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The Peanut Collaborative Research Support Program
International Research Symposium & Workshop

IMPACTS and SCIENTIFIC ADVANCES through COLLABORATIVE RESEARCH on PEANUT

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INVESTING IN THE FUTURE:

SEDAP's Market Opportunities

TABLE OF CONTENTS

Program 9

Welcome and Overview of the CRSPs in USAID 15
Harvey Hortik

The USAID Agriculture and Food Security Office Plan. 17
Diane Janczewski

The Peanut CRSP History and Workshop Objectives 21
David G. Cummins

Impacts of Peanut CRSP Research 27

The Role of the Collaborative Research Support Programs as a Mode of Development Assistance. 29
B. Onuma Okezie

Peanut Farmer Cooperatives In Belize 35
Anil K. Sinha

Women Cooperatives in Peanut Processing in Thailand 45
V. Haruthaithanasan, W. Wattanatchariya , P. Chompreeda, S. Wattanatchariya, N. Thongsiri and C. Oupadissakoon

Quality Enhancement and Technology Transfer of Peanut-root Crop Food Products to Women Processing Groups in Leyte, Philippines 61
L. S. Palomar, L. M. Diamante, J. P. Poa, and R. A. Patindel

' Fleur 11' Impacts in Senegal 75
O. Ndoye, O.D. Smith, and A. Ba

CARDI-Payne Extension and Impacts in Jamaica 81
Joseph I. Lindsay

New Varieties for U.S. Production 97
O. D. Smith

Impact of Funding from Peanut CRSP on Technology Exchange and Management of Two Economically Important Peanut Viruses' 105
D. V. R. Reddy , J. W. Demski

Monitoring network to survey food products for aflatoxin in the Philippines 109
V. V. Garcia and L. R. Beuchat

Detection and Detoxification of Aflatoxin-Contaminated Food Products 117
Timothy D. Phillips

Breeding Peanuts for Pest Resistance 131
T.G. Isleib

Pilot Program for IPM in Thailand 145
Manochai Keerati-Kasikorn

Strengthening Research Capacity 155

Peanut CRSP Human Resource Development 157
Robert L. Moxley, Ph.D., Randall J. Thomson, Ph.D.

National Peanut Program Development in Thailand 173
Aran Patanothai

Strategic and Applied Research Advances 181

Strengthening Applied Research In Countries Hosting The Peanut CRSP Program: *The case of the University of Ouagadougou, Burkina Faso* 183
Dr. Alfred S. Traore

Networks and Linkages with Regional and International Agricultural Research Centers 191
D. McDonald, R.W. Gibbons

Strategic and Applied Research Advances 199

Aspects of Peanut Processing, Packaging and Utilization the Semi Arid Tropics Of Africa: The Case of Burkina Faso 201
M. Elena Castell-Perez, B. Onuma Okezie

Quality Enhancement and Technology Transfer of Peanut Butter 211
Margaret J. Hinds, Manjeet S. Chinnan and Larry R. Beuchat

Improving The Nutritional Value of Foods Through The Use of Peanut 219
L.R. Beuchat, T. Nakayama, P. Chompreeda, V.V. Garcia, L.S. Palomar, C. Oupadissakoon, V. Haruthaithanasan, P. Thamratuwasik, S. Khotaveewattana, R.R. del Rosario, R.C. Mebesa, L.M. Diamante, J.M. Roa, R.A. Patindol, A.V.A. Resurreccion and R.E. Brackett

Sensory Evaluation in Utilization of Peanuts in Value-added Products 235
A.V.A. Resurreccion

The Incidence of Aflatoxin in Stored Groundnut in Ghana and The Effects of Some Plant Extracts on Growth of *Aspergillus parasiticus* and on Aflatoxin Synthesis . . . 249
Richard T. Awuah, Kafui A. Kpodo

Genetics of Aflatoxin Biosynthesis in Aspergillus Fungi 255
Nancy Pulane Keller

Management of Arthropod Pests of Peanuts in North Carolina 261
Rick L. Brandenburg

Impacts and Scientific Advances Through Collaborative Research on Peanut in Nigeria 277
P.E. Olorunju, S.R. Boye-Goni, O. Alabi, J.W. Demski, C.W. Kuhn, and B.R. Ntare

