint becomes more important than the labor constraint.

Preliminary results also suggest that the potential movement of seeds between fields reduces the returns to *Striga* control practices. Further analysis is in process to determine the conditions under which the reductions are so large as to prevent farmers from adopting *Striga* control practices. All analysis will be completed and definitive results available December 1998.

Table 3. Hectares Available and Cultivated, Averaged over Plot Type, UP Size, and Zone

UP Size	Mourdiah				Sirakorola			
	Total	Individual Cultivated	Communal Cultivated	Communal Available	Total	Individual Cultivated	Communal Cultivated	Communal Available
XS	5.3	0.6	3.6	4.7	9	1	4.6	8
S	7	0.6	4.8	6.4	12	1.7	5.6	10.3
M	14.5	3.2	9.1	11.3	12.9	1.8	6.9	11.1
L	11.9	3.1	6	8.8	62.5	5.6	14.3	56.9
XL	29.3	9	17.6	20.3	NA			
XXL	22.5	8.5	14	14	NA			

Table 4. Person-Days of Communal Labor Endowed per Week by Age, Gender, and UP Size

UP Size	Mourdiah				Sirakorola			
	Teens	Men	Women	Total	Teens	Men	Women	Total
XS	0	11.3	2.8	14.1	2.6	11.1	2.8	16.5
S	5.6	11.6	5.8	23	2.4	10.8	2.7	15.9
M	5.6	28.9	14.5	49	2.8	23.1	8.7	34.6
L	11	34.6	20.2	65.8	0	52.5	14.6	67.1
XL	31.7	82.3	32.3	146.3	NA			
XXL	46.7	136.2	68.1	251	NA			

Networking Activities

None.

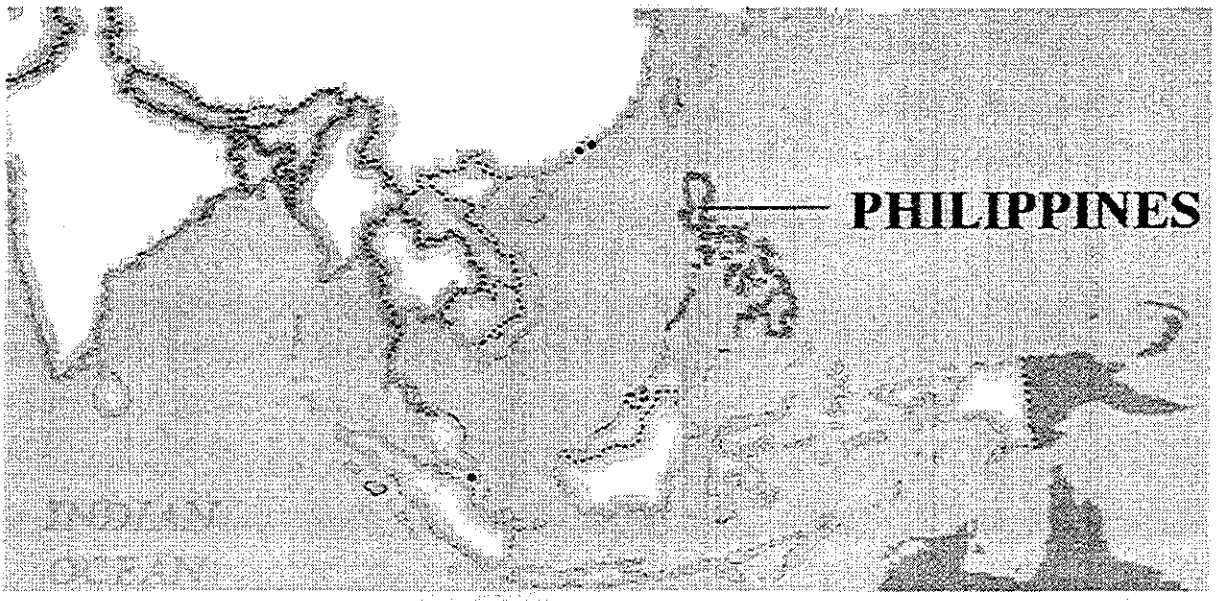
Publications and Presentations

Mullen, Jeffrey D., Demba Kebe, Daniel B. Taylor, and Makan Fofana, "Long-Run *Striga* Control by Subsistence Farmers in Mali," presented at the American Agricultural Economics Association Annual Meeting, Salt Lake City, Utah, August 2-5, 1998.

Mullen, Jeffrey D., Demba Kebe, Daniel B. Taylor, and Makan Fofana, "Modeling Long-Run *Striga* Control in Mali," presented at the Third IPM-CRSP Symposium, Blacksburg, VA, May 15-16, 1998.

Project Highlight

A bio-economic model of millet production in the presence of the parasitic weed *Striga* was developed for two zones in Mali. Preliminary results indicate that low rates of nitrogen application are not profitable as they facilitate *Striga* development. As the application rate increases, nitrogen becomes profitable. The exact rate above which nitrogen impedes *Striga* development and increases net returns is dependent on the density of *Striga* seeds in the soil and millet planting density. For example, at a millet density of 3.5/m2 and Striga seed density of 40,000/m^2 (average for Mourdiah), nitrogen does not become a profitable input until application rates exceed 130 kg/ha are not profitable; at a millet planting density of 0.5/ m^2 and 40,000 Striga seeds/ m^2 nitrogen application rates above 114 kg/ha are profitable.



ASIA

Complementary Weed Control Strategies in Rice-Vegetable Systems (Evaluation of Integrated Weed Management Strategies Against Weeds in Onion)

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Abstract

Field studies were conducted in two farmers' fields in the Asian site in San Jose, Nueva Ecija, Philippines during the 1998 dry seasons. The efficacy of various control strategies against dominant weeds in onion (*Allium cepa* L.), the major vegetable crop grown after rice (*Oryza sativa* L.) in rain-fed rice-based cropping systems, were determined. Treatments, consisting of various combinations of herbicides, hand weeding, and cultural practices, varied among fields depending on the onion cultivar grown and the dominant weed species. In spite of the inherent differences in dominant weeds and prevailing weed control practices between the farms, results point to one common observation. Use of a single herbicide and one hand weeding provided comparable weed control and onion yield with those of the farmers' practice of sequential treatments of two herbicides and two hand weedings. With the farmers' practice in most cases, a second herbicide application was not necessary either because it was not effective on the dominant weed or because the weed population was reduced by use of traditional cultural practices like tillage or mulching with rice straw. With correct choice of herbicide, the farmers' practice can be reduced to a single herbicide application and one hand weeding operation.

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 decreasing production costs due to weed control in rice-onion cropping systems.

Objectives

To evaluate efficacy of various combinations of chemical, cultural, and mechanical methods of weed control in onion in rice-onion cropping systems.

IPM Constraints

The expenses incurred by weeding and herbicide use to manage weeds cover almost 20% of production cost of onion farmers. Cultural practices like tillage, mulching, rice hull burning, as well as reduced hand weeding and herbicide use can be cost-effective and reduce production costs.

Research Methods

Two studies were conducted from November to March during the 1997-98 dry season in two farmers fields located in two towns in the province of Nueva Ecija, Philippines. Treatments consisted of various combinations of herbicides, hand weeding, and cultural practices. The treatments varied among fields, depending on the kind of onion cultivar grown and the dominant weed species in a particular field. Agronomic practices, including fertilizer, water, and pest management were those recommended by the Department of Agriculture and practiced by farmers in the area.

Herbicides were applied with a hydraulic knapsack sprayer calibrated to deliver 500 L/ha using 8002 Teejet flat fan nozzles. The herbicides used were glyphosate [N-(phosphonomethyl)] glycinel, fluazifop [(+2-[4-[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxyl] propanoic acid)], oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-trifluoremethyl) benzene], and oxadiazon [3-[2,4-dichloro-5-(1-methylethoxy) phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one].

Crop injury and weed control were rated visually on a scale of 1 (no injury or 100% control) to 9 (30% or more injury or 60% or less control). Ratings were taken at 7, 15, and 30 days after treatment. Weed counts and weed weights were taken from a 1 m^2 quadrat at 45 days after transplanting and at harvest. Yield data were taken from a 2 x 5 m^2 area at the center of each plot and expressed in t/ha.

Specific Studies

The dominant weeds, herbicides, their application rates and times, hand weeding frequency and times, onion cultivar, and cultural practice(s) varied between the fields.

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Field 1 (Santo Tomas Village)

The dominant weeds were *Cleome viscosa, Trianthema portulacastrum,* and *Cyperus rotundus.*

Onion cultivar Tanduyong, the cultivar grown for local consumption, was used. The farmers' practice is use of rice straw mulch and zero tillage. In all plots, a layer of 5 to 7-cm rice straw mulch was laid out before transplanting. Thirty day-old onion seedlings were transplanted at 10 cm within rows and 30 cm between rows with the use of a dibble. There were five treatments: 1) farmers' practice (glyphosate followed by fluazifop and two hand weedings 15 and 30 days after fluazifop application); 2) glyphosate applied 7 days after land preparation (two plowings and two harrowings) fb one hand weeding 15 DAT; 3) glyphosate applied 7 days before land preparation (two plowings and two harrowings) followed by one hand weeding 15 DAT; 4) hand weeding two times; and 5) unweeded control. Land was prepared in all plots (in all treatments) with two plowings and two harrowings.

In all treatments, glyphosate was applied at 0.9 kg ai/ha 14 days before transplanting and fluazifop at 0.8 kg ai/ha applied 7 days after transplanting. At the time of glyphosate treatment, the grasses and sedges were 6-7 cm tall with 3-4 leaves and broadleaf weeds 2-3 cm tall with 4 leaves.

Field 2 (Bongabon)

The dominant weeds were *Cyperus rotundus, Trianthema portulacastrum, Echinochloa colona,* and *Eleusine indica.*

The field was plowed twice with a tractor and harrowed twice with a carabao-drawn implement. No mulch was used. Forty five-day old seedlings of onion cultivar Yellow Granex were transplanted at 10-cm spacing within rows and 30 cm between rows after the last harrowing. There were six treatments: 1) Farmers' practice (oxyfluorfen and fluazifop followed by one hand weeding; 2) glyphosate applied 14 days before land preparation followed by one hand weeding; 3) glyphosate applied 14 days after land preparation followed by one hand weeding; 4) fluazifop followed by one hand weeding; 5) unweeded (weedy) control; 6) hand weeded (weed-free) control. The application rates and times for glyphosate, oxyfluorfen and fluazifop are similar to those in Field 1. Oxadiazon was applied at 0.6 kg ai/ha in sequential treatment with fluazifop at 7 days after transplanting. At the time of herbicide treatment, sedges and grasses were 4-7 cm high with 2-4 leaves and broadleaf weeds were 2-3 cm high with 4 leaves. Hand weeding was done 15 and 30 days after the herbicides were applied.

Statistical Design and Analysis

The experimental design was Randomized Complete Block Design (RCBD) with four replications. Individual plot size was 4 m by 5 m. Data in each study were subjected to analysis of variance using the General Linear Models Procedure (SAS). Treatment means were compared using Duncan's New Multiple Range Test at 5% level of significance. Data were not combined across locations because the treatments, weed pressure, proportion of dominant weeds, cultivar, and other factors varied between fields.

Research Results and Discussion

Field 1 (Santo Tomas)

Comparable weed control efficacy and yields were observed in plots treated with glyphosate applied either alone or as sequential treatment with fluazifop (Table 1). Applying glyphosate before or after land preparation also provided comparable weed control efficacy and yields. Weed growth was lowest and yields were highest in plots which were hand weeded twice. Unweeded plots had the greatest weed growth, particularly of the broadleaf weeds. Yields in unweeded plots were 80% lower than those in hand weeded plots and 70% lower than yields in herbicide-treated plots.

Table 1. Weed weight and yield in onion cultivar Tanduyong treated with various weed control methods in Santo Tomas Village, San Jose, Nueva Ecija during 1997-1998 dry season.

Treatment[b]	Weed weight at 45 DAT [a]			Yield[a] (t/ha)
	Sedge	Grass	Broadleaf	
	----------g/m^2----------			
G + F + 2 HW	6.8 ab	10.4 a	11.8 a	20.1 a
G(A) + 1 HW	14.2 a	7.7 a	19.8 a	20.2 a
G(B) + 1 HW	3.9 ab	3.0 a	12.8 a	17.3 a
HW 2x	6.7 ab	3.1 a	7.0 a	22.9 a
Unweeded	1.2 b	8.0 a	31.7 a	4.9 b

[a]In a column, means followed by the same letter are not different at 5% significance level using Duncan's New Multiple Range Test, average of four replications, Grass = *E. colona*; Sedge = *C. rotundus;* Broadleaf = *C. viscosa, T. portulacastrum;* DAT = days after transplanting.
[b]G = glyphosate; F = fluazifop; HW = hand weeding; G(A) = glyphosate applied after land preparation; G(B) = glyphosate applied before land preparation.

Weed control efficacy and yields from a single application of glyphosate plus one hand weeding was comparable with those from the farmers' practice applying glyphosate and fluazifop plus two hand weedings. In this field where the dominant weeds are broadleaf weeds, the follow-up treatment of the grass compound fluazifop was not necessary. The effect of applying glyphosate before or after land preparation is not clear; weed growth was reduced when glyphosate was applied before land preparation but yields were slightly lower than when it was applied after land preparation. Mulching did not suppress growth of the dominant broadleaf weeds, particularly *Cleome viscosa,* which grew through the mulch. Similar results were obtained in separate studies evaluating the effects of rice straw mulch on weed growth conducted in this field in 1997 (Baltazar *et al*, 1997).

Field 2 (Bongabon)

Lowest weed densities and comparable weed control efficacy were obtained from plots treated with sequential treatments of oxyfluorfen and fluazifop and from plots treated with single applications of fluazifop, confirming the results obtained in 1997 (Table 2). Yields from plots that received these treatments were comparable and were only 5% lower than yields in weed-free (control) plots that were hand weeded throughout the season.

Table 2. Weed density and yield in onion cv Yellow Granex treated with various weed control methods in Bongabon, Nueva Ecija during the 1998 dry season.

Treatment[b]	Weed weight at 45 DAT [a]			Yield[a] (t/ha)
	Sedge	Grass	Broadleaf	
	----------no./m^2----------			
Oxy + F + 2 HW	24 b	11 bc	19 d	13.8 a
F + 1 HW	20 b	14 b	23 cd	13.2 ab
G (B) + 1 HW	32 b	41 a	35 b	12.5 ab
G (A) + 1 HW	33 b	21 b	27 c	9.6 b
Unweeded	46 a	46 a	59 a	0.3 c
Hand weeded	1 c	2 c	1 c	14.1 a

[a]In a column, means followed by the same letter are not different at 5% significance level using Duncan's New Multiple Range Test, average of four replications, Grass = *E. colona, E. indica*; Sedge = *C. rotundus;* Broadleaf = *T. portulacastrum;* DAT = days after transplanting.
[b]Oxy = oxyfluorfen; F = fluazifop; HW = hand weeding; G (A) = glyphosate applied after land preparation; G (B) = glyphosate applied before land preparation.

Because 90% of the total weed population in 1997 was *C. rotundus*, single treatments of glyphosate applied either before or after land preparation were included in 1998 to control this weed. But in 1998 densities of the sedge, *C. rotundus* (31%) were much lower than in 1997 and were almost equal to those of the grasses *E. colona* and *E. indica* (30%) and of the broadleaf weed (39%). The glyphosate treatments reduced *C. rotundus* density by 30%, and *T. portulacastrum* density by 40% over those in unweeded plots. Applying glyphosate after land preparation resulted in greater reduction (50%) in densities of the grasses than when it was applied before land preparation. But weed growth in plots with both treatments was greater than those treated with fluazifop or oxyfluorfen. Apparently, the timing of glyphosate application, which is about 14 days before planting to avoid injury to onion, cannot provide adequate control through mid-season, which still covers the required critical weed-free period in onion. Oxyfluorfen or fluazifop are applied about 21 days later, at 7 days after transplanting. Yields in the glyphosate-treated plots were lower by an average of 20% than yields in weed-free plots and also lower by 15% than yields in plots treated with oxyfluorfen and/or fluazifop (Table 2). Yields in unweeded plots were reduced by 98% of yields in the weed-free plots and herbicide-treated plots.

Discussion

While the dominant weeds were similar in both fields, their proportion varied among fields. Field 1 (Santo Tomas) had higher broadleaf weed populations than sedges or grasses while Field 4 (Bongabon) had an equal proportion of grass, broadleaf, and sedge populations. In spite of inherent differences in dominant weeds and prevailing weed control practices between the farms, our results point to one common observation. Generally, a single herbicide application and a single hand weeding operation controlled weeds just as effectively and yielded comparably with the farmers' practice of two herbicide applications and two hand weedings.

The second herbicide application and hand weeding were not necessary because the herbicide was not effective on the dominant weed, or because additional weed suppression has been provided by the use of rice straw mulch. Thus, there was no need for a second herbicide application or a second hand weeding operation. This implies that, with the correct choice of herbicide, the farmers' practice can be reduced to one herbicide and one hand weeding.

Use of rice straw mulch in Field 1 helped suppress weed growth except for *C. viscosa*, the dominant broadleaf weed in Field 1. This weed, which can reach a height of more than 60 cm., can grow through the mulch. Similar results were observed in a previous study evaluating the effects of mulching on weed growth (Baltazar *et al*, 1997). Higher weed pressure in Field 2 could have been due to the absence of rice straw mulch. The time spent in hand weeding individual plots in Field 2 was four fold higher than in Field 1 and supports this observation (Table 3).

Table 3. Time spent in hand weeding individual plots in two onion farms in Nueva Ecija during the 1997-98 dry season.

Farm Site	Time spent in hand weeding	
	Minutes/20 m^2	Man-days/ha
Santo Tomas (Field 1)[a]	13.75	4.8
Bongabon (Field 2)[a]	58.78	20.5

[a] Average of two years, 1996-97 and 1997-98 dry seasons.

In our survey of major weeds in these fields conducted from 1994 to 1997, *C. rotundus* ranked most dominant in onion and second most dominant in rainfed rice (Baltazar *et al*, 1997). None of the herbicides currently being used for selective control in vegetables are effective against this weed. Glyphosate is effective but its broad spectrum activity limits its use to preplant applications to avoid injury to onion. Efficacy of glyphosate with mulch, and with or without tillage, against *C. rotundus* has been shown in our results in Field 1. However, its efficacy when applied before or after land cultivation is not clear in our results from Field 1 and 4 and needs further evaluation. A study conducted by other workers on *Imperata cylindrica* has shown reduction

in growth of its underground propagules but not its top growth when glyphosate application was preceded or followed by cultivation (Willard *et al*, 1996).

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 strategies involving ecological approaches that make use of the weeds' biological and ecological properties. For example, long-term management of perennial weeds like *C. rotundus* is dependent on reduction of populations of its underground propagules, the tubers. Management strategies using cultivation prior to or after herbicide application to reduce rhizome or tuber populations effectively controlled certain perennial weeds (Willard *et al*, 1996. In this research, 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 a rotation systems approach, which is the major objective of this research.

The basic principle of integrated weed management (IWM) programs is to enhance the competitive ability of the crop as well as protect it from competition by weeds through a combination of cultural, chemical, biological and ecological methods applied within a critical weed-free period. In our studies, farmers used a combination of cultural, mechanical, and chemical methods to satisfy the required critical weed-free period in onion, which was determined by previous research to be the first 7 to 8 weeks after transplanting under Philippine conditions (Paller *et al*, 1972). The variations in weed species and densities and in the control approaches observed in the two farms support the observations that weed management programs are formed on an empirical case-to-case basis (Thill *et al*, 1991) and that there is no universal approach to IWM (Murphy *et al*, 1996). There are numerous possible combinations of approaches and strategies and their effectiveness will vary among sites and among cropping seasons because weed growth, and soil, crop, and environmental factors vary.

Our results were conducted, and are thus more applicable, to the small-scale, highly diversified rainfed farms in tropical and sub-tropical areas with multiple weed species at a range of densities using mainly cultural, and less chemical, inputs. However, they can serve as basis in formulating IWM systems in large-scale, monoculture grain crops in temperate regions with one or a few weed species at high densities, using mainly chemical, and less cultural, inputs. For example, in the U.S. and Canada, IWM programs are now shifting from purely chemical methods to increasing use of cultural methods with less chemicals in response to environmental concerns (Swanton and Wiese, 1991). Integrating herbicides with cultural methods also prevents or delays the development of herbicide-resistant weeds (Gressel and Baltazar, 1996; Gressel, 1997). Similar to our observations, research on IWM in the U.S. showed that reduced herbicide inputs combined with a cultural practice like inter-row cultivation were just as effective as full rate herbicide inputs in reducing weed populations in both conventional and no till systems (Mulugeta and Stoltenberg, 1997). Although there is a high contrast in the weed-crop-environment situations between tropical and temperate cropping systems, the basic principles of IWM are the same. Research results in both areas can contribute to the study of the fundamental concepts of weed ecology and biology as the foundation and scientific basis of IWM approaches.

Impact on host country (Philippines) and/or the U.S.

Our data (average of two years and four farms) showing that the farmer's practice of two herbicide applications plus two hand weedings can be reduced to one herbicide plus one hand weeding without reducing yields implies a reduction in herbicide and hand weeding costs by 50%. This means lower production costs and thus increased profits for farmers.

On the U.S.

Although our studies were conducted in the Philippines, and are thus more applicable to tropical small scale, highly diversified rainfed farms, they can serve as basis in formulating IWM systems in large-scale, monoculture crops in the U.S. where IWM programs are now shifting from purely chemical methods to increasing use of cultural methods and reduced herbicide inputs.

Networking Activities

Second IPM-CRSP Symposium, Planning Workshop, and Technical Committee Meeting, Guatemala, May, 1997

Third IPM-CRSP Symposium, Planning Workshop, and Technical Committee Meeting, Virginia Tech, May 15-18, 1998

S. K. DeDatta traveled to PhilRice in February to discuss research progress and plans with project scientists.

Publications and Presentations

Baltazar, A.M., E.C. Martin, M.C. Casimero, F.V. Bariuan, S.R. Obien and S.K. De Datta.. 1997. Characterization of purple nudsedge in rainfed rice-onion systems. Proceedings 16th Asian-Pacific Weed Science Society Conference, Kuala Lumpur, Malaysia, September 8-12, 1997, pp.326-329.

Baltazar, A.M., E.C. Martin, M.C. Casimero, F.V. Bariuan, S.R. Obien and S.K. De Datta. 1997. Weed management in rice-onion systems. Proceedings IPM-CRSP Symposium, May 15-21, 1997, Guatemala City, Guatemala, pp.95-104.

Baltazar, A.M., E.C. Martin, M.C. Casimero, F.V. Bariuan, S.R. Obien and S.K. De Datta. 1998. Mahor weeds in rainfed rice-onion cropping systems in the Asia site in The Philippines. IPM-CRSP Working Paper No.98-1, presented, 3rd IPM CRSP Symposium, May, 1998, Virginia Tech, Blacksburg, Virginia, 22 pp.