Control Program of Peanut Virus Diseases in Asia 291
Sopone Wongkaew

Assessments of Crop Loss from Insect Pests 301
Turnjit Satayavirut, Manochai Keerati-Kasikorn

Evolution and Variability in the *Arachis* Species 311
Charles E. Simpson

Unlocking The Peanut Genome 325
H. T. Stalker, M.K. Beute, T.G. Isleib, and G. Kocherr

Transformation of Peanut (Arachis hypogaea L.) for Virus Resistance 343
Zhijian Li, Ming Cheng, Aiqiu Xing, James. W. Demski, Roy N. Pittman

Breeding for Large Peanut Seeds in the Philippines 355
Remedios Miranda-Abilay, and Thomas G. Isleib

Breeding Peanut to Fit Into Thai Cropping Systems 363
Sanun Jogloy, Aran Patanothai, Somjintana Toomsan, T. G. Isleib

Program

I. OPENING SESSION

Chair: Dianne Janczewski

0815	Welcome and Overview of CRSPs in US AID	Harvey Hortik
0830	Peanut CRSP History and Workshop Objectives	David Cummins
0845	Opening Keynote Address	Onuma Okezie
0900	Break	

II. IMPACTS OF PEANUT CRSP RESEARCH

A. Economic Growth

Chair: Onuma Okezie

0940	Peanut farmer cooperatives in Belize	Anil Sinha
1000	Women cooperative in peanut processing in Thailand	Vichai Haruthaithanasan
1020	Quality enhancement and technology transfer of peanut-root crop food products to women processing groups in Leyte, Philippines	Lutgarda Palomar
1040	'Fleur 11' impacts in Senegal	Ousmane Ndoye
1100	'CARDI-Payne' extension and impacts in Jamaica	Joseph Lindsay
1120	New varieties for increased U.S. peanut productivity	Olin Smith
1140	Peanut stripe virus -- disaster averted	D.V.R. Reddy
1200	Lunch	

B. Human Health and Nutrition
Chair: Ousmane N'Doye

1300	Monitoring network to survey food products for aflatoxin in the Philippines	Virgilio Garcia
1320	Detection and detoxification of aflatoxin-contaminated food products	Tom Phillips

C. Environmental Sustainability
Chair: Ousmane N'Doye

1340	Varietal resistance for reduced dependence on chemicals for disease and pest control in the U.S.	Tom Isleib
1400	Pilot programs for IPM in Thailand	Manochai Keerati-Kasikorn
1440	Improving biological nitrogen-fixation in peanuts and integrating this into sustainable farming systems	Gerald Elkan
1500	Break	

D. Strengthening Research Capacity
Chair: Philippe Sankara

1520	Peanut CRSP human resource development	Robert Moxley
1540	National peanut program development in Thailand	Aran Patanothai
1600	Strengthening applied research in countries hosting the Peanut CRSP program	Alfred Traore
1620	Networks and linkages with regional and international agricultural research centers	Ron Gibbons Duncan McDonald
1640	Outlook for continuing cooperation	Farid Waliyar
1700	Dinner	

9

IV. STRATEGIC AND APPLIED RESEARCH ADVANCES

A. Food Science

Chair: Ed Kanemasu

0820	Aspects of peanut processing, packaging and utilization in the semi arid tropics of Africa: The case of Burkina Faso	Elena Castell-Perez
0840	Quality enhancement and technology transfer of peanut butter	Margaret Hinds
0900	Improving the nutritional value of foods through the use of peanut	Larry Beuchat
0920	Sensory evaluation for peanut product development	Anna Resurreccion
0940	Improving peanut post harvest systems	Manjeet Chinnan
1000	Break	

B. Mycotoxin Management

Chair: Duncan McDonald

1040	Entomological ecology and aflatoxin control in peanut	Patoin Ouedraogo
1100	High incidence of *Aspergillus flavus* and aflatoxins in stored groundnuts in Ghana and the effect of some plant extracts on *Aspergillus parasiticus* and aflatoxin synthesis	Richard Auwah Kafui Kpodo
1120	Aflatoxin detection using mutant isolines for food monitoring and germplasm screening	Marian Beremand
1140	Mycotoxin biosynthesis in *Aspergillus* spp.	Nancy Keller
1200	Lunch	

C. Integrated Pest Management
Chair: Narongsak Senanarong

1300	Management of arthropod pests of peanuts in North Carolina	Rick Brandenburg
1320	Impacts and scientific advances through collaborative research on peanut in Nigeria	Phindile Olorunju
1340	Control programs for virus diseases in Asia	Sopone Wongkaew
1400	Assessments of crop loss from insect pests	Turnjit Satayavirut
1410	Screening for disease resistance	Phillipe Sankara
1420	Break	

D. Germplasm Enhancement
Chair: Johnny Wynne

1440	Evolution and diversity of *Arachis* spp	Charles Simpson
1500	Unlocking the peanut genome	Tom Stalker
1525	Gene transfer for variety improvement a. Transformation of peanut (*Arachis hypogaea L.)* for virus resistance	Zhijan Li
1540	b. Progress at NC State University	Arthur Wiesinger
1600	Breeding for large peanut seeds in the Philippines	Remedios Abilay
1620	Breeding peanut to fit into Thai cropping systems	Sanun Jogloy
1640	General Discussion	
1700	Adjourn	
1830	Reception	
1900	Banquet	
1945	Keynote address Strategic research and development for peanut, public and private linkages	Ron Henning

10

V. PRIORITY SETTING WORKSHOP

0800	Regional Working Groups 1. Africa 2. Asia 3. Latin-America and Caribbean	
1000	Break	

V. CLOSING SESSION

Chairman: David Cummins

1030	Reports of working groups	
1110	Report of the EEP	John Cherry
1130	Closing Address	Johnny Wynne
1200	Adjourn	

11

Welcome and Overview of the CRSPs in USAID

Harvey Hortik[1]

Welcome to Washington, D.C. Be sure to see the beautiful Cherry blossoms.

My hope is for you to have a very successful meeting. We are here to discuss the Peanut CRSP program (past, current, and future), to evaluate the constraints, and suggest how to make improvements. Meetings of this type are extremely beneficial because they provide in a short period the chance for many people to contact people they've only talked to over the telephone, and to meet others who share similar interests. I hope you will take full advantage of this opportunity and carry back home new research programs.

The Agency is in turmoil and it seems that it will remain so for a while, especially because of the major validating with the State Dept. The Agency has been reorganizing for the past two years which is a positive step and should complete the process by the end of September this year. What happens about merging with the State Dept. is still unclear.
In developmental aspects the Agency now emphasized five specific areas:

1	Population -	The expanded world increase and its major food demand.
2	Environment -	The enhancement of and conservation of natural resources; agriculture will play an important aspect in this area.
3	Human and Institutional Development -	The CRSPs will have a substantial input in this area.
4	Democracy.	
5	Economic Growth	Agriculture, agricultural research, and the Food Security Office come under this point. The role agriculture plays and the income it generates are significant.

[1]Division Chief, Sustainable Technology Division, Office of Agriculture and Food Security, Global Bureau, USAID/Washington, D.C.

12

Within the Office of Agriculture we have come up with three strategic objectives.

1. Increased availability of food
2. Increased accessibility to that food
3. Environment

As we develop programs, we need to consider the five major strategic objectives of the Agency. Dianne Janczewski will discuss these objectives in further detail later.

What is the future of Peanut CRSP? We'll have to wait and see. My observation over the past year has been that agriculture and agricultural research awareness has increased in Washington, D.C. It doesn't mean it is a top priority item, but at least it is back on the Federal Government's list. Much discussion of world population, and the need to meet future food demands has taken place. How much funding that translates into remains to be seen. The important thing for you to consider is the importance of peanuts, peanut production and utilization in the developing countries, and how you can positively impact on that in future programs.

B

The USAID Agriculture and Food Security Office Plan.

Diane Janczewski[1]

The Agriculture and Food Security Office provides the Agency with analytical, technical and program assistance for global, regional and country-specific agricultural sector programs. The Office's efforts assist in meeting the ever changing and increasing world food, feed, fiber and fuel needs of developing countries and to this end, promotes greater efficiency and productivity in resource use while maintaining long-term environmental integrity.