Project Highlights

- Farmers' weed control practices can be reduced by 50% from two herbicides and two hand weeding operations to just one herbicide and one hand weeding, without reducing weed control efficacy and onion yields, cutting production costs significantly.
- In San Jose, one glyphosate application and one hand weeding was just as effective as farmer's practice of sequential application of gluphosate and fluazifop and two hand weeding operations in onion fields under straw mulch.
- Second herbicide application and hand weeding were not necessary or effective against the dominant weeds, because additional weed suppression was provided by the rice straw mulch.
- Mulching with rice straw suppressed growth of most weeds, but did not suppress growth of dominant broadleaf weeds, especially *Cleome viscosa*, which grew through the mulch.
- In Bongabon, where straw mulching is not a common practice, a single application of fluazifop and one hand weeding were just as effective as sequential applications of oxyfluorfen and fluazifop and two hand weedings for effective weed control.
- Dominant weeds in onion fields of both San Jose and Bongabon sites were similar but differed in proportions of broadleaf weeds, sedges, and grasses; broadleaf weeds were dominant in rice straw-covered onion fields of San Jose, while sedges were dominant in exposed onion fields of Bongabon.

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

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Abstract

Field trials in Bongabon, Nueva Ecija have shown that NPV, Bt, and NPV+Bt are more effective against *Spodoptera* larvae, than Karate insecticide application. Larval counts were significantly lower in the microbial treatments than the control or Karate treatment later in the season. Onion yields in the Bt+NPV- treated and the Karate-treated plots were significantly higher than in the control (no insecticide) plots, although the differences between them were not significant. The lowest yields were observed in control plots. These results show that microbials, alone or in combination, are effective alternatives to insecticide application, confirming their positive potential for *Spodoptera* management.

Onion yields among the treatments in San Jose, Nueva Ecija also had the same trend. Onion yields were significantly higher in NPV+Bt-treated plots than in NPV- and Karate treated plots, respectively. However, the cutworm larval densities were too low to demonstrate the effects of the treatments on them and on onion yields.

[1] UPLB (BIOTECH) [2] PhilRice [3] AVRDC [4] Penn State

The degree of onion leaf damage caused by larvae was relatively higher in the Demonstration farm in Bongabon than in the farmer's field in Palestina, San Jose, Nueva Ecija, which could be attributed to late planting. Onion yields from both sites differed considerably owing to rice hull burning, which could have reduced soil-borne diseases and nematodes, the timing of planting, the planting density, and the soil type.

Objectives

(1) To mass produce NPV-CRSP for field trials in combination with Bt
(2) To develop a better formulation for NPV
(3) To evaluate the efficacy of NPV-CRSP against *S. litura*
(4) To continue field trials using the most promising Bt and NPV-CRSP as microbial control agents against *S. litura*

IPM Constraints

Safe and economical alternatives to chemical control against *Spodoptera litura* in onions were considered as possible options for pesticide reduction.

Research Methods

Plans to develop a viable formulation for NPV-CRSP were proposed to replace the NPV crude extract currently used in field experiments, to minimize if not eliminate the pungent odor of the crude suspension. Mass-rearing of *Spodoptera* was continued using natural host plants to provide for the mass production of NPV-CRSP needed for the experiments.

The best Bt and NPV-CRSP strains continued to be tested in the field together with Karate, a common insecticide used by farmers for *Spodoptera* larval control. A farmer's field in Palestina, San Jose and a field in the Demonstration (Demo) farm in Bongabon, Nueva Ecija were used to compare the effects of Bt alone, NPV alone, NPV + Bt, and Karate application (farmer practice) on cutworm larval densities and onion yields. Each treatment was set up in RCBD using four replicated plots measuring 4m x 5m each. Treatments were applied for six weeks at biweekly intervals. The degree of onion leaf damage caused by larval feeding among the treatments was measured by taking the percent of leaves damaged per plant, using 10 plants for each treatment and replication, every two weeks starting 4 weeks after transplanting.

Research Results

A wettable powder formulation for NPV-CRSP was developed in August 1998 at the Insect Pathology Laboratory, Department of Entomology, U.P. Los Baños. This formulated product will replace the NPV crude extract being used in field experiments for *Spodoptera* control. The characteristic pungent odor of the crude suspension has been greatly minimized in the wettable powder for better handling and preparation of the spray solution. The Insect Pathology laboratory has produced five (5) kilograms of NPV-CRSP wettable powder with 6.785 x 10^8 PIBs per gram. They are maintained in the freezer for future use. Mass production of NPV-CRSP is a continuing activity of the project. The comparative effects of Bt product, NPV-CRSP crude extract and Karate on *Spodoptera litura* and *Helicoverpa* larval populations and onion yields from farmer's field in NOGROCOMA Demonstration Farm, Bongabon, Nueva Ecija are shown in Table 1.

Cutworm larval densities were observed to be relatively low during the season in Bongabon, especially 2 weeks after transplanting (WAT) up to 10 WAT, after which the number per plant increased slightly. However, larval densities differed significantly among treatments 12 WAT . Lowest mean larval density was observed in NPV-treated plots, followed by plots treated with Bt alone, NPV + Bt, and control, in increasing levels. Karate-treated plots had the highest larval densities. Onion yields were highest in NPV+Bt-treated and Karate-treated plots, although the differences between them were not significant. Yields in NPV-treated and Bt-treated plots were not significantly different than in the untreated control.

Table 1. Effect of *B. thuringiensis* product (Bt), NPV-CRSP crude extract and Karate on larval populations and onion yields in Demo Farm, Bongabon, Nueva Ecija, DS 1998.

	Mean number of *S. litura* and *Helicoverpa* larvae (4 Replications) n=10 plants										
Treatment	2 WAT[1]		5 WAT		8 WAT		11 WAT		14 WAT		Yield
	S.litura	*Helico.*	*S.litura*	*Helico.*	*S.litura*	*Helico.*	*S.litura*	*Helico.*	*S.litura*	*Helico.*	(ton/ha)
T1-Bt	0.90a[2]	0	0.43a	0	1.55a	0.18a	0.35b	0.23ab	0.53b	0.38a	16.63ab
T2-NPV	0.20a	0	0.33a	0	0.05a	0.25a	0.25b	0.18b	0.50b	2.73a	16.12ab
T3-NPV+Bt	0.20a	0	0.21a	0	0.95a	0.23a	0.30b	0.53a	0.83ab	0.15a	19.06a
T4-Karate	1.67a	0	0.80a	0	1.05a	0.03a	1.33a	0.33ab	1.33a	0.58a	18.85a
T5-Control	1.03a	0	0.68a	0	0.68a	0.58a	0.77ab	0.28ab	1.18ab	0.10a	14.15b

[1]WAT =Weeks After Treatment
[2]Means in a column with the same letter are not significantly different at 5% level of significance using DUNCAN'S MULTIPLE RANGE TEST.

Whether the yields were affected by other factors, e.g., soil-borne diseases, nematodes, or other insects, remains uncertain. It is also likely that the presence of another larval species, *Helicoverpa armigera*, could have affected the cutworm densities owing to the territorial and solitary behavior of *H. armigera* larvae, exhibiting control of onion

leaves over cutworm larvae. Likewise, the timing of sampling could have affected the observed cutworm larval densities. The shift to night sampling in the next year's activity may reflect a different picture of larval populations. In San Jose, Nueva Ecija, where the farmer planted early (November, 1997), cutworm larval densities were low and did not differ among treatments, which in effect were not adequate to reflect the adavantage of microbials over insecticide applications (Table 2). Likewise, onion yields were very high and did not differ significantly among treatments. The very high yields (four times as high as in the Demo Farm) in San Jose could be attributed to early planting, higher plant density per unit area (no furrows between rows and closer spacing), and the sandy loam type of soil. Moreover, the field was subjected to rice hull burning which has been shown to reduce soil-borne disease incidence, weeds, and nematodes. In contrast, onion fields in the Bongabon Demo farm were planted late (December-January), had lower plant density (plants were arranged in distinct rows with furrows between rows), and the clay loam type of soil. Rice hull burning is not a common practice in Bongabon farms as it is among San Jose farmers. Considering all these factors, which could have influenced onion yields in both sites, the effects of NPV and Bt still remain inconclusive. Perhaps, the real potential of Bt and NPV may be realized at higher concentrations, which should be considered in next year's experiments.

Table 2. Effect of *B. thuringiensis* product, NPV-CRSP crude extract and Karate on *S. litura* populations and onion yields in farmer's field in Palestina, San Jose, Nueva Ecija, DS 1998.

TREATMENT	Number of larvae per plant (4 replications)[1]					Yield (t/ha)
	2 WAT	5 WAT	8 WAT	11 WAT	14 WAT	
T1, Bt alone	0.03a	0.03a	0.68a	0.67a	0a	51.83a
T2, NPV alone	0.03a	0.03a	0.43a	2.00a	0a	58.27a
T3, NPV+Bt	0a	0a	1.38a	2.57a	0.03a	60.48a
T4, Karate	0a	0a	2.00a	1.33a	0a	53.44a
T5, Control	0a	0a	1.00a	1.50a	0.05a	50.13a

[1]Means in a column with the same letter are not significantly different at 5% level of significance using DUNCAN'S MULTIPLE RANGE TEST.

The extent of onion leaf damage owing to larval feeding is shown in Tables 3-4 and Figures 1-2. In the Bongabon site, overall leaf damage did not differ significantly among treatments. Percent damage ranged from as low as 11.5% at 4 WAT to as high as 41.75% at 12 WAT in Karate-treated plots, implying that Karate did not effectively suppress cutworm larval populations. Overall, the NPV-treated plots had the lowest leaf damage (Figure 1).

Table 3. Extent of leaf damage caused by *Spodoptera litura* larvae on Yellow Granex onion using Bt, NPV-CRSP, and Karate, Demo Farm, Bongabon, San Jose, DS 1997-98.

Treatment	Percent (%) Leaf Damage (n = 10 plants)[1]					
	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT	Overall
T1, Bt alone	20.50a	15.00a	20.75a	19.50a	30.50ab	25.34
T2, NPV alone	13.50a	17.25a	18.00a	17.00a	27.00b	18.55
T3, NPV+Bt	13.50a	18.25a	21.00a	21.50a	26.25b	20.10
Karate	11.50a	18.00a	22.25a	25.25a	41.75b	23.75
Control	20.75a	18.75a	25.75a	25.75a	34.50ab	25.10

[1]Means in a column followed by the same letter are not different at 5% level of significance using DUNCAN'S MULTIPLE RANGE TEST

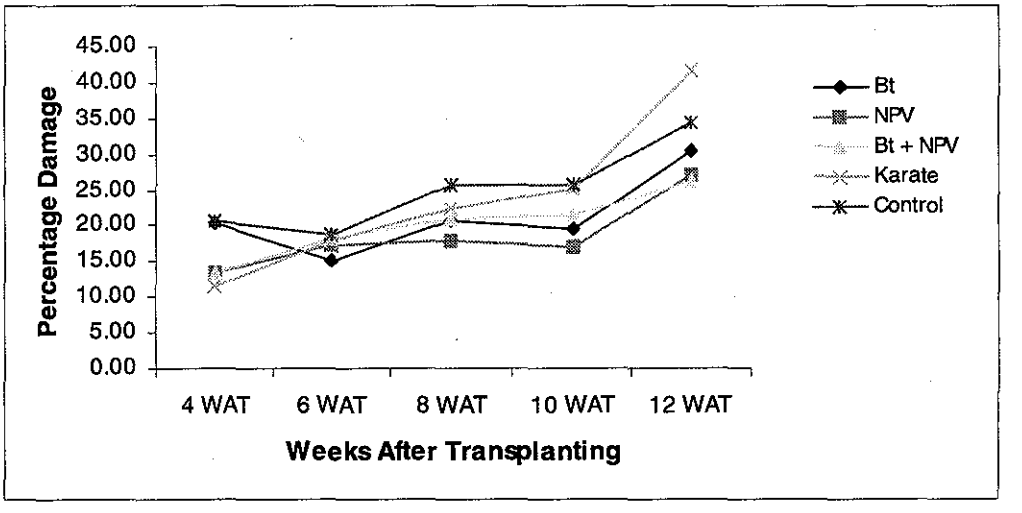


Figure 1. Effects of treatment with Bt, NPV, and Karate on leaf damage caused by cutworm larvae in onion field, Demo farm, Bongabon, Nueva Ecija, DS 1997-98.

In San Jose, the control plots showed the highest leaf damage 4 weeks after transplanting, but there were no significant differences between treatments. No significant differences were observed between treatments or the control for the remainder of the experiment (Table 4, Figure 2). As mentioned earlier, the much lower larval densities in the site may only reflect a negligible level of leaf damage, which ranged from as low as 0 at 4 WAT to as high as 21.75% at 10 WAT in NPV+Bt-treated plots.

The higher level of leaf damage in onion plots observed in the Bongabon Demo site could have been due to the late planting, with the vegetative stage of the crop coinciding with higher cutworm larval populations in the site.

Table 4. Extent of leaf damage caused by *Spodoptera litura* on Yellow Granex onion treated with Bt, NPV-CRSP, and Karate, Palestina, San Jose, Nueva Ecija, DS 1997-98.

Treatment	Percent (%) Leaf Damage (n = 10 plants)					
	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT	Overall
T1, Bt alone	2.00b	10.25a	15.75a	13.75a	3.25a	9.00a
T2, NPV alone	2.50b	6.00a	13.00a	13.25a	3.25a	7.60a
T3, NPV+Bt	0b	5.00a	20.25a	21.75a	3.00a	10.00a
T4, Karate	2.50b	7.25a	18.50a	19.25a	3.25a	10.15a
T5, Control	6.25a	10.75a	18.75a	16.25a	5.25a	11.45a

[1]Means in a column with the same letter are not significantly different at 5% level using DUNCAN'S MULTIPLE RANGE TEST.

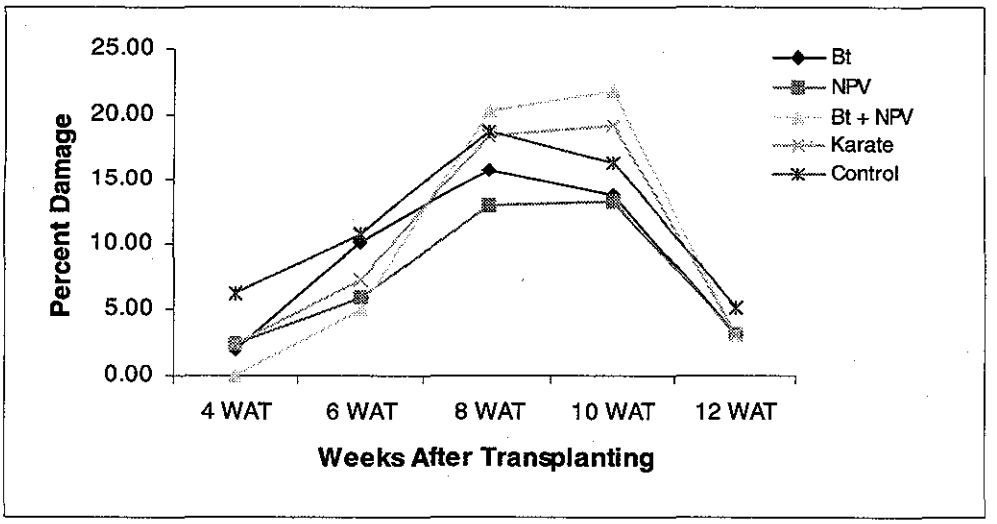


Figure 2. Effects of treatment with Bt, NPV, and Karate on leaf damage caused by cutworm larvae in onion fields, Palestina, San Jose, Nueva Ecija, DS 1997-98.

In the Bongabon site, while the experiment was being conducted, nearby plots were heavily invaded by armyworms (*Spodoptera exigua*). Surprisingly, however, they were not observed in the field where the microbial experiment was conducted. It may indicate that microbials are effective against armyworms.

Impact on host country

The use of Bt and NPV as alternatives to insecticide use would greatly benefit onion farmers who depend heavily on insecticides for cutworm control. Direct effects are reduced pesticide use, better health of farmers, and sustainable *Spodoptera* management. In addition, farm-produced NPV will reduce the 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

Workshops participated in:

Third IPM CRSP Symposium, Planning Workshop, and Technical Committee Meeting, Virginia Tech, Blacksburg, Virginia, May 15-18, 1998

Research Investigator Exchanges

As Scientist exchange (L. Padua) at Penn State University to conduct research on Nuclear Polyhedrosis Virus (NPV) with U.S. counterparts, August – November, 1998

Research information and product exchange

Prepared training booklet on mass production of NPV for adoption by onion farmers.

Distributed NPV materials for use by Bongabon farmers.

Publications and Presentations

L.E. Padua, V.P. Gapud, R.C. Suiza, E.C. Martin, C.V. Pile, B. Santiago, N.S. Talekar, E. Rajotte, and V. Recta. 1998.

Management tactics for *Spodoptera* control, Working Paper, presented, Third IPM CRSP Symposium, May 1998, Virginia Tech, IPM-CRSP, 12 pp.

Training Output

Trained 20 Bongabon farmers in the production of NPV at farmer level.

Project Highlights

- A wettable formulation of NPV-CRSP developed at UPLB (BIOTECH) with mass production capability; 5 kg of wettable NPV-CRSP have been produced.
- The presence of larvae of *Helicoverpa armigera* upset the cutworm larval populations in Demo farm, Bongabon, Nueva Ecija.
- Lowest cutworm larval densities occurred in NPV-treated plots in Demo farm, Bongabon, Nueva Ecija.
- Differences in cutworm larval densities, level of onion leaf damage, and onion yields between San Jose and Bongabon are attributed to timing of planting, planting density, soil type, and the presence of other lepidopterous larvae, e.g., *Helicoverpa armigera*.
- The use of NPV+Bt and NPV alone is a promising alternative to the use of insecticides for managing *Spodoptera litura* and *Helicoverpa* in onions.

Effects of Rice Hull Burning on Soil-Borne Diseases, Weed Survival and Growth, and the Rice Root-Knot Nematode, *Meloidogyne graminicola* in a Rice-Onion Cropping System

Investigators: E. B. Gergon[1], R. T. Alberto[1], M. C. Casimero[1], E.C. Martin[1], M. V. Judal[1], M.V. Duca[1], S.E. Santiago[1], F. Bajo[1], S.R. Obien[1], A.M. Baltazar[2], F.V. Bariuan[2], S.K. De Datta[3], A.M. Mortimer[4], and S. Miller[5]

Abstract

The continuing study on the effects of rice hull burning on soil-borne diseases in San Jose and Bongabon showed that fungal populations were much lower in burned plots than in unburned plots. In San Jose, fungal colonies were slightly higher in burned plots treated with compost than in those without compost, implying that compost could be favorable for fungal growth. Onion yields, however, were the same in both treatments. In unburned fields, a similar trend was observed but at lower levels, and with similarly low yields. It would appear that yields were more influenced by rice hull burning than by compost. Plots exposed to rice hull burning produced twice as much yield as those not exposed.

In the Bongabon Demo farm, pink root (*Phoma terrestris*) incidence and severity were slightly higher in burned fields with compost than in burned fields without compost. In unburned fields, the same trend for pink root was observed. The corresponding onion yields, however, were adversely affected by the armyworm *Spodoptera exigua* infestation associated with the El Niño phenomenon which affected many parts of the country, especially Central Luzon.

Rice hull burning reduced the density and fresh weight of *Cyperus rotundus*, the major weed in Palestina, San Jose, Nueva Ecija, by 88% and 79%, respectively, over unburned plots. Yields in burned plots were increased by 58% over unburned plots.

Experiments in San Jose showed that the heat caused by rice hull burning was effective in suppressing nematode populations up to a soil depth of 20 cm. Under field conditions, rice hull burning effectively reduced nematode populations with or without compost, resulting in larger and heavier onion bulbs. The experiment in Bongabon Demo farm showed a similar trend, but onion yields were greatly reduced by the armyworm infestation, which

[1] PhilRice [2] UPLB [3] Virginia Tech [4] IRRI [5] Ohio State

largely defoliated the onion plants throughout the field.

Objectives

(1) To determine the effectiveness of rice hull burning (RHB) in controlling soil-borne diseases,
(2) To determine the effectiveness of RHB in suppressing weed populations and reducing their survival, regeneration, and growth,
(3) To assess the effect of RHB on root-knot population levels, and
(4) To determine the contribution of RHB to onion yield.

IPM Constraints

The need for non-chemical control of soil-borne diseases, weeds, and root-knot nematode populations in onion fields.

Research Methods

Soil-borne Diseases

The experiment was conducted and superimposed in a farmer's field in Barangay Palestina, San Jose City, and the Demo Farm, Bongabon, Nueva Ecija, to determine the effect of rice hull burning in combination with application of compost on soil-borne diseases and onion yield. Twenty 5m x 6m plots were laid out in a split plot design in a field known to have problems with pink root. Ten of the plots were surface covered with an approximately 6 inches thick of rice hull and burned for 24 to 48 hours. The burned ash was plowed under and incorporated into the soil. Prior to transplanting, 1 kg of Sagana 100 (organic fertilizer) was applied to five of the ten plots with burned rice hull and to another five of the ten plots without burned rice hull. Yellow Granex variety was transplanted into the burned and unburned plots and grown according to fertilizer and water management practices in the area. The burned and unburned plots were separated by 1 m buffer zones. Soil and root sampling were done at 25, 50 and 75 DAT with ten root samples collected at random from each plot. Root samples were assessed for pink root incidence and severity and the soil samples for fungal colony forming units. Onions were harvested from a 2m x 3m area at the center of each plot and yield was expressed in t/ha.

Weeds

The study was conducted in a farmer's field in Palestina from December 1997 to April 1998 (dry season) to determine the effect of rice hull burning on weed growth. Prior to planting/transplanting, approximately 12 cm deep of rice hull was laid out in the seedbed/field and burned for 24 to 48 hours. The burned ash was plowed and incorporated into the soil and the field was harrowed one to two times. An adjacent area was not burned. Onion variety Yellow Granex was planted/transplanted into the burned and unburned plots and grown according to fertilizer and water management practices in the area. The burned and unburned plots were separated by a 1 m area as a buffer zone and were superimposed in the farmers' field. Weed counts and weights were taken from a 1 x 1 m^2 area marked off at the end of each plot. To ensure that only the rice hull burning effect was being measured, this marked area was not treated with herbicides nor hand weeded. Weeds were counted by species and dry weights recorded at 7 to 15 and at 30 to 45 days after transplanting and at harvest. Onion yield from a 2 x 3 m^2 area at the center of each plot was measured and expressed in t/ha.