Increasing broad-based food security and sustainable productivity of agriculture and natural resources are complementary and mutually reinforcing components of the Agency's goal of sustainable economic development. To achieve this goal and optimize agriculture's contribution to sustainable economic growth, continued investments in technology development, improving the enabling environment, and removing constraints to market access are needed. It's not just a question of producing more food, but of having more food produced by the poor, who, though landless, earn their living through farm labor and agroservices and enterprises which are dependent on dependable food and fiber supplies.

Continued investments in the agricultural food and fiber sector are essential to increasing agricultural productivity and broadening access to agricultural markets by rural and urban societies, especially the poor. Sustainable agricultural growth can expand income and food purchasing power throughout rural societies, reducing the incidence of hunger and poverty and thereby reducing food insecurity. Improved technologies in food production, processing and marketing lower the per unit food costs to consumers. In poor sectors of society, reductions in food costs are equivalent to income increases. Broad-based economic growth, which is strongly tied to agricultural growth, contributes to the broadening of food security, reducing population growth and reversing the degradation of the environment.

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[1]Program Manager, Peanut CRSP, Sustainable Technology Division, Office of Agriculture and Food Security, Global Bureau, USAID .Washington, D.C.

The goal for the Office is agriculturally generated food security for peace and prosperity. The strategy for achieving this goal is through an integrated effort, using close collaboration with other donors and an institutional partners, in assessing overall development prospects, analyzing constraints and opportunities for interventions which fit the micro-economic and socio political context of the development situation. A major player in this effort will be the field missions; programs and activities will be designed and implemented to leverage, in a positive way, impacts of the mission's and Office's efforts.

AFS'S PROPOSED STRATEGY, RATIONALE, AND KEY ASSUMPTIONS

The intrinsic linkages between the three areas of food security, economic prosperity, and natural resource management are reflected in the Office of Agriculture and Food Securities's three strategic objectives. Food security is broken down into two components: availability of food and access to food. As evident in the further elaboration of these strategic objectives at the project output level, economic development contributes to the attainment of all three strategic objectives.

The Office's strategic plan emphasizes taking an integrated approach to addressing the above constraints through agricultural development. A number of key issues cut across the three strategic objectives, as seen by comparing the project outputs under each (see Appendix A). These include agricultural productivity, profitability, institutional and human capacity development, agricultural sector policies, and, finally, natural resource management through integrated farming systems. Consistent with the fact that such issues apply to more than one strategic objective, the activities within each program in the office's portfolio will contribute to achieving elements of more than one strategic objective. This results in an office management strategy matrix which links program activities to project outputs.

Given these linkages between different programs, indicators of progress towards achieving the Office's strategic objectives must integrate several different components. Further, the Office recognizes that there are other donor organizations working in similar areas. To maximize coordination both between programs within the Office as well as with other donor organizations, the Office has focused on a process for developing indicators and incorporating them into management of the Office's programs over a three year period (see Appendix B). Developing consensus on indicators with other organizations working in similar areas will allow the Office to draw upon relevant data and resources from other donor organizations, further leveraging the impact of the Office's own programs. In addition, by emphasizing the development of integrative indicators, the full range of impacts resulting from the Office's activities will be captured. In some instances, particularly in the area of natural resource management, appropriate indicators still need to be developed.

16

The strategic plan described above resulted from a three day workshop which included full participation from the Office of Agriculture and Food Security as well as representatives from many of the Office's university and PVO collaborators, contractors. The workshop was facilitated by members of CDIE and their contractors.

It is important to note that for Strategic Objectives #2 and #3, appropriate indicators can only be developed after the Office has identified how it will approach these objectives programmatically. This is necessary to ensure that the indicators will capture the full range of impacts on these objectives. Emphasizing the linkages between programs in the strategic plan described above results in the greatest leveraging of the Office's resources. An integrated approach such as this cannot be described by the type of linear and discrete indicators used in the past. The process outlined above, however, will result in an impact measurement system consistent with the complexity of the constraints identified by the Office's strategic objectives and with the approach the Office is taking through its programs to address these constraints.

5

OFFICE STRATEGIC OBJECTIVE INDICATORS

	Year One	Year Two	Year Three
SO 1	Reach multi donor (including CGIAR) consensus on key indicators for measuring progress towards addressing biological and socio-economic constraints to agricultural productivity in target areas.	Develop a matrix and strategy to link research activities in target areas with indicators agreed upon in year one.	Analyze project outputs and additional data sets in target areas from other sources against impact indicators.
SO 2	In collaboration with FAO's Food Security Service, IFPRI, and other multi donor centers of excellence, select appropriate baseline data on household food access given the following two criteria: - selection of data from among existing tracking systems. -data applicable to agreed upon inventory of constraints to food access in target consumption communities.	Establish benchmark indicators *for* progress towards mitigating food access constraints identified in year one.	Measuring against the monitoring framework established in years two and three, identify which interventions, AFS supported or otherwise, are effectively addressing these constraints and why.
SO 3	Develop potential ways to measure the relationship between agriculture and conservation and management of natural resources and investigate the utility of such measurements.	Complete activities begun in Year one and reach multi donor consensus on indicators.	Develop a matrix and strategy to link research activities in target countries with indicators agreed upon in years one and two.

The Peanut CRSP History and Workshop Objectives

David G. Cummins [1]

Agricultural production and food delivery systems in the United States have provided food for the population and excess for export in quantity and in quality surpassed by no other country. Much of the success can be attributed to the Land Grant System of agricultural education, research, and extension. Plans for this system were conceptualized in the U.S. Congress 1862 Morrill or Land Grant Act, ironically passed when the country was clouded by deep civil conflict. The 1888 Hatch Act and the 1914 Smith-Lever Act provided funds for agricultural research and extension in each state of the United States. The 1890 Land Grant Act brought the predominately black institutions into the system.

The United States became actively involved in Foreign Assistance after World War II with the Marshall plan that helped rebuild war-torn Europe, which was followed by the U.S. Overseas Mission that lead to the present U.S. Agency for International Development mandated by the U.S. Foreign Assistance Act of 1961. Agricultural research and development activities to provide food for growing populations in developing countries has been paramount in U.S. assistance programs since 1961. Many success stories in U.S. foreign assistance in agriculture could be enumerated, one of the classics being the system developed in India.

The U.S. Foreign Assistance Act of 1961 was amended in 1975, and defined the Title XII Program with a goal to prevent and establish freedom from hunger in the developing world. The designers of the Title XII program came from varied backgrounds and experiences, but had a goal of transferring the successes of the U.S. Land Grant System to developing countries around the world.

The Collaborative Research Support Program (CRSP) was created to implement a portion of Title XII. The CRSP contribution to the Title XII goal was to enhance the research capacity of both developing country institutions and U.S. Land Grant Universities through

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[1] Professor and Program Director, Peanut CRSP, University of Georgia

training and collaborative research and focus this capacity on global constraints to food production, distribution, and use. The CRSP activities were implemented through the U.S. Agency for International Development, U.S. Land Grant Universities, and host institutions in developing countries. The successes of the CRSPs in advancing the goals of Title XII are well documented in various review reports, the most recent being an AID study conducted in 1994 on the Impacts of the CRSPs. The implication is that the CRSPs have been successful in transferring the successes of the U.S. Land Grant System to developing country situations.

The CRSPs were designed as long-term, 20-25 year efforts. Since 1978, ten CRSPs have been developed and implemented: Small Ruminant, Sorghum and Millet, Bean/Cowpea, Soil Management, Peanut, Pond Dynamics/Aquaculture, Nutrition, Fisheries Stock Assessment, Sustainable Agriculture and Resource Management, and Integrated Pest Management. All are currently active except Nutrition and Fisheries Stock Assessment. There was wisdom in the long-term nature of the CRSPs, since with the occasional exception of the breakthrough such as hybrid maize or high yielding rice, transformations in agricultural development are relatively slow.

Current U.S. government funding and foreign policy uncertainties do not favor long-term programs. The hope is that the CRSPs can continue to function and reap the benefits and impacts that have resulted from CRSP research, and to continue strategic and priority research and development activities. CRSPs were designed primarily as research programs rather than technology transfer programs, but should relate to in-country technology transfer programs. Dialogue is underway in many instances to better bridge the gap between research and technology transfer.