Meloidogyne graminicola

Two experiments were conducted to determine the effects of heat on the population of *M. graminicola*. In experiment 1, the effective depth of rice hull burning on nematode mortality was determined by burying small canisters made of PVC pipes measuring 5 cm long and 3.8 cm diameter. Each of the canisters was filled with soil infested with 2,000 eggs and J2 (juvenile) nematodes *M. graminicola* prepared from UPLRi-5 plants that had been cultured in the greenhouse. These canisters were buried at 0, 10, 20, and 30 cm deep in the soil with two canisters per treatment replicated five times. The rice hulls covering the field (see above) were burned and allowed to cool for three days. The canisters were retrieved and the soil from one set of canisters was processed individually to extract the nematodes. In the other set of canisters, one-week-old UPLRi-5 seedlings were planted singly and maintained in the greenhouse. After 45 days, the plants were uprooted and assessed for nematode population. In a separate experiment, ten 5 x 6 m plots were marked in a nematode-infested field at two different sites. The plots were arranged in split plot design with five replications. In each replication, one of the plots remained free of rice hulls while the other plots, as well as the rest of the field, were covered with rice hulls 15 cm thick. These plots were further divided into two; on one plot Sagana 100 was applied with as compost plus complete fertilizer 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 yield and quality were determined from both burned and unburned plots.

Research Results

Soil-borne Diseases

As a common practice in Palestina, San Jose City, burning rice hulls piled approximately 6 inches thick in the field at the start of every onion season effectively prevents the occurrence of pink root in onions. The number of colonies of fungi was slightly higher on plots with compost at 30 and

90 DAT than the plots with no compost application. The plots with rice hull burning had higher yields than did those without rice hull burning (Table 1).

Table 1. Effect of rice hull burning and compost on soil-borne fungi. San Jose, DS 1997-98.

Treatments	A. Colonies of fungi / g of soil			Yield (kg/50 bulbs)
	30 DAT*	60 DAT	90 DAT	
T1-RHB w/Compost	12.0	7.8	13.6	4.8
T2-RHB	8.8	8.0	9.6	4.6
T3-No RHB W/ Compost	17.6	9.4	13.6	2.0
T4-No RHB	11.0	10.8	10.6	2.1

*DAT- Days After Transplanting

Table 2. Effects of rice hull burning and compost on pink root incidence and severity and yield of onion. Bongabon Demo Farm, DS 1997-98.

Treatments	Pink root Incidence (%)			Pink root Severity (%)			Yield (t/ha)
	30 DAT*	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	
T1-RHB w/ Compost	15.2	12.8	25.9	45.2	38.6	29.9	3.5
T2-RHB	11.5	9.1	19.8	30.4	36.2	30.1	6.7
T3-No RHB W/ Compost	17.6	20	21.7	57.2	61.6	32.9	6.0
T4-No RHB	9.5	18	20.4	38.4	56.9	33.5	5.4

* DAT- Days After Transplanting

Results of rice hull burning experiments conducted in Bongabon indicated that pink root incidence was slightly higher on treatments with compost. Similar results were observed on pink root severity (Table 2). However, at 90 DAT pink root severity was reduced because at this stage onion roots are reduced in number and deteriorated due to earlier infection at 30 DAT. All treatments showed no effect on onion yield due to the El Niño phenomenon and the late season armyworm infestation. Rice hull burning and the addition of compost had no effect on the number of colonies of fungi in the soil (Table 3).

Table 3. Effect of rice hull burning and compost on soil-borne fungi, Demo Farm, Bongabon, San Jose, DS 1997-98.

Treatments	Colonies of fungi / g of soil		
	30 DAT*	60 DAT	90 DAT
T1-RHB w/Compost	14.6	11.6	25.4
T2-RHB	16.8	11.2	24.4
T3-No RHB W/ Compost	18.0	13.0	32.8
T4-No RHB	19.8	18.2	24.6

* DAT- Days After Transplanting

Weeds

The dominant weeds were *Cyperus rotundus* (sedge), *Eleusine indica* (grass), and *Trianthema portulacastrum* (broadleaf). Weed growth in unburned plots averaged 55% greater in terms of density and 80% greater in terms of weed fresh weight, than in burned plots (Table 4). Suppression of the dominant weed, *Cyperus rotundus* was greatest among the three weed groups. Onion yields in the burned plots were 58% higher than in unburned plots. These results confirm data obtained in 1977, where rice hull burning reduced weed growth by an average of 58% and increased yields by 60% over yields in unburned plots.

Table 4. Effect of rice hull burning on weed growth, Palestina, San Jose, Nueva Ecija, DS 1997-98.

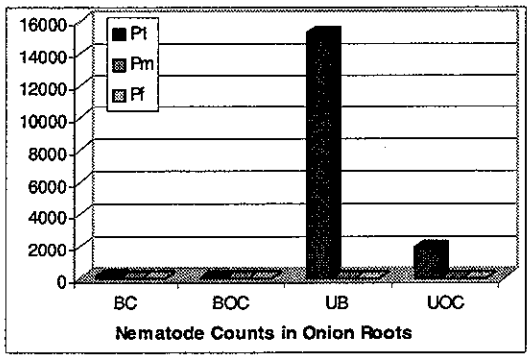
Treatment[a]	*C. rotundus*	*E. colona*	*T.portulacastrum*	Yield (kg/50 bulbs)
Density (no./m^2)				
B + C	6 c	0.2 b	2 b	4.8
B – C	7 c	0.4 b	1 b	4.6
UB + C	38 b	8.0 a	7 a	2.1
UB – C	72 a	6.0 a	4 a	2.0
Fresh weight (g/m^2)				
B + C	53 b	1 a	6 b	
B – C	96 b	7 a	5 b	
UB + C	292 a	27 a	41 a	
UB – C	423 a	28 a	22 ab	

[a]Average of 5 reps; taken at 40-45 DAT (midseason); B = burned; C = compost; UB = unburned.

Meloidogyne graminicola

The canister experiment showed that heat from burning rice hulls 15 cm thick on the surface of the soil was highly detrimental to the nematodes up to a depth of 20 cm but less at 30 cm (Table 5). Some eggs, however, may survive the effect of heat as indicated by nematodes obtained from our indicator UPLRi-5 rice cultivar. The highest number of eggs and J2 juveniles can survive in the soil at 30 cm depth. Our field experiment also showed that the heat generated by burning rice hulls was very effective in reducing the population densities of *M. graminicola* (Figure 3). In unburned fields, more nematodes were recorded from the roots one month after planting than in unburned fields, and at harvest, higher counts were recorded from the soil rhizosphere. The addition of Sagana 100 did not provide additional benefits to the plants, especially regarding yield. However, rice hull burned plots gave significantly bigger and heavier bulbs than unburned plots in San Jose City (Figure 4). Our experiment in Bongabon also showed

reduced nematode populations in burned plots but the yields obtained from the area were not reliable due to heavy armyworm infestation. The plants were totally defoliated at harvest time.



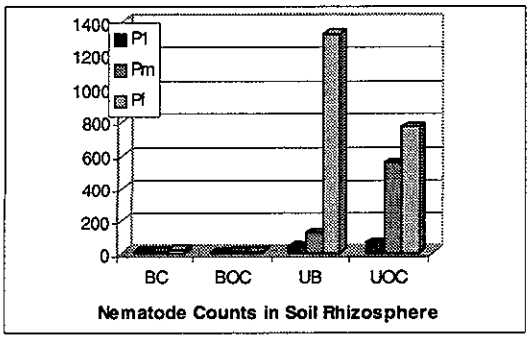


Figure 3. Effect of rice hull burning on population densities of *Meloidogyne* in onion roots and rhizosphere. (B = Burned + compost; BOC = Burned, without compost; UB = Unburned, with compost; UOC = unburned, without compost)

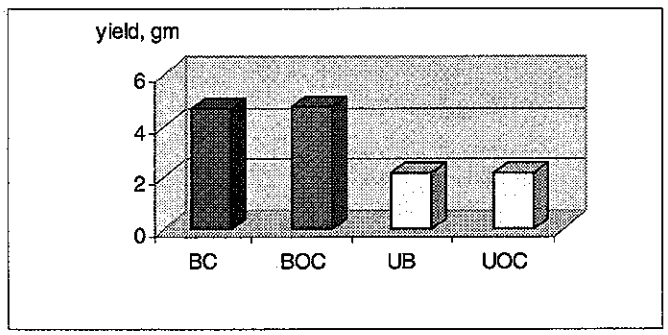


Figure 4. Effect of rice hull burning on onion yields, San Jose, Nueva Ecija. (B = Burned + compost; BOC = Burned, without compost; UB = Unburned, with compost; UOC = unburned, without compost)

Table 5. Effect of rice hull burning on the population densities of *Meloidogyne graminicola* in canisters buried at different depths and on gall formation[1].

Depth (cm)	No. of J2 recovered after burning	No. of J2 recovered after bioassay	Gall index rating
0	0a	1a	1.6a
10	0a	3a	1.6a
20	0a	3a	1.6a
30	21b	18b	1.6a
Untreated Control	-	889c	4.6b

[1]Means followed by the same letter are not significantly different at 5% level of significance by Duncan's Multiple Range Test.

Impact

Rice hull burning has been confirmed to be effective in suppressing soil-borne pathogens, weed growth and survival, and root-knot nematode populations. In the absence of alternative control measures, especially for diseases and nematodes, rice hull burning can considered a useful crop pest management practice. This practice is already an entrenched farmer's practice in some areas of the Philippines. However, given the adverse environmental effects, e.g., air pollution, possible health hazard, destruction of beneficial soil arthropods and microflora, the practice should probably be limited to once per year, just before the onion-growing season. Once better and safer options are developed, rice hull burning will continue to be a preferred management practice for onions.

Networking Activities

Third IPM CRSP Symposium, Planning Workshop, and Technical Committee Meeting, May 15-17, 1998, Virginia Tech, Blacksburg, Virginia.

S. Miller visited PhilRice in November 1997 and February 1998, and S. K. DeDatta visited in February 1998 to discuss research results and plans.

Publications and Presentations

E.B. Gergon, R.M. Gapasin, V. Judal, C. Ravina, C. Pile, and J. Halbrendt. 1998. Management of *Meloidogyne graminicola* in Rice-Onion Cropping System, presented at 3rd IPM CRSP Symposium, May, 1998, Virginia Tech.

E.B. Gergon, *et al.* Working paper on host suitability of *Meloidogyne graminicola*, submitted to Virginia Tech, 1998.

Training Output

- Fact Sheet on *Meloidogyne graminicola* and its management at draft stage.

Project Highlights

- Rice hull burning effectively suppressed soil-borne pathogens, weed growth and survival, and nematode populations in onion fields, resulting in yields two times higher than in unburned plots, with bigger and heavier Yellow Granex onion bulbs in San Jose, Nueva Ecija.
- In San Jose, fungal colonies were higher in burned plots with compost than in those without compost, with compost appearing to favor fungal growth. In unburned plots, a similar trend was observed, but with more fungal colonies.
- Compost did not appear to influence onion yields, whether in burned or unburned plots.
- Pink root incidence and severity were slightly higher in burned fields with compost than on those without compost in the Bongabon Demo farm. In unburned plots the same pink root trend was observed. Fungal colonies did not seem to be affected by compost in burned and unburned fields.
- Onion yields in Bongabon were adversely affected by armyworm infestation, probably associated with the El Niño phenomenon.
- Canister experiments showed that nematodes could be killed by the heat caused by rice hull burning up to a depth of 20 cm. At 30 cm, a few nematodes have survived.

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

Investigators: E. B. Gergon[1], R. T. Alberto[1], M. V. Judal[1], M. S. Valdez[1], C. Ravina[1], and S. Miller[2]

Abstract

The three-year crop rotation experiment intended to suppress/manage pink root disease and root-knot nematode populations in onion-growing areas showed a dramatic reduction in pink root incidence after pepper, rice, and cucumber were planted as rotation crops for two consecutive years, from 70-90% incidence to less than 15%. The disease severity was highest for the onion-fallow-rice-onion scheme, followed by the onion-pepper-rice-onion scheme, then by the mungbean-pepper-fallow-onion scheme, in decreasing order. Onion yields did not differ significantly among the treatments. So far, the mungbean-pepper-fallow-onion rotation pattern appeared to be the most effective for pink root suppression.

Initial populations of *Meloidogyne graminicola* were too low to provide conclusive results. The effects of the varying cropping schemes on nematode populations, therefore, were not clear, being aggravated during the last cropping season by the unusually hot and dry weather conditions caused by the El Niño phenomenon.

Objectives

(1) To determine the effects of different rice-based cropping patterns on the incidence of pink root disease of onion and *Meloidogyne graminicola* population in onion and rice

(2) To identify the most effective crop rotation scheme to suppress nematode population and pink root disease incidence in the rice-vegetable system.

IPM Constraints

Considering the difficulty of eradicating pink root disease and root-knot nematodes, viable long-term alternatives such as crop rotation are needed to suppress their populations.

[1] PhilRice [2] Ohio State

Research Methods

Pink Root Disease and *Meloidogyne graminicola*

The 3-year crop rotation experiment was conducted in the Demo Farm Bongabon, Nueva Ecija. Four different crop sequences were established in 4m x 5m plots with four replications in a randomized complete block design (RCBD). The crop sequence treatments were as follows: T_1, Onion- Pepper- Rice- Onion- Peanut- Rice; T_2, Peanut- Cucumber- Fallow- Pepper- Mungbean- Onion; T_3, Mungbean- Pepper- Fallow- Onion-Peanut - Rice; T_4, Onion- Fallow- Rice- Onion- Rice- Onion. The crops were grown using fertilizer and water management practices common to the area. Sampling was done at 25, 50 and 75 DAT, with ten root samples collected at random from each plot. Root samples were assessed for pink root incidence and severity. For nematodes, soil and root samples were taken one month after transplanting, at mid-season of the crop, and one day before harvest. The samples were processed in the laboratory for nematode extraction. Onions were harvested from a 2m x 3m area at the center of each plots and yield was expressed in t/ha.

Results

Pink Root Disease

Pink root incidence in crop rotation schemes 1 and 4 increased continuously up to 90 DAT. In rotation scheme 3, the disease incidence increased from 30 to 60 DAT but decreased at 90 DAT (Table 1). Initial data during the first cropping season showed 70% and 100% incidence of pink root in onions with corresponding severity of 54% and 73% (Table 2). Mungbean and peanut were not infected with the disease indicating resistance or non-host status to the pathogen. When pepper, rice and cucumber were planted as rotation crops for two consecutive seasons, the incidence of pink root was reduced to 9.90%, 8.89% and 14,25% in rotation schemes 1, 3 and 4, respectively. Pepper, rice, and cucumber were not infected with the disease. Consequently, the corresponding disease severity was also reduced to 45.56%, 42.22% and 58.89%, respectively, but remained relatively high, especially in crop rotation scheme 4. Rotation scheme 4 which involved planting of onion, followed by fallow period, rice, onion, rice, and onion in succession gave a higher onion yield (30.60 t/ha) than rotation scheme 3 (29.4 t/ha), but yields from both schemes did not differ significantly.

Table 1. Effects of crop rotation scheme on pink root incidence, severity and yield of onion. Demo Farm, Bongabon, Nueva Ecija, DS 1997-98

TREATMENTS (Rotation Schemes)[1]	D I (%)			DS (%)			YIELD (t/ha.)
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90DAT	
1	4.6	7.1	9.9	22.8	40	45.6	23.0
2	-	-	-	-	-	-	-
3	9.2	13.5	8.9	44.5	42.2	42.2	29.4
4	1.5	12.0	14.3	18.9	54.4	58.9	30.6

[1] Rotation Schemes: 1) Onion–Pepper–Rice–**Onion**–Peanut–Rice; 2) Peanut–Cucumber–Fallow–**Pepper** – Mungbean–Onion; 3) Mungbean–Pepper–Fallow-**Onion**–Peanut–Rice; 4) Onion – Fallow–Rice–**Onion**–Rice–Onion

Table 2. Effects of crop rotation scheme on pink root and yield of onion, Demo farm, Bongabon, Nueva Ecija, DS 1996-98

TREATMENTS (Rotation Schemes)[1]	D I (%)			DS (%)			YIELD (t/ha.)
	A[2]	B	Diff.	A[2]	B	Diff.	
1	70	9.9[3]	60.1	54	45.6[3]	8.4	23.0
2	-	-	-	-	-	-	-
3	-	8.9[4]	-	-	42.2[4]	-	29.4
4	100	14.3[5]	85.8	73	58.9[5]	14.1	30.6

[1] Rotation Schemes: 1) Onion – Pepper – Rice – **Onion** – Peanut – Rice; 2) Peanut – Cucumber – Fallow – **Pepper** – Mungbean – Onion; 3) Mungbean – Pepper – Fallow - **Onion** – Peanut – Rice; 4) Onion – Fallow – Rice – **Onion** – Rice – Onion

[2] Disease incidence and severity in onion at the start of the experiment

[3] Disease incidence and severity in onion after pepper and rice as rotation crops

[4] Disease incidence and severity in onion after mungbean and pepper as rotation crops and a fallow period.

[5] Disease incidence and severity in onion after a fallow period and rice as rotation crop

Crop rotation appears to be promising for reducing the pink root disease pressure by breaking the cycle of the disease, especially when pink root is known to become severe when onions are grown continuously or with only one year rotation. Since this study needs one more season for all crop rotation cycles to be completed, no definite conclusions on the current results can be made.

Meloidogyne graminicola

Meloidogyne graminicola was detected in the roots and /or soil rhizosphere of all crops used in the study. Its numbers, however, did not increase in peanut, mungbean, cucumber, and pepper varieties used in the study, confirming that they may be poor hosts of this pathogen. The nematodes increased in onion and rice although their level of increase in

onion was very much lower than in rice (Table 3). Onion is a good host of *M. graminicola*, but was observed rarely on this crop this season, possibly because of the unfavorable conditions that prevailed and affected the development and multiplication of the nematode. The populations of *M. graminicola* encountered were definitely not sufficiently high to give conclusive results. This may be attributed to high daily temperature (average was 35 C) and low water supply in the area. Drought may have caused lower nematode recoveries from dry soil. Castillo *et al.* (1995) also obtained low recoveries of *Hemicycliophora* in dry soil in spite of high initial populations due to dehydration. The yields of onion following pepper and a fallow period were significantly higher than those obtained after rice. Since population densities in onion roots at harvest were not significantly different among treatments, the yield of the last onion crop was correlated with the population density of *M. graminicola* detected after the rice crop, which served as initial nematode population for the last onion crop.

Table 3. The influence of crop rotation on population of *M. graminicola*, Demo Farm, Bongabon, Nueva Ecija, DS 1997-98.

	Ave. number of juveniles/root system/200 cc soil (4 replicates)[2]				
Treatment[1]	Before Crop	First Crop	Second Crop	Third Crop	Fourth Crop
T1	7a	10	2	400b	9
T2	7a	7	3	15a	0
T3	7a	7	2	3a	11
T4	5b	11	3	384b	18

[1]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]Means followed by a common letter are not significantly at 5% level by Duncan's Multiple Range Test.

The initial populations of *Meloidogyne graminicola* in the soil at the start of the experiment were low. One month after transplanting, during the first cropping season, a significant increase in nematode densities from onion roots became evident until the final harvest (Figure 1, A-D).

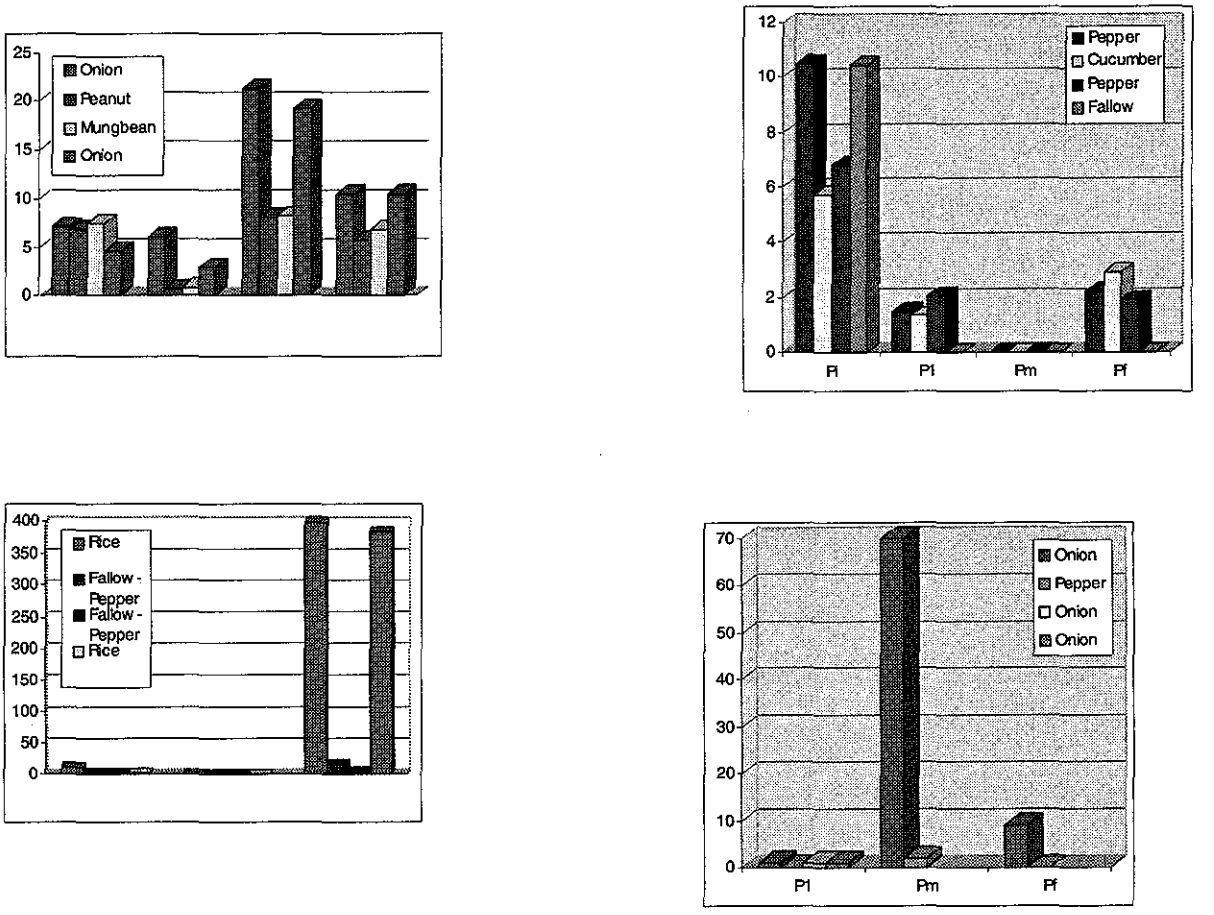


Figure 1, A-D (clockwise from upper left). Increase in Nematode Densities in Various Crops - Cropping Seasons 1, 2, 3, and 4.