The Peanut CRSP was about the fifth CRSP to be designed and implemented. USAID and BIFAD staff met in Atlanta, Georgia with University representatives concerned with peanut research in 1979. Deliberations led to The University of Georgia being named the Planning Entity for the Peanut CRSP. The Planning Grant was funded in August 1980. Dr. Curtis R. Jackson, formerly a peanut pathologist and then Associate Director of the Georgia Agricultural Experiment Stations, and David G. Cummins, Professor of Agronomy at The University of Georgia (both based at the Georgia Station, Griffin) led the planning effort.

A Planning Grant Steering Committee was named that provided valuable guidance throughout the planning effort.

A questionnaire was sent by USAID/Washington to all country AID Missions. In concert with country research programs each Mission indicated primary, secondary, or tertiary interest of country participation in the Peanut CRSP.

19

The Planning team sent questionnaires to all countries with peanut research programs that provided information on constraints to peanut production and use, and an indication of research program strength.

Based on the questionnaires and advice from the Steering Committee, site visits were made by the Planning Team to 13 countries to further determine needs, interest, and capabilities for participation in a CRSP effort in peanut. Fortuitously, the First International Groundnut Workshop was held at ICRISAT-India in October 1980, which enabled the Planning Team to meet with scientists from 20 countries around the world and obtain additional information, valuable to the planning effort.

In addition to the Steering Committee, a Technical Panel was established which helped determine the scope of the program and set criteria for Requests for Proposals for program participation and project leadership. Two members of the Technical Panel, Dr. Ron Gibbons, then Groundnut Breeder and Program Leader at ICRISAT, and Dr. Onuma Okezie, Food Scientist and International Programs Director at Alabama A&M University were present at the Workshop. The Request for Proposals were based on identified constraints to peanut production and use with a global relevance. The Technical Panel helped in the selection (from 40 proposals) of 12 projects representing Alabama A&M University, The University of Georgia, North Carolina State University, Texas A&M University, in collaboration with Senegal, Mali, Niger, Burkina Faso, Nigeria, Sudan, CARDI-Trinidad (primary sites in Jamaica and Belize), Philippines, and Thailand. Sudan later left the program and Ghana was added. Projects covered the general areas of breeding, agronomy/physiology, disease and insect management, soil microbiology, and food technology.

During the planning process, information gained was compiled into a State-of-the-Art document. Production estimates, summary country reports, research being conducted, researchers, research locations, and constraints to production and use were included. The publication has been a valuable resource document for many people since 1982.

The Planning Grant ended with visits by the U.S. investigators to collaborating countries to meet collaborators and finalize research plans. Final activities were completed in April 1982.

The Peanut CRSP research grant was received in August 1982 effective July 1, 1982. The program has evolved through a three-year extension in 1987 and a new five year grant in 1990. A one-year extension of the present grant planned by AID will extend the program to June 30, 1996.

All of you present today are a product of the Peanut CRSP process. You represent institutions in Alabama, Georgia, North Carolina, Texas, Philippines, Thailand, Belize, Jamaica, Burkina Faso, Ghana, Mali, Niger, Nigeria, Senegal, and India. The success of the program depends on the commitment and interest of you as scientists, although it takes the support of your institutions and the funding agencies.

SYMPOSIUM OBJECTIVES

The Symposium has three major objectives.

1. Review progress of key Peanut CRSP research and impacts of the technology developed through your presentations. A Proceedings will record the information.

2. Based on the research and past impacts, determine overall progress to date in the various disciplines represented in the Peanut CRSP.

3. Plan for the future during the last morning of the symposium when we break into working groups.

VISION FOR THE FUTURE

The success of a future Peanut CRSP depends on the leadership you or any new participants provided to the program. Investments have been made in all of us whether degree or short-term training, or opportunities to conduct research and technology transfer activities or provide administrative support. These investments add up to experience, valuable for the future.

I would like to challenge you to do your best in the future, whether or not it is in Peanut CRSP activities. I would suggest five things for you to consider as we face life in the 21st Century. This philosophy of life will help us take advantage of opportunities and avoid problems. The 21st Century promises to offer unprecedented opportunity, but at the same time keen competition in a global environment.