During the second cropping where resistant crops were grown, higher counts were recorded from pepper and fallow treatments grown in plots previously planted to onions than cucumber and pepper grown in plots previously planted to peanut and mungbean. This showed the effect of the previous crop on the level of nematode densities for the succeeding crops. Moreover, since pepper is resistant to *M. graminicola* (based on previous studies), the nematodes were not able to multiply until the end of the season, providing very low initial populations for the next crops. After some time, with the presence of rice, which is a good host of *M. graminicola*, the nematodes reproduced rapidly in rice as indicated by significantly higher counts in their roots than fallow-pepper treatments. Unfortunately, during the fourth cropping season, we experienced very dry and hot weather conditions, which were unfavorable for nematodes and other pathogens as well as onion culture. High nematode populations were detected in onion from one plot previously planted to rice during mid and final harvests.

The populations of *Meloidogyne graminicola* encountered were not high enough to give conclusive results. However, some trends on the effect of crop rotation on the population of the nematode were evident. The yields of onion following pepper and a fallow were significantly higher than those obtained after, which may be attributed to higher inoculum provided by the rice crop to the succeeding onion crop.

Impact on Host Country

The search for rotation crops resistant to *Meloidogyne graminicola* and at the same time economically profitable for farmers to grow, if successful, may effectively suppress pink root disease incidence and severity and nematode populations, which seriously affect onion yields. Moreover, if farmers provide ample time for their farms to be left at fallow to break the cycles of both pathogens, then both can be managed successfully.

Networking Activities

S. Miller visited PhilRice in November 1997 and February 1998, and S. K. DeDatta visited in February 1998 to discuss research results and plans.

Third IPM CRSP Symposium, Planning Workshop and Technical Committee Meeting, May 15-16, 1998, Virginia Tech, Blacksburg, Virginia

Training Output

- Fact sheet on *Meloidogyne graminicola* and its management in rice-onion systems has been prepared for review.
- Fact sheet on pink root disease and its management in onion systems has been prepared for review.

Project Highlights

- Pink root disease incidence (DI) and severity (DS) in the crop rotation plots at the Demo farm, Bongabon, Nueva Ecija were reduced from 70% DI and 54% DS to 9.9% DI and 45.6% DS in the onion-pepper-rice-onion scheme, and from 100% DI and 73% DS to 14.25% DI and 58% DS in the onion-fallow-rice-onion scheme.
- The mungbean-pepper-fallow-onion scheme appeared to be the most effective for pink root disease suppression.
- Pepper, peanut, mungbean, and cucumber were either resistant to both pink root and *Meloidogyne graminicola* or were simply non-hosts to both; the pink root pathogen, *Phoma terrestris*, is so far known to be exclusive to onions, while *M. graminicola* has many alternate hosts.
- Initial populations of *M. graminicola* were too low to provide conclusive results for the crop rotation experiment. The effects of these rotation schemes on the nematodes were aggravated by the unusually dry and hot weather conditions, resulting from the El Niño phenomenon, which severely affected the survival of the nematodes.

Effects of Soil Amendments on Populations of *Meloidogyne graminicola* in Rice-Onion System

Investigators: E. B. Gergon[1], M. V. Judal[1], C. Ravina[1], R. Gapasin[2], S. Miller[3], and J. Halbrendt[4]

Abstract

None of the five biofertilizers/soil inoculants tested for suppression of root-knot nematode populations in onion roots and soil were effective in either San Jose or Bongabon. Under greenhouse conditions, none of the biofertilizers/soil inoculants contributed to the improved emergence and growth of onion seedlings.

In VISCA, microplot experiments showed that *Tagetes* sp. and two *Crotalaria* species (*C. incana* and *C. mucronata*) significantly reduced the number of galls and nematode population in onion roots and soil. Likewise, clean fallow even for 2 months can also effectively reduce nematode populations in the soil.

Objectives

(1) To evaluate different soil amendments for possible suppression of root-knot nematode populations

(2) To evaluate possible side effects of soil amendments as disease enhancers

(3) To determine the effects of *Tagetes* and *Crotalaria* and clean fallow on the root-knot nematode populations

IPM Constraints

The need to replace synthetic chemical control of nematodes with alternative practices such as use of biofertilizers and plants with nematicidal properties.

Research Methods

Several biofertilizers and soil inoculants, as possible soil amendments for suppression of *Meloidogyne graminicola*, were evaluated in the field and in the greenhouse in a randomized complete block design with five replications. The field experiment was conducted in 5 x 6 m plots in four farm sites using three onion cultivars - Red Creole, Tanduyong, and Yellow Granex in two sites. The biofertilizers used and their rates of application based on manufacturer's recommendation were as follows: Rhizo-N, 200 kg/ ha; Biogreen, 5,000 kg/ha; and Sagana 100, 500 kg/ha with additional 100 kg urea/ha. The soil inoculants were 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 a control. All treatments were broadcast on the field prior to transplanting, with the exception of Bio-N. Bio-N was mixed in water and the seedlings were soaked in this solution for 30 minutes, one hour before transplanting. Root and soil samples for nematode extraction were collected in the same manner as for the crop rotation experiment, three times during the experiment.

A greenhouse experiment using the same treatments, rates, and methods of applications was also done using plastic trays (35 cm x 27 cm x 11 cm) filled with *M. graminicola*-infested soil. Seedling emergence, heights, and number of nematodes in the roots after 45 days exposure to *M. graminicola* were determined for two onion varieties, Yellow Granex and Red Creole.

At the VISCA experimental area, microplots with an area of 2.4 m x 0.75 m were prepared and inoculated with 1,000 eggs of *M. graminicola* and later sown with 30 seeds of rice (cultivar UPLRi5). The rice plants were allowed to grow in the microplots for 60 days. Rice plants were harvested and their galled roots together with the egg masses were evenly buried in the plots. The plots were constantly watered to enhance egg hatching and increase of nematode populations in the microplots. After one week, seeds of *Crotalaria incana, C. mucronata, Tagetes* sp. and rice (UPLRi5) were sown in the microplots. A clean fallow treatment was included and the treatments were replicated three times. The plants were allowed to grow for 90 days. After 60 days, 10 plants from each microplot were harvested. 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 as described above. The larvae extracted from the roots and soil were counted.. The same procedures were followed for plants harvested at 90 days.

[1] PhilRice [2] VISCA [3] Ohio State [4] Penn State

Results

Results of field experiments at four sites with three onion varieties showed that none of the biofertilizer/ soil inoculant treatments were significantly different from each other or the control in terms of nematode reduction in roots and soil and in onion yield (Tables 1, 2, and Figure 1).

Under greenhouse conditions, none of the treatments improved seedling emergence as claimed by the manufacturers (Table 3). Biogreen, however, produced the tallest Red Creole 4 and 6 weeks after seeding.

The effectiveness of organic wastes in reducing nematode populations has been attributed to toxic products of their decomposition, increase in number of natural enemies, and alteration of plant-nematode relationship (Sayre, 1971). It could also be due to ammonification of organic materials (Walker, 1969) and heat (Sussman, 1982).

Table 1. Effect of different biofertilizers and soil inoculants on nematode densities[1] in onion field trials.

	San Jose City		Bongabon	
Treatment	Yellow Granex	Tanduyong	Yellow Granex	Red Creole
4 WAT[2]				
Bio-N	19	25	1469	48
Rhizo-N	2	10	531	17
Biogreen	2	34	133	20
VAM	2	14	128	45
Sagana 100	1	10	393	24
14-14-14	4055	17	1975	31
8WAT				
Bio-N	9	10	715	190
Rhizo-N	33	7	229	474
Biogreen	47	14	277	261
VAM	8	5	238	192
Sagana 100	20	5	237	152
14-14-14	11	66	359	126
12 WAT				
Bio-N	31	7	232	71
Rhizo-N	306	59	236	89
Biogreen	115	17	121	149
VAM	129	0	86	187
Sagana 100	49	345	419	155
14-14-14	35	3	437	148

[1]Replicated four times; [2]Weeks after Transplanting

Table 2. Effect of biofertilizers and soil inoculants on onion seedlings under greenhouse conditions[1].

	% Emergence		Seedling Height (cm) 1MAS	
Treatment	Yellow Granex	Red Creole	Yellow Granex	Red Creole
	6 days after seeding		**14 days after seeding**	
Bio-N	53.24	37.50	6.16	8.23
Rhizo-N	50.25	47.25	6.20	6.20
Biogreen	46.50	23.25	5.50	5.90
VAM	75.25	53.50	7.29	6.80
Sagana 100	43.50	26.25	6.53	5.54
14-14-14	56.25	28.00	5.73	6.61
Inoculated control	39.75	36.75	5.55	5.70
	12 days after seeding		**30 days after seeding**	
Bio-N	65.25	48.50	9.59b	9.80b
Rhizo-N	50.50	68.50	10.51ab	9.02ab
Biogreen	62.25	43.50	8.55bc	6.30b
VAM	71.50	62.25	12.66a	11.74a
Sagana 100	43.50	40.25	9.03bc	7.01b
14-14-14	60.50	44.50	9.54b	9.02ab
Inoculated Control	50.00	61.25	6.39c	6.21b

[1]Replicated four times.

Table 3. Effect of biofertilizers and soil inoculants on the yield of onion cultivars.

	B. Mean Yield (kg/20 m^2) of Onion Cultivars (4 replications)			
	San Jose City		Bongabon	
Treatment	Yellow Granex	Tanduyong	Yellow Granex	Red Creole
Bio-N	3.53	15.77	5.74	7.71
Rhizo-N	3.40	17.33	4.87	8.95
Biogreen	3.43	17.07	4.22	8.43
VAM	3.28	17.20	4.69	9.04
Sagana 100	2.40	17.59	5.22	7.86
14-14-14	3.25	15.44	4.91	8.02

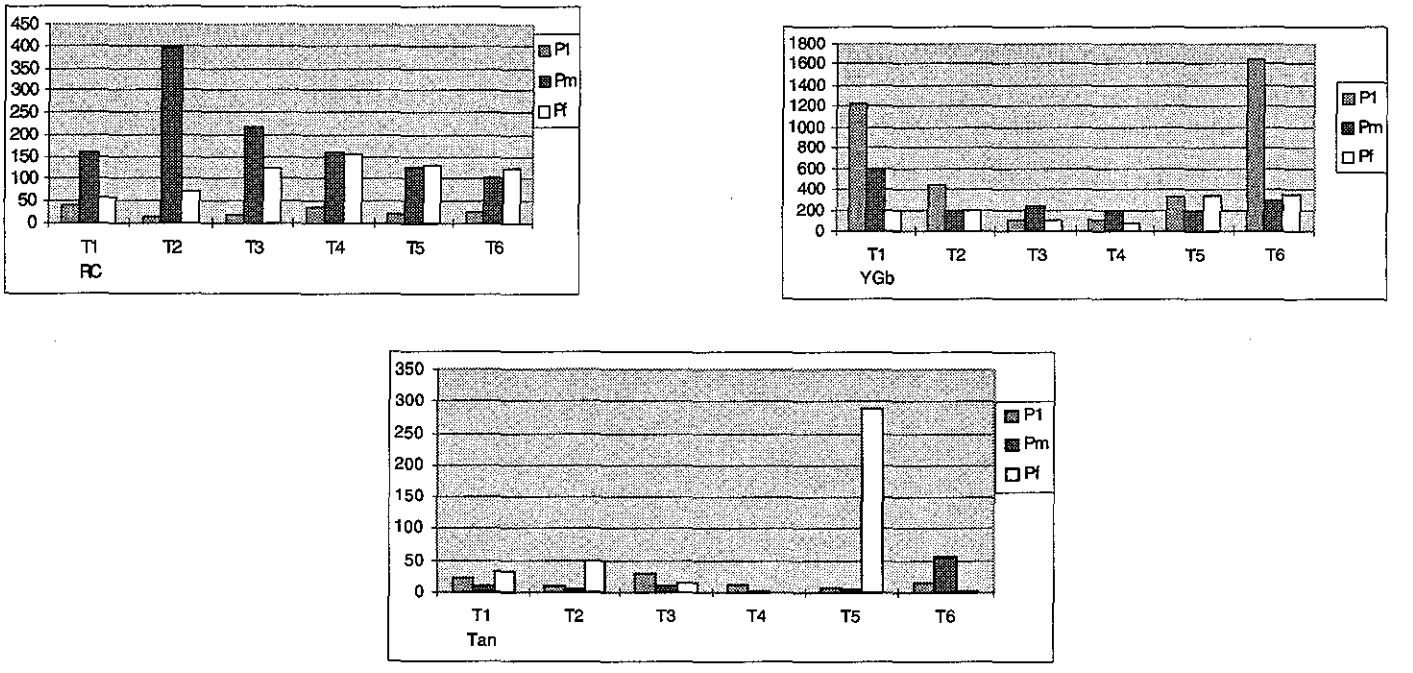


Figure 1 (three graphs, clockwise from left). Effects of biofertilizers and soil inoculants on the nematode populations in different onion varieties.

The biofertilizers used in the study had been processed and air dried. The helpful microbials that may be responsible for decomposition and multiplication of biocontroltrol agents against *M. graminicola* may have died. The same suggestion was made by Castillo (personal communication) as to why chicken manure is often not effective in controlling nematodes. Results of studies at VISCA on the effect of *Tagetes* and *Crotalaria* are shown in Table 4. No galls were observed on *Crotalaria* and *Tagetes* roots 60 and 90 days after planting within the nematode-infested microplots, suggesting that they were either antagonistic to, or non-hosts of the nematodes. Two compounds [a-terthienyl and 5-(3-buten-1-ynyl)-2,2'-bithienyl] from *Tagetes* are known to be effective against several nematodes, including root-knot species. The alkaloid monocrotaline in *Crotalaria* may also 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 planting. This was expected since the plots were weeded and turning over the soil may have had a profound effect on nematode juveniles owing to solar radiation. The results of this microplot experiment confirm the earlier results from pot experiments using the same treatments.

Table 4. Effect of *Tagetes, Crotalaria*, and clean fallow on *Meloidogyne graminicola* under microplot conditions, VISCA, Baybay, Leyte, DS 1997-98[1].

	Number of Galls	Nematode Density In Roots	Nematode Density in Soil
60 days			
Tagetes sp.	0a	0a	5.23a
Crotalaria mucronata	0a	0a	7.46a
Crotalaria incana	0a	0a	6.23a
Clean fallow	-	-	3.20a
Rice (UPLRi5)	49.3b	199.1b	496.3b
90 days			
Tagetes sp.	0a	0a	2.56a
Crotalaria mucronata	0a	0a	2.56a
Crotalaria incana	0a	0a	2.96a
Clean fallow	-	-	2.53a
Rice (UPLRi5)	305.7b	354.7b	368.6b

[1]5-g root system and 200-g soil per plant; n = 10 plants per plot.
Means in a column with the same letter are not significantly different at 5% level of significance, using Duncan's Multiple Range Test.

Impact on host country (Philippines) and/or the U.S.

Planting *Tagetes* and *Crotalaria* and using clean fallow can be effective management strategies against rice root-knot nematodes in the rice-onion system. While farmers practice a fallow period before planting onion, the clean fallow may be more effective for nematode reduction, since root-knot nematodes survive very well in several weed species growing in the field in the absence of both rice and onion.

Networking Activities

Second IPM CRSP Syposium, Planning Workshop, and Technical Committee Meeting, May, 1997, Guatemala City, Guatemala (R.M. Gapasin)

S. Miller visited PhilRice in November 1997 and February 1998 to discuss research results and plans.

Project Highlights

- Densities of *Meloidogyne graminicola* did not differ significantly among biofertilizer/soil inoculant treatments.
- Under greenhouse conditions, none of the biofertilizers/soil inoculants influenced emergence and growth of onion seedlings as claimed by their manufacturers. VAM-treated seedlings were the tallest 4 and 6 weeks after seeding.
- Nematode populations appeared to be highest in Yellow Granex onions, regardless of the treatment, followed by Red Creole, and lowest in Tanduyong onions.
- *Tagetes* and *Crotalaria* were confirmed to be either resistant to *M. graminicola* or non-hosts as observed in microplots. The clean fallow treatment had the lowest nematode densities since the absence of weeds and turning over of soil adversely affected nematode survival.

The Effectiveness of Trap Plants and Pheromone Traps for *Spodoptera litura* and *Leucinodes orbonalis* Management

Investigators: V.P. Gapud[1], C. Pile[1], B. Santiago[1], G. Balagot[1], N.S. Talekar[2], E. Rajotte[3], and V. Recta[3]

Abstract

The use of castor as trap plants for *Spodoptera litura* feeding on onions continued to be assessed during the onion-growing season. While castor plants effectively attracted *S. litura*, as well as another lepidopterous pest, *Helicoverpa armigera* (Hubner), it was not clear whether the trapping role of the castor plants is adequate to prevent these pests from entering the onion fields. So far, the larval densities within onion plots were low and did not differ significantly between plots surrounded by castor and those without castor plants.

Pheromone traps for *Spodoptera* confirmed the presence of *S. exigua*, which occurred in outbreak proportions. In the initial years of the project, the pest had not been detected despite the traps. The occurrence of *S. exigua* inflicted heavy damage of onions in many parts of Nueva Ecija, especially those where onions were planted late (January).

Objectives

(1) Determine the effectiveness of castor as trap plants for *Spodoptera litura*

(2) Evaluate pheromones as indicators of relative abundance of *S. litura.*

IPM Constraints

The need to develop safer and economical methods of control for *Spodoptera litura* and other lepidopterous pests attacking onion as efforts toward reduction in the use of pesticides without adversely affecting onion yields.

[1] PhilRice [2] AVRDC [3] Penn State

Research Methods

Castor seeds were planted in individual black soil-filled plastic bags and kept in the greenhouse. When seedlings were a month old, they were placed around the designated 10 m x 5 m plots in the four corners of the farmer-cooperators' fields, with plants set apart by 1 meter. All 28 castor plants in each of four plots were monitored every 2-3 days for larvae and egg masses which were recorded on a per plant basis. All larvae and egg masses collected were either destroyed or brought to the laboratory for parasitoid emergence. The larval populations of *S. litura* were monitored within the onion plots with castor plants and plots without castor every two weeks, using twenty plant samples per plot. The effectiveness of castor in attracting *S. litura* and the larval population within the onion plots was evaluated. Onion were harvested from 5m x 2m plots within each treatment.

Two one-half hectare areas of onion stands were used for the pheromone trap monitoring. Each area was divided at the middle according to the prevailing wind direction. In each half, two commercial pheromone traps (pherocon, trece) were set up on 1-m high poles after onion seedlings were transplanted. The number of *S. litura* adult catches were recorded every week for the duration of the onion season. Captured adults were removed after counting. Trap bottoms were replaced when 30% or more of the trap surface had been contaminated or every month whichever came first. Emitters were replaced every two weeks.

Research Results

Castor as Trap Plants

In addition to *Spodoptera litura*, castor plants also attracted *Helicoverpa armigera*, an equally polyphagous lepidopterous pest (Table 1, Figure 1). Although *S. exigua* larvae were observed, they did not appear to prefer castor plants (0.7 larva/plant in 7 weeks).

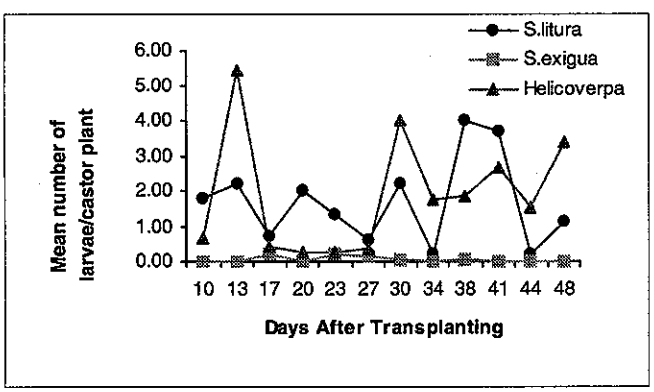


Figure 1. Larval catches from castor plants around onion plots, Demo farm, Bongabon, San Jose, DS 1997-98.

Table 1. Larval densities observed on castor plants around onion plots, Demo farm, Bongabon, Nueva Ecija, DS 1997-98.

Days After Transplanting (DAT)	Mean Number of larvae/castor plant (n=28 plants)[1]		
	S. ltiura	*H. armigera*	*S. exigua*
10 DAT	1.81	0.67	0
13 DAT	2.19	5.44	0
17 DAT	0.73	0.41	0.21
20 DAT	2.00	0.27	0
23 DAT	1.33	0.27	0.21
27 DAT	0.6	0.34	0.15
30 DAT	2.19	3.98	0.06
34 DAT	0.20	1.73	0.02
38 DAT	3.99	1.84	0.05
41 DAT	3.67	2.68	0
44 DAT	0.23	1.52	0
48 DAT	1.12	3.39	0
7 weeks	**20.1**	**22.54**	**0.7**

[1]Values are means of 4 replications.

Overall, a slightly higher number of *Helicoverpa* larvae were retrieved (22.54 larvae/ plant in 7 weeks) in relation to *S. litura* (20.1 larvae/plant in 7 weeks). It also appears that the distribution patterns of both *Spodoptera* and *Helicoverpa* are random-clamped, although this observation needs to be verified.

Populations of *Spodoptera litura* larvae in onion plots with or without castor plants did not differ significantly. *Helicoverpa* larval populations were sometimes but not always lower in castor-surrounded plots. As in the microbial experiment (I.2), larval densities in onion were not very high and did not appear to represent any considerable pest pressure. It may be that the sampling period, regularly during the day, does not reflect actual larval densities in the field. *Spodoptera litura* larvae are known to rest in the soil during the day, even as some may be found within the damaged leaf. The proportion of those in the soil, however, is not known. However, the yield of onions harvested from fields surrounded by castor plants was significantly higher than the yield in plots without castor plants (Table 2).

Table 2. Larval densities in onion plots in relation to castor as trap plants, Demo farm, Bongabon, Nueva Ecija, DS 1997-98.

Treatment	Mean number of larvae/plant (n=20 onion plants)[1]								Yield (t/ha)
	4 WAT		6 WAT		8 WAT		10 WAT		
	Spod.	*Helico.*	*Spod.*	*Helico.*	*Spod.*	*Helico.*	*Spod.*	*Helico.*	
With Castor	0.2a	0.04a	0.013a	0.65a	0.08a	0.29a	0.28a	0.33a	24.11a
No Castor	0.3a	0.29b	0.064b	0.28a	0.01a	0.38b	0.28a	0.44a	16.03b

[1]Means in a column with the same letter are not significantly different at 5% level of significance using Duncan's Multiple Range Test; values are means of 4 replicates.