1. Continue to learn. We have much experience, but when we stop being students we slow our progress. There is so much information about us that we must know how to sort through to develop technology useful for our clientele. Learn by mistakes as well as successes.

2. Develop a good attitude. Attitude is how we feel. How do we feel about our accomplishments? How do these accomplishments apply to present needs of our clientele? How do we feel about the future problems, and opportunities? Develop an attitude that will accept the challenges the future holds.

24

3. Be active. Mental and physical activities are the basics of life, even the life of a scientist. Do what you can, and be the best you can.

4. Be results oriented. Weigh your progress. Success is in part a numbers game. Measure the value of the results. Make your results available to your clientele. Become a critical judge of your progress.

5. Study life around you. Is your world different because you are there, for good or bad? Are your research and development activities making a difference in your community or country? Will the world be better because there is or has been a Peanut CRSP?

All of us have a stake in the future. What are we going to do with the challenges and opportunities of the 21st Century? Only you can determine your contribution.

Thank you for your attention and I am looking forward to a really profitable Symposium.

Impacts of Peanut CRSP Research

The Role of the Collaborative Research Support Programs as a Mode of Development Assistance.

B. Onuma Okezie[1]

INTRODUCTION

The Peanut Collaborative Research Support Program (P-CRSP) is one of nine CRSPs now in existence. These are Bean & Cowpea, Fisheries Stock Assessment, Integrated Pest Management, Peanut, Small Ruminant, Soil Management, Sorghum and Millet, and Sustainable Agriculture and Natural Resource Management. The Nutrition CRSP was phased out a few years ago.

The results, accomplishments and impacts of the different CRSP projects are very well documented in various scientific, trade and industry journals, reports and congressional presentations. It is not my purpose to reproduce them here. However, it is relevant and instructive to note that as a development assistance mechanism, the CRSPs have played a major and very important role and their impacts on various aspects of development have been far reaching. For instance, the CRSPs have enabled the participating developing countries to build their capacity for production and distribution research on the food commodity of each subject CRSP. The CRSPs have a strong record of sustained or sustainable institutions and programs. They have produced significant spin-offs for U.S. Agriculture and food distribution. Records show that the economic impact of the CRSP research in the U.S. alone far exceeds the total cost of the programs since their inception. The CRSPs cover a wide range of research areas involving U.S. Universities in more than 29 states and Puerto Rico and partner institutions in over 32 developing countries. The collaborative nature of the CRSPs brings together resources of developing countries and the U.S. Institutions towards the achievement of increased efficiencies of food production,

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[1] Professor of Food Science and Nutrition; Director, International Programs; and Chairman of the Peanut CRSP Board of Directors,
Alabama A& M University, Normal, AL 35762

distribution and utilization systems in the developing countries with beneficial returns to the United States.

HUMAN RESOURCE DEVELOPMENT

It is also pertinent to mention the human resource development impact of the CRSPs. As one peanut CRSP administrator once noted, "reverse technology transfer of sustainable agricultural strategies from developing countries is of increasing importance to the U.S. One way in which the CRSPs have accelerated reverse technology transfer is through strong international linkages reinforced by our unique training programs."

Since the inception of the program, the CRSPs have collectively trained over 600 Ph.D. Students and over 700 M.S. Students. About 70% of these are from the developing countries and the remainder are from the United States. The CRSPs have also developed and conducted short-term training programs that have improved the technical skills of over 4, 000 developing country scientists. Many of these students and scientists trained under the CRSP programs return to their countries to important positions in their government or industry. For instance, the Director General of the National Institute of Agronomic Research in Niger, Dr. Mamadou Ouattara, received his Ph.D. from Texas A&M under the Soil Management CRSP. The former Vice Minister of Agriculture of Bolivia, Dr. Jose Salinas, now the Director General of the Bolivian National Institute of Research and Technology, received his Ph.D. from North Carolina State University. Also under the Soil Management CRSP, Dr. Moussa Traore, whose graduate program was sponsored by the Sorghum & Millet CRSP, is Vice Minister of Agriculture in Mali. Dr. Lukas Gakale, another Sorghum & Millet CRSP sponsored student, is the Director of the Agricultural Research Department in Botswana. Experience received by developing country Principal Investigators of the CRSPs has enabled them to advance in their careers. For example, Dr. Amadou Ba of the Peanut CRSP in Senegal has been appointed Director of the Field Crops section of ISRA. In Burkina Faso, Peanut CRSP researchers and Principal Investigators have also advanced. Dr. Alfred Traore now serves as the Rector (President) of the University of Ouagadougou and Dr. Philippe Sankara has recently been appointed Director of the National Center for Science and Technology Research.