Pheromone Traps for *Spodoptera*

Pheromone trap catches of *Spodoptera* adults from two fields in the vicinity of the Demo farm at Bongabon, Nueva Ecija showed relatively high numbers for *S. litura* at 7 WAT, declining thereafter (Table 3). During this season, outbreaks of *S. exigua* were observed in other parts of Nueva Ecija, including Bongabon. In the Demo farm area, *S. exigua* catches were already high at 7 WAT, but increased dramatically thereafter. At 7 WAT, the larval densities in the first field, based on 20 plants, were already 2.8 and 4.9 larvae per plant for *S. litura* and *S. exigua*, respectively. In the second field, the levels were 3.9 and 6.2 larvae per plant for *S. litura* and *S. exigua*, respectively. The effects of larval feeding were devastating to onion fields that were invaded, including many of the experimental plots in the Demo farm.

Table 3. Pheromone trap catches of *Spodoptera*, Demo farm area, Bongabon, Nueva Ecija, DS 1997-98.

Farm/*Spodoptera* species	Mean No. Adults/trap (n=2 traps)				Accum. Mean
	7 WAT	8 WAT	9 WAT	10 WAT	
Mang Tolome's field					
S. litura	82.5	28.5	24.5	25.5	161
S. exigua	58	247.5	299	124	728.5
Mang Teteng's field					
S. litura	75.5	48	21	28	172.5
S. exigua	51.5	216	321	228	816.5

In the farmer's field in Sto. Domingo, Nueva Ecija, overnight catches reached up to 81 adults per trap in March, 1998. In the field, larvae congregatied at the tips of onion leaves in midday, completely overrunning the. The occurrence of *S. exigua* could be attributed to the El Niño phenomenon, characterized by a long dry spell and high temperatures. As a result, many alternate host plants of *S. exigua* may have died out during this period, impelling the pest to migrate to remaining standing crops, such as onions. In addition, this weather disturbance could have affected the survival of natural enemies, especially insect parasitoids of *S. exigua*, which could have released them from parasitoid pressure, resulting in an outbreak magnitude of the pest. Under normal conditions, this pest would hardly be of serious concern, as has been the case during the past four years of the project.

Impact

Castor as trap plants, once shown to be consistently effective, can serve as a viable alternative to insecticide application for *Spodoptera* larvae in onions. This variety originated from India, and was provided to the project by Dr. N. S. Talekar of AVRDC. Ultimately, it could be tested together with our wild castor, which grows profusely in uncultivated areas, especially near river banks and moist areas.

Pheromones have had a dramatic effect in quantifying the outbreak of *S. exigua*. A more precise monitoring of this pest using its corresponding pheromone will be necessary in the future to anticipate the level of this pest and strategically apply tactics to manage it.

Networking Activities

E. Rajotte visited PhilRice in November 1997 and February to discuss research results and plans.

Training Output

Distribution of castor seeds to Bongabon farmers as requested by them for their own use for testing it as trap plant for cutworms.

Project Highlights

- Castor plants attracted both *Spodoptera litura* and *Helicoverpa armigera* in almost similar proportions. Larval catches for *S. exigua* were very low.
- Larval densities in onion plants did not differ significantly between plots with castor and those without castor. However, onion yield was significantly higher in plots with castor plants than plots without castor.
- Larval densities in onion were low in both San Jose and Bongabon, slightly higher in the latter site, and may not be adequate to inflict considerable damage to onion plants.

- Pheromone traps confirmed the presence of *S. exigua*, which was not detected in the previous four years of the project.
- Pheromone trap catches were relatively high for *S. litura* at 7 WAT (83 and 76 adults/ trap in two farmers' fields) in Bongabon Demo farm, declining thereafter, while those for *S. exigua* were lower at 7 WAT (58 and 52 adults/trap in two farmers' fields) but increased drastically at 8 WAT (248 and 216 per trap) and 9 WAT (299 and 321 per trap), with densities still high at 10 WAT (124 and 228 per trap).

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. Pile[1], B. Santiago[1], R. Suiza[1], E.C. Martin[1], E. Rajotte[2], and V. Recta[2]

Abstract

In efforts to reduce labor costs attributed to the weekly removal of damages shoots and fruits of eggplant to minimize damage by and populations of *Leucinodes orbonalis*, the varying frequencies of shoot and fruit removal were tested together with the triweekly insecticide (Brodan) application. In two farmers' fields and at the PhilRice Central Experimental Station, weekly removal of damaged shoot and fruit continued to be the best option for farmers' adoption. Yields of total and healthy fruits were highest, and the amount of damaged fruit and fruit borer larval densities were lowest in this treatment, followed by triweekly insecticide application. In terms of actual production of marketable fruits, the biweekly removal of damaged shoots and fruits is a fairly good (third) option for farmers to adopt.

Objective

Determine appropriate frequency of damaged fruit removal to reduce *Leucinodes orbonalis* and most economically produce undamaged eggplant fruits.

IPM Constraints

Appropriate frequency of damaged shoot and fruit removal as an effective alternative to insecticide use will contribute to reduction of frequency of insecticide application without considerable effect on eggplant fruit yield.

Research Methods

Using a farmer's field (Mang Berto) in Abar 1st, San Jose, Nueva Ecija, 4m x 5m plots were set up with 5 treatments and 4 replications in RCBD, with 1 row of eggplant between each of them. During the season, the treatments used were: T1, triweekly spraying of Brodan; T2, weekly removal of damaged shoots and fruits; T3, biweekly removal of damaged shoots and fruits; T4, triweekly removal of damaged shoots and fruits; and T5, untreated control. The farmer's 4-5 day harvesting schedule was followed to determine the effect of the treatments on eggplant production and fruit borer populations. The eggplant season lasted for 5-6 months. All damaged fruits were brought to the laboratory for monitoring of larval parasitoids of the fruit borer.

During the growing season, the farmer's field was increasingly infected with bacterial wilt (caused by *Pseudomonas solanacearum*). The experiment was stopped at 125 days after transplanting (DAT) during which the field incidence of the disease had reached 18%, with accompanying data analyzed only to this point. The experiment was transferred to another farmer's field (Mang Fredo) with an already existing eggplant crop but which had negligible bacterial wilt incidence. An experimental field was also set up at the PhilRice Central Experimental Station (CES) to backstop the farmer-based experiment.

Research Results

Owing to the occurrence of bacterial wilt in the first farmer's field (Mang Berto), the data analyzed were restricted to the period covering 125 days (4.5 months), while those for the second framer's field (Mang Fredo) covered a period of 167

[1] PhilRice [2] Penn State

days (about 6 months). Data for the PhilRice experimental field covered a period of 132 days (about 5 months). Results on the possible effects of the treatments on eggplant production and fruit borer larval densities are shown in Tables 1-3.

Table 1. Effects of frequency of damaged fruit removal and insecticide application on accumulated eggplant production over a 4.5-month period, Mang Berto's field, Abar 1st, San Jose, Nueva Ecija, DS 1997-98[1].

Treatment	Total No. of Fruits/ha	No.of Healthy fruits/ha	Wt.of Healthy fruits (t/ha)	No. of Damaged fruits/ha	Wt. Of Damaged fruits/ha	Percent Fruit Damage (%)	No. of Borer larvae/ha
T1,Triweekly spray	350,490	300,000a	13.93a	50,470a	2.38a	14.40	12,880a
T2,Weekly removal	367,150	326,900a	15.75a	40,250a	2.03a	10.96	7,910a
T3, Biweekly Removal	340,410	297,220a	13.86a	43,190a	2.10a	12.69	13,720a
T4, Triweekly Removal	361,130	313,110a	14.70a	48,020a	2.31a	13.30	12,250a
T5, Control	337,960	290,010a	13.90a	47,950a	2.31a	14.19	17,150a

[1]Means in a column with the same letter are not significantly different at 5% level of significance based on Duncan's Multiple Range Test; replicated 4 times.

Table 2. Effects of frequency of damaged fruit removal and insecticide application on accumulated eggplant production over a 6-month period, Mang Fredo's field, Abar 1st, San Jose, Nueva Ecija, DS 1997-98[1].

Treatment	Total No. of Fruits/ha	No.of Healthy fruits/ha	Wt.of Healthy Fruits (t/ha)	No. of Damaged fruits/ha	Wt. Of Damaged fruits/ha	Percent Fruit Damage (%)	No. of Borer larvae/ha
T1,Triweekly spray	652,300	437,840a	18.16b	214,480a	10.32a	32.88	97,520a
T2,Weekly removal	720,160	516,000a	23.92ab	203,840a	9.92a	28.30	84,960a
T3, Biweekly Removal	687,360	464,720a	23.12ab	221,400a	11.04a	32.39	89,280a
T4, Triweekly Removal	699,904	475,760a	22.48ab	223,280a	10.56a	31.94	81,360a
T5, Control	666,400	432,000a	20.96a	234,400a	10.96a	35.17	99,280a

[1]Means in a column with the same letter are not significantly different at 5% level of significance based on Duncan's Multiple Range Test; replicated 4 times.

In Mang Berto's field, which was infected with bacterial wilt during the season, the fruit yields were affected by the disease (Table 1). Yields and number of undamaged fruits did not differ significantly among treatments. The damage levels ranged from 10.96% to 14.4%, with the highest observed in insecticide-treated plots, followed by the control plots. It is highly likely that experimental results observed in this field were adversely affected by the incidence of bacterial wilt and may not reflect the normally healthy situation.

However, in Mang Fredo's field, where bacterial wilt incidence was very low (below 10%), there were also no significant differences among treatments and the control in yield. The extent of fruit damage was very high, ranging from 28.3% (T2 plots) to 35.17% (control plots). The very high densities of fruit borer larvae (81,360/ha to 99,280/ha), imply that the farmer-cooperator may have added insecticide sprays during the experiment beyond the intended treatments.

At the PhilRice experimental station, where most of the field operations were more closely monitored, the number of healthy fruits as well as the number and weight of damaged fruits differed significantly among treatments (Table 3). The highest number of healthy fruits were observed in T_2 (257,640/ha), followed by plots sprayed every three weeks with Brodan (T_1), then by plots subjected to biweekly removal of damaged fruits (T_3), triweekly removal (T_4), and control (T_5), in decreasing order. The weights of healthy fruits, however, did not differ significantly among treatments. In contrast, the lowest number of damaged fruits was observed in T_2 plots, followed by T_3, T_1, T_4, and T_5, in increasing order. In terms of weight, however, the lowest was observed in T_2, followed by T_3, T_1 and T_4, with T_5 having the highest damage.

Table 3. Effects of frequency of damaged fruit removal and insecticide application on accumulated eggplant production over a 5-month period, PhilRice experimental field, Maligaya, Muñoz, Nueva Ecija, DS 1997-98[1].

Treatment	Total No. of Fruits/ha	No.of Healthy fruits/ha	Wt.of Healthy Fruits (t/ha)	No. of Damaged fruits/ha	Wt. of Damaged fruits/ha	Percent Fruit Damage (%)	No. of Borer larvae/ha
T1,Triweekly spray	261,360	222,000ab	11.22a	39,360ab	1.80ab	15.06	18,120a
T2,Weekly removal	284,760	257,640a	11.28a	27,120b	1.20b	9.52	20,880a
T3, Biweekly Removal	219,000	187,020b	7.56a	31,800b	1.44ab	17.10	17,760a
T4, Triweekly Removal	217,080	175,500b	11.34a	41,580ab	1.80ab	23.69	21,750a
T5, Control	209,880	154,260b	13.38a	55,620a	2.28a	26.50	31,700a

[1]Means in a column with the same letter are not significantly different at 5% level of significance based on Duncan's Multiple Range Test; replicated 4 times.

Based on farmers' fields and the PhilRice experimental field, it appears that weekly removal of damaged shoots and fruits and triweekly spraying remain as viable management options for farmers, confirming the results of the previous year's experiment. The options for biweekly and triweekly removal of damaged fruits remain promising but with inconsistent results. Considering the labor costs involved in removing damaged fruits, these two options need to be verified further. However, if the regular removal of damaged fruits is made to coincide with the farmer's schedule of harvest every 4-5 days, then the labor costs attributed to this option become part of the harvest effort.

Impact on Host Country

The three options available for sound management of the eggplant shoot and fruit borer, namely, weekly removal, triweekly insecticide application, and biweekly removal of damaged shoots and fruits will significantly reduce pesticide use in eggplant farms. In practical terms, the combination of weekly harvest by farmers and weekly removal of damaged shoots and fruits would reduce production costs attributed to labor.

Network Activities

Second IPM CRSP Symposium, Planning Workshop, and Technical Committee Meeting, May 1997, Guatemala City, Guatemala.

Third IPM CRSP Symposium, Planning Workshop, and Technical Committee Meeting, May 15-16, 1998, Virginia Tech, Blacksburg, Virginia.

E. Rajotte visited PhilRice in November 1997 and February 1998 to discuss research results and plans.

Publications and Presentations

V.P. Gapud, C. Pile, B. Santiago, R. Suiza, E.C. Martin, E. Rajotte, V. Recta. 1998. Management of Eggplant Leafhopper, *Amrasca biguttula* (Ishida) and Shoot and Fruit Borer, *Leucinodes orbonalis* (Guenee) in Rice-Vegetable System, Working Paper submitted to Virginia Tech for review.

V.P. Gapud, R.C. Suiza, E.C. Martin, C. Pile, B. Santiago, G. Balagot, M.C. Lit, E. Rajotte, and N. S. Talekar. 1998. Management of Eggplant and Stringbean Insect Pests, paper presented in the Third IPM CRSP Symposium, May 1998, Virginia Tech, Blacksburg, Virginia

Project Highlights

- At 18% incidence of bacterial wilt in the farmer's field (Mang Berto), eggplant fruit yields did not differ statistically among treatments. Damage levels ranged from 10.96% (T2) to 14.4% (insecticide-treated plots).

- At PhilRice experimental field, the number and weights of damaged fruits differed significantly among treatments, with the lowest damage observed in T2 plots. Inversely, the highest number of healthy fruits was observed in T2 plots.

- Overall, weekly removal of damaged shoots and fruits remained the best option for farmers in terms of fruit production, marketable fruits and level of fruit damage. The triweekly insecticide application remained a second option, followed by biweekly removal of damaged shoots and fruits as a third option.

- Labor costs can be reduced if the weekly removal of damaged shoots and fruits would coincide with the regular fruit harvesting schedule of the farmers.

Movement of Arthropod Predators

Investigators: K.L. Heong[1], L. Sigsgaard[1], V. Gapud[2], G. Arida[2], J. Ramos[2], and E. Rajotte[3]

Abstract

The aim 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 the arthropod predators' activity-density and directional movement between habitats in the fallow and rice system at four different farms in the province of Nueva Ecija. We are also assessing density and species composition in the field edge and at increasing distance from the field edge. We will continue this in the onion system when onion is planted in November to cover a full cropping cycle. Pitfall trap sampling at one location at IRRI serves as a control, and here we are also currently testing possible trap improvements. We have used directional pitfall traps placed in the bunds and sticky boards and window traps. Special emphasis is placed on spiders and coleopterans. We are analyzing the temporal patterns of the movements in and out the fields. Density of pests and natural enemies are assessed by visual count and suction sampling. This serves as a control of the catches in the pitfall traps. In addition, detailed biology and ecology of one or two selected generalist predators is being quantified in a combination of field and lab studies.

Objectives

(1) To identify the predator species moving between the habitats

(2) To quantify movements of predators between habitats in rice-onion cropping systems

(3) To assess the predators' impact on pest abundance.

IPM Constraints

Understand and improve natural biological control in the field by maintaining natural enemies in the field. How bunds are managed for best pest control.

Research Methods

Arthropod predators directional movement between habitats in the rice-onion system, are monitored by directional pitfall traps placed in the bunds of rice-onion fields. Four localities are sampled weekly with these directional pitfall traps. In each locality five traps are placed. Each trap includes two pitfall traps divided by a 40 cm wide barrier for walking insects. In two of the localities there are window traps to follow trends in the movement of flying insects over the season. Density of predators as well as their prey in the bunds and field is also assessed by suction sampling. Finally the plant community of the bunds has also been sampled. We put special emphasis on spiders and coleopterans. Temporal patterns of these arthropods activity-densities and directional movements will be 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 are doing a parallel experiment at one location at IRRI farm, where we are also testing possible trap improvements. In addition, detailed biology and ecology of one or two selected generalist predators will be quantified in a combination of field and lab studies.

Research Results

This section is kept fairly short since we only resumed activity by the end of April this year, so this is in reality a 6 months report and data are not yet fully compiled nor analyzed. The data are expected to generate information on the dynamics of generalist predators and their possible roles in maintaining control of pests. Detailed biological studies one or two selected generalist predators are also being planned.

Our insect samples for this first half of 1998 covering the onion-fallow and the rice crop have not yet been keyed out. The IRRI farm control showed a clear effect of farm operation upon the catches in the pitfall traps. It is noteworthy that there is no clear trend separating the catches from the parts of the directional pitfall traps facing the field and those facing the bund at IRRI. We assume that this may be due to a diurnal pattern of movements into and out of the field that is not detected, but our 24 hours sampling pattern may show this, which will be investigated further.

[1] IRRI [2] PhilRice [3] Penn State

Two spiders, *Callitrichia formosana* and *Pardosa pseudoannulata* and a carabid, *Pherosophus javanus*, have been selected for further studies in the laboratory based on their high abundance in the pitfall traps and/or in the field. Preliminary studies of the diurnal pattern of the two first species were inconclusive, and need to be repeated in a different set-up. Functional response and density dependent predation for *C. formosana* was also assessed in a preliminary study and results indicate a type two or three response, but will need to be replicated at a larger scale to decide which.

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 provide information to help refine the timing of pesticide spray recommendations developed in other projects.

Project Highlights

There is a clear effect of farm operations upon the catches in the pitfall traps, documenting movement across the bunds when there are field operations, however, a possible trend separating the catches from traps facing the field and the exterior still needs further study.

Effectiveness of Selected Larval Parasitoids against *Spodoptera litura, Maruca testulalis*, and *Leucinodes orbonalis*

Investigators: V.P. Gapud[1], C. Pile[1], B. Santiago[1], G. Balagot[1], R. Suiza[1], N.S. Talekar[2], and E. Rajotte[3]

Abstract

The field level of parasitism of *Leucinodes orbonalis* by the ichneumonid parasitoid, *Trathala flavoorbitalis* was monitored to gain insights into the parasitoid's performance in the farmer's field. Based on the two farmers' fields grown to eggplant from October to May every year, its highest level of occurrence is experienced throughout March. At most, the parasitoid is present in the field as early as mid-January up to the first week of April.

In farmers' fields, the degree of parasitism by *T. flavoorbitalis* varied widely from none to as high as 70%. Overall, however, parasitism averaged about 20-25% in most fields. Parasitoids were recovered from all treated plots, including insecticide-treated plots. With the planned mass-rearing of *L. orbonalis* in artificial diet, *T. flavoorbitalis* may yet be successfully mass-reared and strategically mass-released in farmers' fields.

Objectives

(1) Evaluate effectiveness of larval parasitoids against *S. lituralis, M. testulalis,* and *L. orbonalis*

(2) Explore other natural enemies of *Spodoptera, Maruca,* and *Leucinodes* within and outside the country.

IPM Constraints

The need to explore the effectiveness of biological control against *S. litura, M. testulalis*, and *L. orbonalis* to reduce pesticide use in vegetable systems, particularly in eggplant.

Research Methods

The activity for this year focused on the level of larval parasitism of *Leucinodes orbonalis* by *Trathala flavoorbitalis* under field conditions (farmers' fields). Damaged fruits from the farmers' fields being used for the fruit removal experiment were retrieved every 4-5 days from January to April, 1998. They were brought to the laboratory, from which fruit borer larvae were removed and transferred into individual vials and provided with eggplant in cut cubes. The emerging parasitoids and borer adults were recorded according to the treatments used in the fruit removal experiment. Representative adults of *L. orbonalis* and *T. flavoorbitalis* were mounted on insect pins and preserved as voucher specimens.

[1] PhilRice [2] AVRDC [3] Penn State

Research Results

Based on the larvae of *L. orbonalis* collected from farmers' fields, larval parasitism by *T. flavoorbitalis* varied from none to moderate levels depending on the month of the year.

In Mang Berto's field (Table 1), which was planted to eggplant in mid October, field parasitism was observed as early as mid-January, but was practically non-existent for the rest of the month up to February. Parasitism started picking up again in March, reaching up to 75% (March 4) in plots subjected to weekly removal of damaged shoots and fruits in a previous experiment. However, after the first week of April, no parasitoids were retrieved from field-collected larvae of *L. orbonalis*. In insecticide-treated plots, parasitoids were retrieved, reaching a level of up to 28.5% parasitism (March 4). It is not certain whether the relatively lower level of parasitism in these plots was actually due to insecticide sprays. Whether the parasitoids' effectiveness is influenced by fruit borer density remains to be determined.

In Mang Fredo's field (Table 2), retrieval of fruit borer larvae from damaged fruit began after mid-February up to April. February levels of parasitism reached only 10.5%. However, in March, parasitism reached as high as 47% (March 3) from plots subjected to weekly removal of damaged shoots and fruits (T2), declining during the first week of April and practically gone for the rest of April.

Observations from farmers' fields indicate that the period of activity of *T. flavoorbitalis* is rather short, mid-January to March, after which parasitism seems to cease. Whether the unusually dry and hot weather conditions had any effect on the occurrence of these parasitoids remains to be determined. During March, at least, field parasitism can reach up to 75%, indicating that these parasitoids may contribute significantly to the management of *L. orbonalis* through an augmentation intervention, through mass-rearing and mass-release, together with the weekly fruit removal and triweekly insecticide spray options.

Impact on Host Country

The heavy use of insecticides in eggplant farms (1-2 times a week for 5 –6 months), may in the past have been detrimental to the parasitoid, *T. flavoorbitalis*, considering its low density in the field. The possible success of mass-rearing of this parasitoid through mass-rearing of *L. orbonalis* in artificial diet, will make possible their mass release in eggplant growing areas, which may further encourage eggplant farmers to reduce their insecticide applications to at least every three weeks. If these efforts succeed, then the hazards to the environment and human health posed by pesticides would be greatly minimized. Moreover, other Asian countries could benefit from the use of this parasitoid, which happens to occur also in most parts of Asia.

Networking Activities

E. Rajotte visited PhilRice in November 1997 and February 1998 to discuss research results and plans.

Project Highlights

- In a farmer's field (Mang Berto), field parasitism of *L. orbonalis* by *T. flavoorbitalis* was observed as early as mid-January, negligible in February, and reoccurred in March up to first week of April, after which no parasitoids were retrieved. Parasitism varied from none to as high as 75% (March 4). Overall, however, the average level of parasitism was about 20-25%, with peak of activity within March.

- In another farmer's field (Mang Fredo), field parasitism started in mid-February, continuing up to first week of April, with peak occurrences in March. The performance of the parasitoid varied from none to as high as 46.6% (March 3), with a probable average of 20% parasitism of field-collected fruit borer larvae.

- The period of activity of the parasitoid, *T. flavoorbitalis*, was brief, from as early as mid-January to as late as first week of April, even when the eggplant crop lasted up to the end of May. Whether this trend was influenced by the unusually hot and dry weather conditions remains to be known.

Table 1. Parasitism in field-collected larvae of *Leucinodes orbonalis*, Mang Berto's field, Abar 1st, San Jose, Nueva Ecija, DS 1997-98.

Date/Treatment	No. of Larvae	Parasitoids	% Parasitism	Adult Borers
16 Jan 98				
T1	3	0	-	
T2	4	2	50.0	2
T3	6	1	16.7	1
T4	3	1	33.3	1
T5	6	2	33.3	1
20 Jan 98				
T1	4	0	-	2
T2	3	0	-	1
T3	4	0	-	1
T4	3	0	-	1
T5	6	0	-	3
27 Jan 98				
T1	5	0	-	3
T2	8	2	25.0	3
T3	3	0	-	1
T4	5	2	40.0	4
T5	10	3	30.0	7
11 Feb 98				
T1	5	0	-	5
T2	2	0	-	2
T3	3	0	-	3
T4	4	0	-	4
T5	3	0	-	3
4 Mar 98				
T1	7	2	28.5	4
T2	4	3	75.0	1
T3	7	2	28.5	5
T4	5	0	-	5
T5	7	3	42.8	4
9 Mar 98				
T1	16	1	6.25	12
T2	14	3	21.4	10
T3	11	4	36.3	6
T4	10	0	-	10
T5	26	7	26.9	18
13 Mar 98				
T1	8	1	12.5	6
T2	4	0	-	4
T3	8	2	25.0	5
T4	5	2	40.0	3
T5	9	2	22.2	5
21 Mar 98				
T1	5	1	20.0	4
T2	3	1	33.3	2
T3	3	1	33.3	2
T4	3	0	-	3
T5	17	6	35.2	11
Date/Treatment	No. of Larvae	Parasitoids	% Parasitism	Borer larvae
24 Mar 98				
T1	42	8	19.0	32
T2	15	3	20.0	11
T3	12	0	-	10
T4	13	0	-	12
T5	31	3	9.6	24
29 Mar 98				
T1	11	1	9.1	9
T2	11	1	9.1	10
T3	9	1	11.1	7
T4	8	0	-	7
T5	10	0	-	6
2 Apr 98				
T1	7	2	28.5	5
T2	4	0	-	4
T3	3	0	-	3
T4	5	0	-	5
T5	28	2	9.1	23

Table 2. Parasitism in field-collected larvae of *Leucinodes orbonalis*, Mang Fredo's field, Abar 1st, San Jose, DS 1997-98.

Date/Treatment	No. of Larvae	Parasitoids	% Parasitism	Adult Borers
21 Feb 98				
T1	21	2	9.5	16
T2	12	0	0	10
T3	10	1	10.0	9
T4	9	0	0	8
T5	29	1	3.7	11
25 Feb 98				
T1	19	2	10.5	12
T2	13	0	0	5
T3	20	1	5.0	13
T4	10	0	0	4
T5	24	2	8.3	19
3 Mar 98				
T1	0	0	-	-
T2	15	7	46.6	6
T3	18	3	16.6	10
T4	0	0	-	-
T5	0	0	-	-
10 Mar 98				
T1	5	1	20.0	4
T2	10	0	-	10
T3	7	0	-	7
T4	3	0	-	3
T5	10	3	30.0	10
17 Mar 98				
T1	7	1	14.2	6
T2	5	1	20.0	4
T3	7	1	14.2	6
T4	8	0	-	8
T5	11	0	-	11
22 Mar 98				
T1	3	1	33.3	2
T2	2	0	-	2
T3	2	0	-	2
T4	2	0	-	2
T5	11	0	-	11
26 Mar 98				
T1	17	4	23.5	12
T2	33	4	10.5	29
T3	38	8	21.1	30
T4	29	7	24.1	22
T5	28	3	10.7	25
31 Mar 98				
T1	28	9	32.1	15
T2	10	2	20.0	8
T3	10	1	10.0	9
T4	21	3	14.3	18
T5	48	12	25.0	36
Date/Treatment	No. of Larvae	Parasitoids	% Parasitism	Borer Adults
4 April 98				
T1	18	1	5.6	8
T2	12	1	8.3	0
T3	18	3	16.7	0
T4	19	2	10.5	0
T5	25	5	20.0	3
9 April 98				
T1	30	0	-	8
T2	9	0	-	4
T3	10	0	-	4
T4	10	0	-	3
T5	21	0	-	9

Detection, Carryover, and Biological Control of Soil-borne Pathogens in Rice-Vegetable Systems

Investigators: R.T. Alberto[1], M. V. Duca[1], V.L. Judal[1], S.E. Santiago[1], R.M. Gapasin[2], and S.A. Miller[3]

Abstract

During the four years of continuous monitoring of soil-borne pathogens infesting rice-vegetable systems in San Jose, Nueva Ecija, five were found seriously affecting rice and vegetable crops, namely, seedling damping-off of onions (*Fusarium* sp.), bulb rots of onions (*Fusarium* sp. and *Rhizoctonia solani*), pink root of onions (*Phoma terrestris*), bacterial wilt of eggplant, tomato and pepper (*Pseudomonas solanacearum*) and sheath blight of rice (*Rhizoctonia solani*). In Bongabon, Nueva Ecija soil-borne diseases affecting onions were pink root and bulb rot. The incidence of bacterial wilt in San Jose City was high in eggplant growing areas.

***In vitro* evaluation of the five species of *Trichoderma* as potential biocontroltrol agents showed antagonistic effects to all of the seven soil-borne pathogens. *Bacillus* sp. 1 showed inhibitory effects against *Fusarium* sp. 1, 3, *P. terrestris* and *Sclerotium rolfsii*, while *Bacillus* sp. 2 and *Bacillus pumilus* were both effective against *Fusarium* 1 and 3.**

Objectives

(1) Identify potential biological control (BCAs) agents against soil-borne pathogens in rice-vegetable systems

(2) Evaluate selected biocontrol agents for activity against the root-knot nematode and fungal pathogens of onion

(3) Develop and validate a system for rapid identification of intraspecific groups of *Rhizoctonia solani* important in rice-vegetable cropping systems

(4) Develop a bioassay for evaluation of biocontrol agents active against *Phoma terrestris*

(5) Develop a system for delivery of biocontrol agents to onion seedlings.

IPM Constraints

Most soil-borne pathogens of onions are not effectively controlled by chemicals. Cultural and biological controls need to be explored to manage these diseases. Biological control agents are considered environmentally safe and can reduce the competitiveness of soil-borne pathogens, which may result in improved plant health and increased yields.

Research Methods

Research at PhilRice

Five species of *Trichoderma* (*Trichoderma viride, T. harzianum, T. aureoviride, T. glaucum* and T5 - isolated from onion) and three *Bacillus* strains (*Bacillus pumilus, Bacillus* sp. 1 and *Bacillus* sp. 2) were evaluated *in vitro* to determine their efficacy as biocontrol agents against the soil-borne pathogens *Rhizoctonia solani, Sclerotium rolfsii, Phoma terrestris,* and *Fusarium* spp. 1, 2 and 3 using the Agar Plug Technique. Each of the *Trichoderma* species were paired with the pathogens in petri dishes and incubated for 6 days. The degree of antagonism was measured by using the rating scale described by Bell *et al.* (1982). The biocontrol efficacies of the *Bacillus* species at different concentrations were evaluated by measuring the inhibition zones developed between the growth of the pathogens and the *Bacillus* species on the surface of the medium. Effective isolates of *Trichoderma* and *Bacillus* were selected for greenhouse experiments.

Research at VISCA

At VISCA, Baybay. Leyte, five species/isolates of *Trichoderma* (*T. aureoviride, T. glaucum, T. harzianum, T. viride,* and T5 isolate (from onion)), as well as three *Bacillus* species strains (B_v VISCA isolate, *B. macerans*, and *B. pumilus*, (PhilRice isolate from Dr. X. Truong) were evaluated for their biocontrol efficacy against pathogens of onion causing bulb rot (*Fusarium*), seedling rot (*Rhizoctonia* and *Sclerotium*), and pink root (*Phoma*).

To test their biocontrol efficacy, the dual culture (*in vitro*) method was used. The biocontrol agents and pathogens were initially grown separately 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

[1] PhilRice [2] VISCA [3] Ohio State

with the biocontrol agents. The plates with the organisms were incubated for 6 days. The degree of antagonism by the *Trichoderma* species was measured as described above.

The biocontrol efficacy of *Bacillus* spp. strains were evaluated by measuring the inhibition zone developed between the pathogen and *Bacillus*. Different concentrations of the *Bacillus* (10^4, 10^6, 10^8) were also tested against the pathogens using the pour plate method. One plug cut from the edge of fungal colonies was transferred to PDA medium with the *Bacillus* and then incubated for 72 hours. The zone of inhibition and radial growth of the pathogens were measured.

Trichoderma viride and T5 onion isolate were evaluated further against *Fusarium*, *Rhizoctonia*, and *Sclerotium* causing damping-off of onion under greenhouse conditions. The *Trichoderma* species were cultured in sawdust-rice bran mixed media while *Rhizoctonia* and *Sclerotium* were grown in rice grain-rice hull mixed medium. *Fusarium* species were grown in PDA cultures placed in flat bottles. Sterile soil was placed in 8-inch diameter clay pots and later infested with the three pathogens. The 25-gm rice grain-rice hull mixed culture of *Rhizoctonia* and *Sclerotium* were inoculated into the pots, while the spore density of 10^3 was inoculated for *Fusarium* species. After one week, 100 g of *Trichoderma* culture was mixed with the potted soil and later 50 seeds of Yellow Granex onion were evenly sowed into the pots. Onion seeds were soaked in the *Bacillus* suspension with concentration of 10^4 for 30 minutes before sowing. For the soil drench method, the *Bacillus* suspension at 10^4 concentration was poured into the pathogen-infested pots and later 50 onion seeds were evenly sowed. Percent damping off was recorded at 7, 14, 21, and 28 days after sowing.

Incidence of Bacterial Wilt of Eggplant

Monitoring of bacterial wilt incidence was conducted in Abar 1st, San Jose City from December 1997-April 1998. The proportion of plants with symptoms of bacterial wilt was assessed in farmers' fields. The causal organism (*Pseudomonas solanacearum*) was isolated, grown in TZC medium and characterized for pathogenicity..

Research Results

Research at PhilRice

All the five *Trichoderma* species tested are potentially good biocontrol against the seven soil-borne pathogens tested. The antagonists overgrew the pathogens and covered the entire surface of the medium six days after incubation using agar plug technique (Table 1). Of the five potential fungal biocontrol agents, *Trichoderma aureoviride* and *T. viride* were the most promising, showing high antagonistic effects at the early stage of incubation.

At 10^4 CFU/ml, *Bacillus* sp. 1 showed antibiotic effects against four of the seven soil-borne pathogens tested, with the most apparent zone of inhibition against *Fusarium* sp. 3(p), followed by *Fusarium* sp. 1 (c) (Table 29). Least apparent inhibition zones were observed against *P. terrestris* and *S. rolfsii*. *Bacillus* sp. 2 showed apparent inhibition of *Fusarium* sp. 1(c) and 3 (p). It was least effective against the rest of the pathogens tested. *Bacillus pumilus* was also effective against *Fusarium* sp. 1(c) and *Fusarium* sp. 3 (p).

Table 1. Degree of antagonism by different *Trichoderma* six days after incubation with seven species of soil-borne pathogens in rice-vegetable systems, PhilRice, Nueva Ecija.

FUNGAL ANTAGONIST	SOIL-BORNE PATHOGENS [1]						
	P. Terrestris	*R. solani*-1	*R. Solani*-2	*Fusarium* 1 (c)	*Fusarium* 2 (o)	*Fusarium* 3 (p)	*S.. Rolfsii*
Trichoderma sp.(T5)[2]	1[3]	1	1	1	1	1	1
T. harzianum	1	1	1	1	1	1	1
T. viridae	1	1	1	1	1	1	1
T.aureoviridae	1	1	1	1	1	1	1
T. glaucum	1	1	1	1	1	1	1

[1] *P. terrestris* = *Phoma terrestris*, *R. solani*-1= *Rhizoctonia solani* isolated from weeds, *R. solani*-2= *Rhizoctonia solani* isolated from rice, *Fusarium* 1 (c)= *Fusarium* sp, cream colored, *Fusarium* 2 (o)= *Fusarium* sp, orange colored, *Fusarium* 3 (p)= *Fusarium* sp, purple colored, *S. rolfsii*-*Sclerotium rolfsii*

[2] *Trichoderma* sp. isolated from onion.

[3] Bell *et al.* Scale: 1 - antagonist completely overgrew the pathogen and covered the entire medium
2 - antagonist overgrew at least two thirds of the medium surface
3 - antagonist and pathogen each colonized approximately ½ of the medium surface (more than 1/3 and less than 2/3)
4 - pathogen colonized a least 2/3 of the medium surface and appeared to withstand encroachment by the antagonist
5 - pathogen completely overgrew the antagonist and occupied the entire medium surface

Table 2. Antagonism of *Bacillus* species against soil- borne pathogens six days after incubation, PhilRice, Nueva Ecija.

BACTERIAL ANTAGONIST[1]	ZONE OF INHIBITION (mm)[2]						
Antagonist	*P. terrestris*	*R. solani*-1	*R. Solani*-2	*Fusarium* 1 (c)	*Fusarium* 2 (o)	*Fusarium* 3 (p)	*S.. rolfsii*
Bacillus pumilus	0.00	0.00	0.00	1.00	0.00	3.00	0.00
Bacillus sp. *1*	1.00	0.33	0.33	2.33	0.17	2.67	1.00
Bacillus sp.2	0.17	0.00	0.00	1.33	0.00	2.17	0.00

[1] Concentration = 10^4 CFU/ml

[2] *P. terrestris* = *Phoma terrestris*, *R. solani*-1= *Rhizoctonia solani* isolated from weeds, *R. solani*-2= *R. solani* isolated from rice, *Fusarium* 1 (c)= *Fusarium* sp, cream colored, *Fusarium* 2 (o)= *Fusarium* sp, orange colored, *Fusarium* 3 (p)= *Fusarium* sp, purple colored, *S. rolfsii*-*Sclerotium rolfsii*

Incidence of Bacterial Wilt of Eggplant

Bacterial wilt of eggplant was first noticed as early as 1996 in Abar 1st, San Jose, Nueva Ecija, at which time the disease had very low field incidence, affecting very few eggplants. In the succeeding year, however, the disease had spread out throughout the eggplant-growing area of the village and progressed steadily up to as high as 45%. The disease, being soil-borne, has become an emerging problem for all solanaceous crops being grown in the area, especially eggplant. This problem will be addressed in next year's workplan, with the testing of eggplant cultivars resistant to bacterial wilt in combination with selected cultural practices.

Research at VISCA

All the *Trichoderma* species were found to be effective biocontrol agents against the pathogens tested with ratings of antagonism of 1 after 6 days incubation (Table 3). *T. aurioviride* and *T. viride* were the most promising. *In vitro* evaluation showed different reactions of the pathogens to *Bacillus* species, using the dual culture method (Table 4).

Table 3. Antagonism of *Trichoderma* species against pathogens causing diseases in Yellow Granex onions, VISCA, Baybay, Leyte.

Antagonist/ Incubation Time	PATHOGENS					
	F1 (C)	F2 (O)	F3 (P)		*Rhizoctonia*	*Sclerotium*
2 days						
T. aurioviride	2	2	2	2	1	1.67
T. glaucum	2	2	2	3	2	2
T. harzianum	2	2	2	2	1	2
T. viride	2	2	2	2	1	2
T. sp. (onion)	2	2	2	2	2	1.67
3 days						
T. aurioviride	1	1	1	1	1	1
T. glaucum	1.67	1	1.33	1	1	1
T. harzianum	1.33	1.67	1.33	1	1	1
T. viride	1	1	1.33	1	1	1
T. sp. (onion)	1.33	1	1.67	1	1.67	1
6 days						
T. aurioviride	1	1	1	1	1	1
T. glaucum	1	1	1	1	1	1
T. harzianum	1	1	1	1	1	1
T. viride	1	1	1	1	1	1
T. sp. (onion)	1	1	1	1	1	1

F1 (C) = *Fusarium* (Cream), F2 (O) = *Fusarium* (Orange), F3 (P) = *Fusarium* (Purple); V = VISCA.

Table 4. Inhibition zone (mm) in dual cultures of *Bacillus* species and Yellow Granex onion pathogens, VISCA, Baybay, Leyte.

Antagonist/Incubation Time	PATHOGENS					
	F1 (C)	F2 (O)	F3 (P)	Phoma	Rhizoctonia	Sclerotium
2 days						
Bacillus (V)	2.67	3.00	4.33	1.83	3.33	3.00
Bacillus (1)	3.33	1.33	4.00	0.33	2.00	1.67
Bacillus (2)	3.00	1.33	3.33	0.33	0.00	1.00
3 days						
Bacillus (V)	1.17	1.33	3.33	1.17	1.67	1.67
Bacillus (1)	2.33	0.17	2.67	0.00	0.00	1.00
Bacillus (2)	1.33	0.00	2.17	0.17	0.17	0.00
6 days						
Bacillus (V)	0.33	0.00	1.00	0.00	0.00	0.33
Bacillus (1)	0.67	0.00	0.33	0.00	0.00	0.33
Bacillus (2)	0.00	0.00	0.50	0.00	0.00	0.00

F1 (C) = *Fusarium* (Cream), F2 (O) = *Fusarium* (Orange), F3 (P) = *Fusarium* (Purple); V = VISCA.

The zone of inhibition between the antagonist and *Bacillus* at 10^4 CFU/ml concentration was the most effective, suppressing radial growth of all pathogens. *Bacillus* sp. 1 was the most promising when radial growth was the parameter. The inhibition zone was very apparent in cultures with *Fusarium* sp. 2 (O), *Fusarium* sp. 3 (P), *Phoma terrestris*, and *Sclerotium rolfsii* (Tables 5, 6), suggesting antibiotic properties of the antagonists.

The result of the greenhouse experiment showed that T5 onion isolate was more effective in most cases, compared with *T. viride* in suppressing damping off except in the *Fusarium* (Orange) species) (Table 7). Percent suppression was 67% when T5 was applied against *Rhizoctonia* and 42% against *Sclerotium*. Low percent damping off was observed in the *Fusarium* species suggesting that they may not be as important as damping off pathogens, compared with *Sclerotium* and *Rhizoctonia*, which showed higher percent damping off at 28 days after seeding.

Table 5. Inhibition zone (mm) in cultures of *Bacillus* species at varying concentrations with pathogens causing diseases in Y.G. onions, VISCA, Baybay, Leyte.

Antagonist/ Incubation time/ Concentration	PATHOGENS					
	F1 (C)	F2 (O)	F3 (P)	Phoma	*Rhizoctonia*	Sclerotium
2 days/10^4						
Bacillus (V)	0.0	3.0	3.0	0.0	0.0	1.0
Bacillus (1)	0.0	3.67	4.0	1.0	0.0	0.0
Bacillus (2)	0.0	4.0	4.0	0.0	0.0	2.67
3 days/10^4						
Bacillus (V)	0.0	3.0	2.67	0.0	0.0	1.33
Bacillus (1)	0.0	3.0	1.67	1.33	0.0	1.0
Bacillus (2)	0.0	3.3	3.0	0.0	0.0	2.0
6 days/10^4						
Bacillus (V)	0.0	1.33	0.0	4.0	0.0	0.0
Bacillus (1)	0.0	4.0	0.83	4.0	0.0	2.0
Bacillus (2)	0.0	3.0	1.67	5.0	0.0	1.0
2 days/10^6						
Bacillus (V)	0.0	0.0	0.0	0.0	0.0	0.0
Bacillus (1)	0.0	1.33	0.0	0.0	0.0	3.0
Bacillus (2)	0.0	3.67	0.0	0.0	0.0	0.0
3 days/10^6						
Bacillus (V)	0.0	0.0	0.0	1.33	0.0	0.0
Bacillus (1)	0.0	1.0	2.0	0.33	0.0	1.33
Bacillus (2)	0.0	1.33	1.0	0.0	0.0	0.0
6 days/10^6						
Bacillus (V)	0.0	0.0	0.0	0.67	0.0	0.0
Bacillus (1)	0.0	0.0	1.0	1.0	0.0	0.33
Bacillus (2)	0.0	0.33	0.0	0.0	0.0	0.0
2 days/10^8						
Bacillus (V)	0.0	0.0	0.0	0.0	0.0	0.0
Bacillus (1)	0.0	0.0	0.0	0.0	0.0	0.0
Bacillus (2)	0.0	0.0	0.0	0.0	0.0	0.0
3 days/10^8						
Bacillus (V)	0.0	0.0	0.0	0.0	0.0	0.0
Bacillus (1)	0.0	0.0	0.0	0.0	0.0	0.0
Bacillus (2)	0.0	0.0	0.0	0.0	0.0	0.0
6 days/10^8						
Bacillus (V)	0.0	0.0	0.0	0.0	0.0	0.0
Bacillus (1)	0.0	0.67	0.33	1.0	0.0	0.0
Bacillus (2)	0.0	0.0	0.0	0.0	0.0	0.0

F1 (C) = *Fusarium* (Cream), F2 (O) = *Fusarium* (Orange), F3 (P) = *Fusarium* (Purple); V = VISCA.

Table 6. Radial growth (mm) of pathogens of onion with *Bacillus* species at varying concentrations in dual cultures, VISCA, Baybay, Leyte.

Antagonist/ Incubation time/ Concentration	PATHOGENS					
	F1 (C)	F2 (O)	F3 (P)	Phoma	*Rhizoctonia*	Sclerotium
2 days/10^4						
Bacillus (V)	6.17	6.50	7.17	6.84	16.17	11.84
Bacillus (1)	5.50	7.00	7.17	7.17	13.17	11.34
Bacillus (2)	6.00	8.34	9.34	8.17	21.84	11.67
3 days/10^4						
Bacillus (V)	7.34	9.34	10.67	8.67	18.34	13.34
Bacillus (1)	6.50	8.67	10.50	8.00	14.34	12.67
Bacillus (2)	7.84	10.50	13.17	11.84	24.00	13.84
6 days/10^4						
Bacillus (V)	8.50	11.00	14.34	9.17	21.17	14.84
Bacillus (1)	8.00	13.75	12.84	8.84	14.34	14.34
Bacillus (2)	9.17	11.34	16.67	14.84	25.34	17.17
2 days/10^6						
Bacillus (V)	12.17	9.67	10.67	16.34	26.84	19.84
Bacillus (1)	7.50	8.84	12.00	11.50	17.50	15.34
Bacillus (2)	9.67	9.50	7.17	14.84	36.67	24.84
3 days/10^6						
Bacillus (V)	13.67	11.50	14.34	17.00	29.84	24.34
Bacillus (1)	8.33	11.34	12.50	14.00	19.84	17.67
Bacillus (2)	10.84	12.34	15.17	17.00	45.00	29.34
6 days/10^6						
Bacillus (V)	14.84	14.34	19.17	17.50	45.00	27.50
Bacillus (1)	10.17	14.00	14.84	18.34	20.50	18.34
Bacillus (2)	12.00	14.50	19.84	22.67	45.00	33.34
2 days/10^8						
Bacillus (V)	13.50	11.67	11.50	19.17	45.00	24.85
Bacillus (1)	12.50	9.34	10.17	16.00	45.00	25.33
Bacillus (2)	14.67	9.50	9.84	16.17	45.00	23.84
3 days/10^8						
Bacillus (V)	19.84	17.34	17.84	29.84	45.00	45.00
Bacillus (1)	19.84	13.17	15.50	23.17	45.00	42.00
Bacillus (2)	20.50	13.84	15.67	31.50	45.00	45.00
6 days/10^8						
Bacillus (V)	45.00	31.50	34.50	45.00	45.00	45.00
Bacillus (1)	45.00	19.84	29.00	26.33	45.00	45.00
Bacillus (2)	45.00	35.84	45.00	45.00	45.00	45.00

F1 (C) = *Fusarium* (Cream), F2 (O) = *Fusarium* (Orange), F3 (P) = *Fusarium* (Purple); V = VISCA.

Table 7. Effects of *Trichoderma viride* and *Trichoderma* sp. (T5) on damping off of Y.G. onion caused by *Fusarium*, *Sclerotium*, and *Rhizoctonia* at varying days after inoculation (DAI), VISCA, Baybay, Leyte.

TREATMENT	Percent (%) Damping off				Percent (%) Suppression
	7 DAI	14 DAI	21 DAI	28 DAI	
Fusarium (Cream) alone	0.00	4.39	10.06	10.06	-
Fusarium (Cream) + *T5*	0.54	2.30	4.65	4.65	53.8
Fusarium (Cream) + *Tv*	0.00	2.45	4.95	4.95	50.8
Fusarium (Orange) alone	0.00	1.31	3.86	3.86	-
Fusarium (Orange) + *T5*	0.00	1.82	3.57	3.57	7.5
Fusarium (Orange) + *Tv*	0.00	1.13	1.13	1.13	70.7
Fusarium (Purple) alone	0.00	2.87	7.03	7.03	-
Fusarium (Purple) + *T5*	0.00	2.27	5.12	5.12	27.2
Fusarium (Purple) + *Tv*	0.00	2.38	5.53	5.53	21.3
Rhizoctonia alone	2.12	10.48	23.00	26.46	-
Rhizoctonia + *T5*	0.60	2.52	8.11	8.68	67.2
Rhizoctonia + *Tv*	2.32	2.38	17.75	18.35	30.7
Sclerotium alone	3.19	17.46	33.87	37.11	-
Sclerotium + *T5*	1.96	10.34	19.42	21.49	42.1
Sclerotium + *Tv*	2.44	10.16	20.98	25.71	30.7
Uninoculated (Control)	0.00	0.00	0.00	0.00	-

T5 – *Trichoderma* (onion isolate 5); *Tv* – *Trichoderma viride*; % suppression = pathogen alone – pathogen + *Trichoderma*/pathogen alone x 100

Impact

The use of microbial antagonists against damping off pathogens of onion 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 tested in the field especially during the seedling stage of the onion crop. Their use should compliment the use of chemicals. Efforts to discover other antagonists especially from manure, organic waste materials, and soil-rich organic matter must be continued.

Networking Activities

S. Miller visited PhilRice in November 1997 and February 1998 to discuss research results and plans.

Publications and Presentations

R.T. Alberto, L. Sanchez, G.B. Amar, J. Rillon, M.L. Judal, M. Valdez, S.E. Santiago, and S.A. Miller. 1998. Management of Soil-Borne Diseases in Rice-Vegetable Systems, paper presented in 3rd IPM CRSP Symposium, May 15-16, 1998, Virginia Tech, Blacksburg, Virginia.

Training Output

Dr. Ronaldo Alberto completed a two month training in molecular detection techniques and biocontrol at Ohio State University in the laboratory of Dr. S. Miller, August-October, 1998.

Fact Sheet on *Phoma terrestris* and its management prepared for submission to U.S. counterpart (Dr. S. Miller) for review.

Project Highlights

- Five species of *Trichoderma* were antagonistic against *Rhizoctonia solani, Sclerotium rolfsii, Phoma terrestris,* and three species of *Fusarium* in separate studies at PhilRice and VISCA. Of these, *T. aureoviride,* and *T. viride* were the most effective and promising biological control agents. In addition, *T5* (onion isolate) was more effective than *T. viride* in suppression of *R. solani* and *S. rolfsii.*

- Several *Bacillus* spp. strains were also antagonistic against fungal pathogens of onion in *in vitro* tests. Zones of inhibition indicated antibiotic activity.

- Bacterial wilt, initially negligible in farmers' fields in 1996, has now spread throughout the eggplant-growing areas in Abar 1st, reaching as high as 45% incidence.

Characterization and Control of *Cyperus rotundus* Ecotypes

Investigators: M.C. Casimero[1], E.C. Martin[1], F. Bajo[1], S.R. Obien[1], L.S. Sebastian[1], A.M. Baltazar[2], F.V. Bariuan[2], G. Mortimer[3], and S.K. De Datta[4]

Objectives

(1) Determine ecotypic or genotypic variations in *C. rotundus*

(2) Determine responses of *C. rotundus* ecotypes to control treatments.

IPM Constraints

A continuing study of the adaptation of *C. rotundus* to a wide variety of environments will be useful in gaining a better understanding of its growth characteristics toward a more effective management scheme.

Research Methods

In pot experiments, the transplant approach will be used to determine the ecotypic/genotypic differences of upland and lowland samples of *C. rotundus*. The tubers of this weed will be grown in pots from germination to maturity under simulated upland and lowland conditions. The following data will be taken: plant height, number and size of leaves, culms, flowers, tubers, and other vegetative and reproductive characteristics related to fitness or adaptation.

In the laboratory, the DNA fingerprinting of the lowland and upland types of *C. rotundus* will be scheduled to be done using RAPD-PCR to confirm if they are ecotypes or genotypes.

[1] PhilRice [2] UPLB (NCPC) [3] IRRI [4] Virginia Tech

In the greenhouse, *C. rotundus* will be grown in pots simulating upland and lowland conditions for the herbicide experiments. Six recommended herbicides (glyphosate, glufosinate, bensulfuron, MCPA, 2,4-D, and bentazon) will be tested against the two types to determine if differential responses exist between them. At 30 days after treatment, fresh and dry weights of plants will be measured and recorded.

Research Results

A continuing research activity of the previous year, this has been turned over to a graduate student (Madonna Casimero) who is in the process of pursuing the studies involved herein for a Ph.D. dissertation. The activity was temporarily delayed owing to the course work being taken up by the student at UPLB and the 6-month course work she undertook at Virginia Tech. In addition, she trained in the RAPD-PCR method while at Virginia Tech under the supervision of Drs. Foy and Jim Westwood. Her course work has been completed and she is ready to conduct her dissertation. Upon her return to PhilRice, she is expected to resume greenhouse and field studies on the morphological and genetic variation in lowland and upland *C. rotundus*, the latter using RAPD-PCR technique as early as October, 1998.

Networking Activities

Participated in the Third IPM CRSP Symposium, Planning Workshop, and Technical Committee Meeting, Virginia Tech, May 15-18, 1998.

IPM-CRSP Consultative Meeting on progress of Work and Planning for Phase II. 9 -13 February 1998. PhilRice Maligaya, Muñoz, Nueva Ecija.

Training Output

The Ph.D. program funded by IPM CRSP for Ms. Casimero has provided tremendous support to the CRSP project and to PhilRice. Moreover, through the help of its collaborating and lead CRSP institution, Virginia Tech, she was given the opportunity to update her knowledge of weed science and hands-on training in the use of RAPD-PCR technique.

Gender Roles and Intra-household Decision Processes in Relation to Rice-Onion Pest Management

Investigators: I. Tanzo[1], T. Paris[2], K.L. Heong[2], and S. Hamilton[3]

Abstract

Both PA results and those of a household survey conducted in San Jose and Bongabon, Nueva Ecija during 1997 suggest that women are involved in decision domains that directly affect pest management practices. Among the 58 rice-onion farm households surveyed in 1997, 32 female household heads were interviewed. One-third of these women reported participating in "farm-related decisions." Most of these farm decision makers participated in decisions relating to amount of money to spend for pesticides, who should buy the pesticides, and selection of brands of pesticides to be used.

Among all female household heads, sixty percent reported being the primary purchaser of pesticides for their households. PA findings that women are likely to decide when and what to spray and to purchase pesticides, even though their husbands are more likely to do the spraying, are consistent with these results. Given these results, the small number of female households heads surveyed, and the format of questions relating to farm decision making (which may have resulted in many women not being questioned about participation in pest management decisions) it is posited that women's participation in decisions relating to pest management may be even greater than survey results indicate.

Survey sampling techniques from several IPM CRSP sites are reviewed. It is recommended that, at all project sites, equal numbers of female and male household heads be interviewed in baseline surveys designed to elicit information on intrahousehold decision processes relating to pest management.

Objectives

(1) To assess the labor participation of male and female members of farming households

[1] PhilRice [2] IRRI [3] Virginia Tech

(2) To assess gender differences in pest management decisions and access to and control of household income and expenditures

IPM Constraints

The need to make the male and female roles in pest management more explicit. The role of women in intrahousehold decision processes relating to/impacting pest management needs to be better understood to improve household capacity for pest management decisions. Constraints women face in IPM adoption need to be addressed.

Research Methods

Bivariate and multivariate statistical analysis of 1996-97 quantitative survey data. Differences between women and men, with respect to access to institutions, involvement in particular decision domains, and socio-economic variables were tested using t-tests.

Research Results

The survey was conducted in two rice and onion-based farming communities in Nueva Ecija. The municipalities, San Jose and Bongabon, were the sites IPM CRSP experiments were being conducted. Fifty-eight farming households were interviewed with 85 males and 46 females. The selected household members were those helping in the household farm and/or earning /has a job already.

Data analysis showed that male and female perceptions of women's roles can differ. Differences between men's and women's reports concerning who is the primary purchaser of pesticides for the household were statistically significant (Table 1). However, nearly 90% of both male and female household heads agree that women are the primary managers of pooled household incomes (Table 1). Women's role as money managers is especially important as pest management options can be influenced by the household's ability and willingness to finance pesticide purchases and labor for alternative IPM practices. Undersampling female household heads is a problem because women appear to be decision-makers who (1) influence household use of pesticides through decisions regarding how much the household can spend for pesticides, whether the household will borrow to buy pesticides, brand selection, and actual purchase negotiation; (2) prioritize spending for pesticides as much as do men; (3) have less negative perceptions regarding the effects of pesticide reduction than men and; (4) are less willing than men to adopt IPM for onion (Table 1). Differences between men's and women's willingness to adopt IPM for onion were statistically significant (Table 1), but the number of female heads who responded was so small that caution should be used when interpreting this result.

Table 1: Comparison of Means (T-Tests)
Activities, Knowledge, and Perceptions Relating to Household Pest Management Practice by Gender of Household Head

	Male Heads N = 54		Female Heads N = 32		
	Mean	SD	Mean	SD	Sig. t 2-tail
Reporting Roles of Both Male and Female Head					
Report Primary Pesticide Buyer is Male Head	**63%**	49	**41%**	50	.045
Report Primary Pesticide Buyer is Female Head	**26%**	44	**59%**	50	.003
Report Primary Financial Manager is Female Head	**89%**	32	**88%**	34	.848
Reporting Role of Self Only					
Will Borrow for Pesticide Purchase	**91%**	29	**94%**	25	.627
Spend for Food First	**50%**	51	**47%**	51	.782
Spend for Pesticide First	**17%**	38	**25%**	44	.354
Divide Equally Between Food and Pesticide	**22%**	22	**22%**	42	.971
Reduced Pesticie Use > No Perceived Benefit	**39%**	49	**47%**	51	.474
Reduced Pesticide Use > Crop Loss, Damage	**33%**	48	**16%**	37	.058
Reduced Pesticide Use > Saving Money	**9%**	29	**19%**	40	.245
Knowledge of IPM	**44%**	50	**34%**	48	.364
Willingness to Adopt for Onion (N = subsample of male and female heads with knowledge of IPM)	**100% (N = 25)**	0	**81% (N = 11)**	40	.167

Data Source: IPM CRSP Household Survey, Nueva Ecija, Philippines, 1996-97.

Impact on Host Country

Women are involved in pest management and, as such, it is recommended that equal number of males and females be interviewed in baseline surveys to ensure that accurate information will be gathered on pest management-related information.

Networking Activities

The Third IPM CRSP Symposium, Planning Workshop, and Technical Committee Meeting. 15 - 18 May 1998. Virginia Tech.

IPM-CRSP Consultative Meeting on progress of Work and Planning for Phase II. 9-13 February 1998. PhilRice Maligaya, Muñoz, Nueva Ecija.

Project Highlights

- Fifty-eight (58) rice-onion farm households surveyed in San Jose and Bongabon, Nueva Ecija during 1997 had 32 female household heads. One third of these women heads were involved in farm-related decisions, such as budget for pesticides, who buys the pesticides, what pesticides to use, and when to spray.
- Of the 32 female household heads, 60% took charge of buying the pesticides.
- Perceptions on pesticide use and pest management differed between men and women household members. Women were less inclined to adopt IPM for onion than men because of the economic risks involved. Moreover, women are less inclined toward pesticide reduction.

Economic Impacts of IPM Practices in the Rice-Vegetable System

Investigators: G. Norton[1], L. Cuyno[1], and S. Francisco[2]

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. Each of the experiments had at least one treatment with a higher yield, lower pesticide use, and higher net return than the farmers' practice.

Objective

To evaluate and project impacts of IPM practices tested in multidisciplinary field experiments on household income and on society as a whole.

IPM Constraints

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.

Research Methods

Research methods for this activity 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 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.

Preliminary results presented last year were confirmed with respect to the benefits of biweekly or no spraying with Brodan for control of onion thrips as compared to the farmers' practice of weekly spraying. These two practices were not significantly different from each other in terms of net revenue, but were significantly better than weekly spraying at the 90% confidence level. They gave a net revenue advantage of more than 50,000 pesos per hectare.

In eggplant experiments, the best management strategy for fruit and shoot borer is to either spray every three weeks or to remove damaged fruits and tips. Current practice is to spray twice a week. Spraying every three weeks gave the highest net return, with an added return of almost 54,000 pesos per hectare compared to farmers' practice.

Rice hull burning on onion fields in San Jose gave an added net benefit of P142,000 per hectare compared to fields without rice hull burning.

Other results are found in a draft paper entitled Economic Impacts of Alternative IPM Strategies in Rice-Vegetable Systems by Francisco and Norton. This paper will not be published until results are confirmed with data from one more year's field experiments.

[1] Virginia Tech [2] PhilRice

Networking Activity

G. Norton traveled to the Philippines in February to discuss research results with Philippine colleagues.

Publications

Tjornhom, J.D., G.W. Norton, and V. Gapud, "Impacts of Price and Exchange Rate Policies on Pesticide Use in the Philippines", *Agricultural Economics,* 18(1998): 167-175. (This publication is based on an activity in a previous workplan that is now completed but was related to this current activity).

Training Output

S. Francisco (PhilRice) spent one month at Virginia Tech on short-term training on impact assessment.

Research Highlight

Rice hull burning, provides net economic returns that are more than double those for onion fields without rice hull burning in San Jose, Nueva Ecija, The Philippines.

Environmental Impacts of IPM

Investigators: G. Norton[1], L. Cuyno[1], and A. Rola[2]

Abstract

A survey questionnaire to obtain information from Philippine households on their willingness to pay for reduced health and environmental hazards due to pesticides was administered to 206 households in Nueva Ecija. The hazards associated with the various pesticides being applied in the region are also being assessed 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, are being combined with the willingness to pay and hazard information to calculate the economic benefits of the environmental and health effects. This analysis is part of the Ph.D. dissertation of Leah Cuyno and will be completed in Year 6 of the IPM CRSP.

Objective

To estimate the economic value of the environmental benefits of IPM practices developed on the IPM CRSP.

IPM Constraints

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

A survey questionnaire was prepared, pilot tested and administered to 206 households in Nueva Ecija, The Philippines to obtain information to help estimate the willingness to pay to reduce health and environmental hazards due to pesticides. Results of this survey have been summarized and are being combined with information on potential pesticide reductions if IPM practices are adopted and on the hazards of the pesticides. This analysis will be completed in the next few months and will provide information on the economic value of the health and environmental benefits of the practices developed on the IPM CRSP. Ms. Cuyno's dissertation is about two-thirds written.

Networking Activity

G. Norton traveled to the Philippines in February to discuss research results with Philippine colleagues. Leah Cuyno spent four months at PhilRice and UPLB while testing and administering the household level survey and gathering other information.

Presentation

Presentation of preliminary results of the study at the May 1998 IPM CRSP symposium, Blacksburg, Virginia, May 16, 1998.

[1] Virginia Tech [2] UPLB

Training Output

Ph.D student Leah Cuyno from the Philippines is working on her Ph.D. dissertation on this activity at Virginia Tech.

SPECIAL PROJECT - Adoption Profiles: Intrahousehold Decision Processes, Community Socio-economic Networks and IPM in San Jose and Bongabon, Nueva Ecija

Investigators: I. Tanzo[1], T. Paris[1], K.L. Heong[1], S. Hamilton[2], and G. Norton[2]

Abstract

Seven female farmers from San Jose and Bongabon, Nueva Ecija had been interviewed for case study research. Preliminary results of these case studies supported the survey and PA that showed that women are indeed involved in pest management. Selection of pest management strategy to use was generally jointly decided by male and female heads of the household. Data also showed that regardless of what socio-economic standing they belong to, women will still be involved in pest management. The case study also revealed that women were also knowledgeable of the pests in the field and generally were the pesticide buyer. Pesticide companies contact farmer organizations so that they could hold seminars in the areas with lures such as raffles. The use of insecticide was perceived as necessary to control onion pests for lack of alternatives. Three more case studies will still be conducted.

Objectives

To conduct qualitative data collection concerning intrahousehold decision processes in rice-onion pest management

IPM Constraints

1) Intrahousehold decision processes relating to/impacting pest management

2) Constraints women face in IPM adoption

3) Womens' role in pest management

Research Methods

Case study research of 10 female farmers will be conducted focusing on joint and individual decision-making processes that result in selection of pest management strategies and technologies; women's knowledge of pest management and the social and institutional channels through which this knowledge is disseminated; and constraints to women's access to project and other institutions related to IPM development and dissemination. Research activities include informal participant observation at research sites, identification of socio-economically representative sample, about four hours of open-ended interviewing with seven female household heads, transcription of interviews, and descriptive data analysis.

Research Results

Three female farmers from Bongabon and four from San Jose have been interviewed. The purposely chosen female farmers represented the socio-economic variation of households in the study sites.

One of the female farmers from Bongabon is a former Nogrocoma Officer and is now a new local government unit staff. She is a college graduate, married to someone with a lower educational attainment and is a farm owner and leasee. The other Bongabon farmer is a Nogrocoma officer, single, college graduate and owns and leases her farm land. The third farmer is a local government unit staff, a farm inputs dealer, married, and owns and manages some farm land separately from her husband.

One of the San Jose female farmers is a tenant, married and had reached third year high school only. The other female farmer from San Jose is a widow, farm owner and the oldest in the group being 72 years old. Another female farmer is married, active in different farm and barangay organizations

[1] PhilRice [2] Virginia Tech

and is a contract farmer of an onion company (Farm Fresh). The fourth farmer is married to an officer/farm coordinator of an onion company (Farm Fresh) and is thus a contract farmer also. The last two farmers own their farm land.

Interviews with these diverse female farmers revealed that they perform varying roles in rice and onion pest management. Women were knowledgeable of rice and onion pests and generally jointly decided with their husband what pest management strategy to use. For rice, IPM was commonly used. But for onion, the use of insecticide was still the prevailing norm for lack of alternatives. They also believed that insecticide use is a necessity for onion. Though the women interviewed generally were the ones who attend pesticide-related seminars, one of the female farmers from San Jose mentioned that she does not because only the males get invited to such activities in their area. Most of the onion pest management information these women get came from seminars conducted by different pesticide companies, pesticide dealers, and their husbands. Cooperatives or farm organizations are usually contacted by pesticide companies for a free demonstration of their products. Thus, female farmers who are members of such organizations are requested to attend. They had also noticed that insecticide use affected their health negatively.

Three more case studies will still be conducted.

Impact on Host Country

The case studies support the results from the survey and PAs that women are indeed involved in pest management. Thus, they should also be involved and exposed to the science, technology, economics, and even welfare considerations of rice and onion farming systems to improve the quality of their pest management decisions.

SPECIAL PROJECT - Interaction Effects of *Phoma terrestris*, *Meloidogyne graminicola*, and *Fusarium* spp. on Pink Root and Bulb Rot Severity in Onion

Investigators: R.T. Alberto[1], L.S. Sebastian[1], E.R. Tiongco[1], E.B. Gergon[1], R.M. Gapasin[2], and S.A. Miller[3]

Abstract

***Phoma terrestris*, the pink root pathogen of onion, and *Meloidogyne graminicola*, causal agent of onion root knot, were widely distributed in onion-growing regions throughout the Philippines. Bulb rot, caused by *Fusarium* spp., was also a serious problem in many fields. Methods for identification of *P. terrestris* in culture were established, and used to characterize isolates from onion fields. A rapid molecular method for detection of *P. terrestris*, utilizing the polymerase chain reaction assay (PCR) was also developed. PCR primers specific for *P. terrestris* were developed, and DNA extraction techniques for fungal mycelium and onion roots were adapted. This technique will allow rapid detection of *P. terrestris* in onion and differentiation of the pathogen from other fungi common in roots.**

Objectives

(1) To determine the effects of *Phoma terrestris*, *Fusarium* spp., and *Meloidogyne graminicola*, singly and in combination, on the severity of root-knot, pink root, and bulb rot diseases in onion

(2) To determine the nematode/spore densities that can cause significant yield redution in onion

(3) To develop a rapid and efficient method for detection of *Phoma terrestris* in onion root tisue

Research Methods

Survey of Major Soil-borne Diseases

Surveys were conducted in 13 farmers fields in three villages of San Jose City and Bongabon, Nueva Ecija from 1994 to 1997. Extent of pink root incidence and severity were determined by disease surveys in different onion growing areas in Pangasinan, Nueva Vizcaya and Nueva Ecija. The plant samples collected were placed in plastic bags and brought in the Crop Protection Division Laboratory at PhilRice. Incidence and severity were determined before the root systems were removed from the bulb. The root systems

[1] PhilRice [2] VISCA [3] Ohio State University

were sealed in plastic bags and placed inside the freezer. *Phoma terrestris* was isolated from the roots using a weak cornmeal medium and identified using sterilized wheat straw culture.

Survey of Nematodes in Onion and Garlic Growing Areas

We surveyed different onion and garlic growing areas, concentrating mainly in the provinces of Ilocos Norte, Pangasinan, Nueva Vizcaya, and Nueva Ecija. A total of 84 farmers' fields scattered in the provinces were surveyed. Ten plant samples including the soil in the rhizosphere were randomly taken from each field. Each sample, made of one hill and about 300 cm^3 soil, was processed separately following the methods described above.

Greenhouse and Laboratory Experiments (PhilRice)

Microplot Experiments (VISCA)

Diagnostic Assay for Detection of *Phoma terrestris*

PCR primers specific for *P. terrestris* were developed from the internal transcribed spacer (ITS) region of the ribosomal RNA (rRNA) of the fungus. Universal rRNA primers were used to amplify the ITS region, which was then purified and the DNA sequence determined in a DNA sequencing facility at Ohio State University. Primers were developed using the seuence data. Initial work was done using two U.S. isolates of P. terrestris, and primers were screened against other fungi and Philippine *P. terrestris* isolates. For the assay, DNA was extracted from fungi and onion roots using a standard CTAB extraction method, as well as a rapid alkaline extraction method.

Research Results

Survey of Soil-borne Diseases

Five major diseases were found to be seriously affecting the rice-vegetable systems in San Jose, Nueva Ecija. These were seedling damping off and bulb rots of onions caused by *Fusarium* spp. and *Rhizoctonia solani*, pink root of onions caused by *Phoma terrestris*, bacterial wilt of eggplant, tomato and pepper caused by *Pseudomonas solanacearum* and sheath blight of rice caused by *Rhizoctonia solani*. In Bongabon, Nueva Ecija, three diseases of soil origin were seriously affecting onions, namely, pink root and bulb rots. Among the major diseases, pink root was the most widespread and damaging. In the onion-growing areas of Nueva Ecija, thirty two of forty seven sampling sites were positive for pink root. A 100% distribution was observed in San Jose 1 and Llanera where rice hull burning is not being practiced (Table 1). This was followed by Munoz and Bongabon with 60% and 57%, respectively. The disease is least distributed in the town of Guimba with only 25%. Disease incidence was highest in the town of Laur (88%), followed by Munoz and Sto Domingo with 87% and 75%, respectively. Lowest incidence 20% was recorded in Rizal. Highest disease severity of 63% was recorded in San Jose 1, followed by the towns of Llanera, Laur, Bongabon,Sto Domingo and Guimba with 56%. Lowest percent disease severity was observed in Rizal. The rest of the localities were not positive for pink root, especially those localities subjected to rice hull burning. In the province of Pangasinan, eight out of ten sampling sites were positive for pink root. The disease was highly distributed in the town of Umingan (67%) and with an incidence and severity of 95% and 44%, respectively. Pink root was also found in the towns of Bayambang and Bautista but at low distribution of 33%. In Bautista, the incidence was 75% and in Bayambang 50%. Both have a disease severity of 56%. Pink root was not present in San Quintin. In Nueva Vizcaya, pink root was found only in Aritao with 40%, 75% and 56%, distribution, incidence and severity, respectively. The disease was not detected in Dupax del Sur and Bambang.

Table 1. Survey of pink root disease of onion in Nueva Ecija, Pangasinan and Nueva Vizcaya. DS 1997-1998

LOCALITIES	SAMPLING SITES	PR + SITES[1]	DISTR[2] (%)	DI[3] (%)	DS[4] (%)
NUEVA ECIJA					
San Jose 1	6	6	100	72	63
Llanera	2	2	100	75	56
Bongabon	4	2	57	64	56
Laur	7	4	50	88	56
Sto Domingo	3	1	33	75	56
Guimba	3	1	25	71	56
Munoz	5	3	60	87	48
Rizal	2	1	50	20	33
Pantabangan	1	0	0	0	0
San Leonardo	3	0	0	0	0
Lupao	2	0	0	0	0
Talavera	3	0	0	0	0
San Jose 2	6	0	0	0	0
TOTAL	47	20			
PANGASINAN					
Bayambang	3	1	33	50	56
Bautista	2	1	33	75	56
Umingan	3	2	67	95	44
San Quintin	2	0	0	0	0
TOTAL	10	4			
NUEVA VIZCAYA					
Aritao	4	2	40	75	56
Dupax del Sur	2	0	0	0	0
Bambang	2	0	0	0	0
TOTAL	8	2			

[1] Pink root positive sampling sites

[2] % Distribution = Number of pink root infected sites/ The total number of sampling sites x 100

[3] % Disease Incidence = Number of infected plants/ The total number of sample plants x 100

[4] % Disease Severity = $\frac{n(1) + n(3) + n(5) + n(7) + n(9)}{N \times 9} \times 100$

Where: n = No. of infected plants classified by grade; N = Total number of samples

Survey of *Meloidogyne graminicola*

Surveys conducted in different onion growing areas in four provinces showed that *Meloidogyne* infected both onion and garlic. The nematodes were present in 62 out of 84 fields (74%). Highest population densities were observed in samples collected from Pangasinan. Disease incidence was lowest in Ilocos Norte but lowest population densities were obtained in samples from Nueva Vizcaya (Table 2). Fortuner and Merny (1973) categorized nematodes as frequent when detected in 30% of the fields and abundant when there are 20 individuals/g root. Species falling within these criteria are classified active parasites. Based on these criteria, *M. graminicola* was considered an active parasite of onion. Prot *et al.* (1994) also classified *M. graminicola* as a potentially important pest of rice especially in areas with intermittent irrigation when they observed high nematode population levels in Central Luzon and Southern Tagalog.

Table 2. Population densities of *Meloidogyne graminicola* from onion or garlic roots collected from different fields, DS 1998.

Field No.	LOCATION	*M. graminicola*/ gram root
	Ilocos Norte	
1	Pias Norte, Currimao	0
2	Surgui,Paoay	373
3	Salbang, Paoay	134
4	Catuguing, San Nicolas	0
5	Catuguing, San Nicolas	9
6	Catuguing ,San Nicolas	9
7	Sta. Rosa , Sarrat	0
8	Sta. Rosa, Sarrat	0
9	Tabunay, Sarrat	0
10	Bengcag,Laoag	37
11	Baay 13, Batac	6
12	Bungon, Batac	0
	Pangasinan	
13	Ligue, Bayambang	0
14	Buayan,Bayambang	131
15	Buayan, Bayambang	2
16	Amancosiling, Bayambang	119
17	Amancosiling, Bayambang	6
18	Wawa, Bayambang	1610
19	Laoac West, Bautista	0
20	Nangkalabasan,Umingan	241
21	Don Montano, Umingan	1360
22	Caurdanitaan, Umingan	303
	Nueva Vizcaya	
23	Calitlitan, Aritao	1
24	Calitlitan, Aritao	3
25	Bone South, Aritao	11
26	Bone South, Aritao	22
27	Bone North, Aritao	15
28	Nagcuartilan, Aritao	99
29	Gabut, Dupax del Sur	91
30	Indiana,Bambang	44
31	Indiana, Bambang	0
32	San Leonor, Salinas	0
33	San Leonor, Salinas	0
	Nueva Ecija	
34	Sicsican, Talavera	0
35	Sicsican, Talavera	40
36	Lomboy, Talavera	2
37	San Pascual,Talavera	0

Table 2 *continued*

38	Calipahan, Talavera	2
39	Gulod,Talavera	7
40	Gulod, Talavera	9
41	Sn. Pascual, Talavera	9
42	Bunol, Guimba	123
43	Bunol, Guimba	335
44	Bunol West, Guimba	52
45	Cabaruan, Guimba	2600
46	Consuelo, Guimba	1200
47	Manggang Marikit, Guimba	36
48	Sn. Francisco Sto. Domingo	0
49	Sn.Fabian, Sto. Domingo	196
50	Sn.Fabian Sto . Domingo	1500
51	Sn. Agustin Sto. Domingo	17
52	Sn. Agustin Sto. Domingo	0
53	Sn. Agustin Sto. Domingo	11
54	Sn. Agustin Sto. Domingo	0
55	Bical, Munoz	0
56	Bical, Munoz	26
57	Cabisuculan, Munoz	400
58	Cabisuculan, Munoz	34
59	Magtanggol, Munoz	0
60	Magtanggol , Munoz	48
61	Magtanggol ,Munoz	11
62	Magtanggol, Munoz	0
63	Caanauan, Sn.Jose City	0
64	Abar 1ST Sn. Jose City	0
65	Sibut, Sn. Jose City	18
66	Palestina, Sn. Jose City	43
67	Lomboy, Sn. Jose City	24
68	Lomboy, Sn. Jose City	0
69	Kita-kita, Sn. Jose City	147
70	Bangkerohan,Bongabon	170
71	Lusok, Bongabon	211
72	Malapajo, Bongabon	1403
73	Macapsing, Bongabon	119
74	Vega, Bongabon	732
75	Palo Maria,Bongavon	320
76	Larcon, Bongabon	94
77	Tugatog, Bongabon	40
78	Tienzo,Lupao	136
79	Gonzalo,Lupao	7
80	Paresta,Lupao	220
81	Poblascion Norte, Rizal	163
82	Ganduz, Pantabangan	163
83	Bato Perry, Laur	12
84	Brgy 4, Laur	13

Detection of Phoma terrestris by PCR

Primers developed for PCR to detect *P. terrestris* were highly specific for the U.S. isolates of the pathogen and did not react with other fungal species or genera tested. However, they also did not react with the two Philippines isolates tested. The ITS region of these two isolates is being amplified and sequenced, and sequences will be compared so that new primers can be made.

Impact

Very little work has been done outside the IPM CRSP on the pink root disease of onion or on the possible interaction of *Meloidogyne graminicola* with fungal pathogens of onion. The project will shed light on this biological phenomenon,

which could lead to recommendations for changes in disease management practices, depending on the relative importance of each pathogen and interaction. The development of a PCR assay will result in the availability of a practical tool for pathogen detection and will also provide an opportunity for PhilRice staff to become more involved in the use of PCR for detection of fungal plant pathogens.

Training Output

Research conducted at Ohio State University (OARDC).

Project Highlights

- Surveys of onion-growing areas showed widespread occurrence of pink root, *Phoma terrestris*, and the root-knot nematode, *Meloidogyne graminicola.*

- Thirty two of 47 onion-growing sites in Nueva Ecija were positive for pink root disease, 8 of 10 sites in Pangasinan and 4 of 4 sites in Nueva Vizcaya had pink root.

- *M. graminicola* occurred in 62 out of 84 fields (74%). Highest population densities were observed in samples Pangasinan. Disease incidence was lowest in Ilocos Norte but lowest population densities were obtained from Nueva Vizcaya

- *Phoma terrestris* from infected onion roots has been isolated using corn meal agar and has been confirmed using sterilized wheat straw. *Fusarium, Rhizoctonia,* and *Sclerotium* were also isolated from pink root-infected roots.

- Isolated onion fungal pathogens and roots of pink root-infected plants are being tested on sets of DNA primers developed at the Ohio State.

- Under laboratory conditions, onion fungal pathogens tested for pathogenicity showed high aggressiveness on four onion varieties, except for *Phoma* and *Fusarium* sp. 1.

- Pathogenicity tests under greenhouse conditions showed low incidence of pre-emergence damping-off on onions inoculated with *Phoma, Fusarium* sp. 1 and combination of *Phoma* and *Fusarium* so. 2. High incidence was observed on onions inoculated with combinations of the three *Fusarium* species, followed by *Fusarium* sp. 2, and the combination of *Phoma* and *Fusarium* sp. 3.

TRAINING

Table 1 gives the list of IPM CRSP supported trainees up to the end of Year 5 (1997-98). There were a total of 50 trainees receiving partial or complete IPM CRSP financial support. These trainees have either completed or are undergoing their degree or short-term training objectives. Looking at the gender distribution, 18 of the 50 or 36 % of the trainees were females. The vast majority (72%) of the trainees were from our collaborating host countries or regions. The disciplines in which the trainees are involved cover the whole range of IPM-related topics including entomology, plant pathology, weed science, nematology, ecology, agricultural economics, statistics, and sociology. The specific thesis topic for each student is also shown in Table 1. The training sites have been both the collaborating host country institutions and US universities.

Table 1. IPM CRSP Student Training Participants, Up to Year 5 (1997-98)

Latin America Region												
No	Student Name	Sex	Nationality	Discipline	Site / Country	Degree	Start Date	Comp. Date	IPM CRSP Fund	Advisor/ PI	Thesis Topic	University
1	R. Justicia	F	Ecuador	Ecology	Ecuador	Ph.D.	Sep 96	Aug 99	Partial	R. Carroll	Land Use Change in Ecuador	University of Georgia
2	T. Thom	F	U.S.A.	Ecology	Ecuador	M.S.	Sep 97	Aug 99	Partial	R. Carroll	Impact of Agric. Landsc on Aquatic Ecosystems	University of Georgia
3	T. Yamagiwa	M	Japan / El Salvador	Ag. Econ	Ecuador	M.S.	Jul. 97	Jul. 99	100%	G. Norton	Analysis of Policies on Pesticide Use in Ecuador	Virginia Tech
4	A. Dix	F	U.S.A.	Agroecology	Guatemala	Ph.D	Sep. 93	Sep. 97	100%	R. Carroll	IPM in Non-Traditioal Export Crops	Univ of Georgia
5	C. Palada	M	Guatemala	Entomology	Guatemala	Ing. Agr.	Apr. 96	Dec. 97	35%	M. Zeiss	Broccoli Entomology	Zamorano
6	H. Morales	F	Guatemala	Agroecology	Guatemala	Ph.D	Jul. 93	May 98	75%	R. Williams	Traditional Pest Control	Ohio State
7	J. Julian	M	U.S.A.	Marketing	Guatemala	M.S.	Jul 95	Jun 98	50%	G. Sullivan	Snowpea Marketing Structure in Guatemala	Purdue
8	P. Lamport	M	Guatemala	Plant Science	Guatemala	M.S.	Aug. 97	Jun. 99	100%	S. Weller		Purdue
9	R. Perez	M	Guatemala	Entomology	Guatemala	M.S.				R. Williams		Ohio State
10	E. Espana	M	Guatemala	Entomology	Honduras	Ing. Agr.	Apr. 96	Apr. 97	35%	M. Zeiss	Maize Entomology	Zamorano
11	F. Dubon	M	El Salvador	Plant Pathology	Honduras	Ing.Agr.	Apr 97	Aug 98	Partial	M. Zeis	Management of Ginger Soil Diseases	Zamorano
12	F. Mendez	M	El Salvador	Pathology	Honduras	Ing. Agr.	Apr. 97	Apr. 98	20%	M. Zeiss	Ginger Pathology	Zamorano
13	H. Armas	M	Ecuador	Plant Pathology	Honduras	Ing.Agr.	Apr 97	Aug 98	Partial	M. Zeis	Passion Fruit Diseases Survey and Control	Zamorano
14	H. Salazar	M	Ecuador	Pathology	Honduras	Ing. Agr.	Apr. 97	Apr. 98	50%	M. Zeiss	Passion Fruit Diseases	Zamorano
15	J. Kaehler	M	Guatemala	Plant Pathology	Honduras	Ing.Agr.	Jan 98	Apr 99	Partial	M. Doyle	Shade and N Effect on Ginger Leaf Spots	Zamorano
16	R. Barrientos	M	El Salvador	Entomology	Honduras	Ing. Agr.	Jan. 97	Apr. 98	20%	M. Zeiss	Pineapple Entomology	Zamorano
17	S. Vega	M	Ecuador	Plant Pathology	Honduras	Ing.Agr	Jan 98	Dec 98	Partial	M. Doyle	Anthracnose Mgt in Passion Fruit	Zamorano

Caribbean Region												
No	Student Name	Sex	Nationality	Discipline	Site / Country	Degree	Start Date	Comp. Date	IPM CRSP Fund	Advisor/ PI	Thesis Topic	University
18	C. Haenchen	F	U.S.A.	Agronomy	Jamaica	M.S.	Sep. 94	Sep. 96	50%	F. Eivazi	Nutritional Req. of Hortricultural Crops	Lincoln
19	G. Schlosser	M	U.S.A.	Geography	Jamaica	M.S.	Aug. 97	May 99	50%	S. Hamilton	Gender and IPM	Virginia Tech
20	J. Himes	M	U.S.A.	Entomology	Jamaica	M.S.				C. Pitts	Sociological Aspects of IPM	Penn State
21	J.Ogrodowczyk	M	U.S.A.	Agric. Economics	Jamaica	M.S.	Jan 97	Dec 98	100 %	D. Bosch	IPM Policies on Economic Incentives	Virginia Tech
22	M. Huelsman	F	U.S.A.	Entomology	Jamaica	M.S.				C. Edwards	IPM in Peppers	Ohio State
23	S. McDonald	F	Jamaican	Entomology	Jamaica	M.S.	Aug. 95	Sep. 98	100%	F.W. Ravlin	Viruses of Pepper	Virginia Tech
24	T. Schlosser	F	U.S.A.	Geography	Jamaica	M.S.	Aug. 97	May 99	Partial	S. Hamilton	Gender, Health, and IPM	Virginia Tech

Africa Region												
No	Student Name	Sex	Nationality	Discipline	Site / Country	Degree	Start Date	Comp. Date	IPM CRSP Fund	Advisor/ PI	Thesis Topic	University
25	S. Mwangi	M	Kenyan	Plant Pathology	Kenya	Ph.D	Jun. 95	Dec. 97	25%	H. Warren	Maize Diseases	Virginia Tech
26	A. Ndiaye	M	Mali	Entomology	Mali	M.S.	Sep. 97	Jun. 99	100%	H. Willson	Entomology	Ohio State
27	D. Jenkins	M	U.S.A	Entomology	Mali	M.S	Jan. 96	May 98		F. Dunkel	Sustainable Practices of Neem Use	Montana State
28	F. Djibode	F	Benin	Biology (minor in Entomology)	Mali	Ph.D	Aug. 95	May 98		F. Dunkel	Optimum Conditions for Local Production of Botanicals	Montana State
29	J. Amirault	M	Canadian	Horticulture	Mali	M.S.	Sep. 93	Aug. 96	65%	J. Caldwell	IPM in Horticultural Crops	Virginia Tech
30	J. Mullen	M	U.S.A.	Ag Econ	Mali	Ph.D	Aug. 94	Oct. 97	50%	D. Taylor	Economics of IPM	Virginia Tech
31	M. Noussourou	M	Malian	Entomology	Mali	M.S.	Oct. 97	Oct. 99	100%	K. Gamby / J. Caldwell	Predator-Pest Relationships on Hibiscus	IER/Virginia Tech/Purdue
32	A. Russ	M	U.S.A.	Ag Econ	Mali, Philippines	M.S.	Jan. 95	May 96	100%	R. Balakrishnan	Gender Differential Constraints on IPM	Virginia Tech
33	C. Mukankusi	F	Uganda	Plant Pathology	Uganda	M.S.	Oct 98	Jun. 2000	100%	Adipala and Warren	Groundnut Diseases	Makerere
34	M. Kauma	F	Uganda	Entomology	Uganda	M.S.	Sep. 97	Jun. 99	50%	S. Kyamanywa	Parasitoids of Stemborers	Makerere
35	M. Orawu	M	Uganda	Plant Pathology	Uganda	M.S.	Sep. 97	Sep. 99	60%	A. Ekwamu	Cowpea Diseases	Makerere
36	P. Isubikalu	F	Uganda	Sociology	Uganda	M.S.	Sep. 97	Jun. 99	50%	M. Erbaugh	Understanding Farmer Knowledge of IPM	Makerere
37	R. Opolot	M	Uganda	Crop Protection	Uganda	M.S.	Sep. 97	Dec 99	100%	Oryokot and Gebrekidan	Striga IPM in Uganda	Makerere

Asia Region												
No	Student Name	Sex	Nationality	Discipline	Site / Country	Degree	Start Date	Comp. Date	IPM CRSP Fund	Advisor/ PI	Thesis Topic	University
38	T. Debass	M	U.S.A.	Agric Economics	Bangladesh	M.S.	Jan. 98	Dec. 99	100%	G. Norton	Assessing the Impacts of IPM	Virginia Tech
39	C. Pile	F	Philippines	Entomology	Philippines	Short Term Training	May 98	Oct. 99	100%	N.S. Talekar	Mass Rearing of Insects	AVRDC
40	E. Gergon	F	Philippines	Nematology	Philippines	Short Term Training	Jun. 98	Sep. 98	100%	J. Eisenback	Nematode Identification	Virginia Tech/ OARDC
41	J. Tjornhom	F	U.S.A.	Ag Econ	Philippines	M.S.	Aug. 93	Jul. 95	100%	G. Norton	IPM Policy	Virginia Tech
42	L. Cuyno	F	Philippines	Ag Econ	Philippines	Ph.D	Aug. 95	Sep. 98	100%	G. Norton	Environmental Impacts in IPM	Virginia Tech
43	L. Padua	M	Philippines	Insect Pathology	Philippines	Short Term Training	Sep. 98	Nov. 98	100%	E. Rajotte	Molecular Biology of NPV	Penn State
44	L. Sanchez	M	Philippines	Plant Pathology	Philippines	Short Term Training	Jul. 96	Sep. 96	100%	S. Miller	Biological Control of Soil-Borne Plant Pathogens	Ohio State
45	M. Casimero	F	Philippines	Weed Science	Philippines	Ph.D	Jun. 96	Apr. 99	100%	A. Baltazar	Weeds in Rice-Onion Systems	UPLB
46	R. Alberto	M	Philippines	Plant Pathology	Philippines	Short Term Training	Aug 98	Oct. 98	100%	S. Miller	Research on Soil-Borne pathogens	Ohio State
47	R. Suiza	M	Philippines	Entomology	Philippines	M.S.	Jun 94	Jun. 96	50%	N. S. Talekar		UPLB/AVDRC
48	V. Recta	F	Philippines	Statistics	Philippines	Ph.D	Aug. 96	Jun. 99	100%	E. Rajotte, J. Rosenberg	Statistical Analysis for IPM	Penn State
49	R. Suiza	M	Philippines	Entomology	Taiwan	M.S.	Jul. 95	Mar. 96	100%	N.S. Talekar	Host Plant Resistance	AVRDC

Eastern Europe Region												
No	Student Name	Sex	Nationality	Discipline	Site / Country	Degree	Start Date	Comp. Date	IPM CRSP Fund	Advisor/ PI	Thesis Topic	University
50	L. Daku	M	Albania	Agric. Economics	Albania	Ph.D.	Apr. 98	Jun 2000	100%	G. Norton	IPM Impact Assessment in Albania	Virginia Tech

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
BUWOSA	Bukedia Women Strugglist Association
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
GEXPRONT	Gremial de Exportadores de Productos No Tradicionales

GIL	ground infected leaves
GIS	Geographic Information Systems
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
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
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