One can indeed say without fear of contradiction that the CRSPs are extremely successful programs. Their accomplishments are outstanding and measurable, and their impacts are felt both here in the U.S. and in those countries of the world where the programs exist.

MODES OF DEVELOPMENT ASSISTANCE

The Title XII of the U.S. Foreign Assistance Act as amended in 1975 provided a broad framework for delivering development assistance to the less developed countries (LDCs). Among the more common modes or forms of contract activities are direct contracting; host country contracting, which may include institution building type contracts; participant

26

training, which may form part of any development project or could be a contract on its own; and the collaborative research support programs, which are generally executed in the form of cooperative agreements rather than contracts.

In a brief and simple way, let me try to explain the tenets of these modes of contracting. With the exception of the CRSP programs, there is generally very limited input from host countries in project identification, planning or development and implementation of most development projects. USAID mission staff and some direct hired consultants from the U.S. often are responsible for these stages of project activity. In direct contracting projects, there is even less involvement of host or recipient country nationals in the implementation and management of the projects than in host country contracts. A contractor in this type of project deals with either USAID Washington or the USAID mission as to how the projects are implemented and managed. In host country type contracting, a greater degree of involvement of the host country in project implementation and management is provided. Of course as many of you who are familiar with these contracting modes will agree, the U.S. contractors hated host country contracts because their sole decision making power on such projects was curtailed since approval for certain actions had to come from host country officials. They did not have a free hand to run or implement such projects. As a result, there were very few host country contracts even though they were the ones that embodied provisions for inputs from or some degree of real participation by the host country nationals, thereby giving them a certain sense of ownership of and commitment to such projects. In contrast, with the direct contracting mode, we went to the recipient country and identified what we perceived to be the most urgent needs of the country. We planned and developed what needed to be done. We decided how and when it should be done and then did it with little or no input from or participation of the host country. Could we have done these things differently? Maybe not, because foreign assistance as provided by the donor countries was tied first and foremost to the foreign policy interest of the particular donor country and not necessarily to the priority needs of the recipient countries.

For the United States and some Western European countries, the primary foreign policy objective was the fight against or suppression of communism. It is fair to say that this fight dictated the direction which foreign assistance policy and action took. Every other evil that existed around the world appeared almost unimportant. Thus, these donor countries allowed and condoned the existence of corrupt and dictatorial leaderships in various developing countries such as Ferdinand Marcos in the Philippines, General Noriega in Panama, President Mobutu in Zaire and Jonas Sivimbi in Angola, to name just a few.

Even today as we define the direction and extent of the foreign assistance to be provided by the United States to the less developed countries in the post-cold war era, we are still doing it the old fashioned way. We are making all the decisions in our own best interest

and not necessarily in the best interest of those whose lives would be affected by such actions.

LESSONS LEARNED: WHAT WORKED AND WHAT DIDN'T WORK

After more than three decades of foreign assistance, we are still groping for evidence of real accomplishments or improvement in the quality of the life of people in Africa, Latin America and many parts of Asia. Many of these countries still face chronic problems of poverty, food insecurity and environmental degradation. In fact, when compared to where they were many years ago, many of them are worse off today in many respects. Some of these countries are experiencing negative economic growth exacerbated by the heavy burden of foreign debt service or payment.

I am of the view that to continue to plan and provide development assistance to the developing countries in the old fashioned way is a grave and unpardonable mistake. We should not apply or adopt a sort of generalized or blanket political guidance to specific worldwide foreign assistance priorities, especially at a time such as this of limited resources and cut backs.

I believe that the application of lessons learned from these decades of foreign assistance is perhaps the most important element for achieving any meaningful improvement and real accomplishments in the U.S. government's development assistance programs. We must learn to respond primarily to the priority needs of the recipient countries and take their views about these priority needs seriously, letting them have ownership of their development programs by involving them meaningfully as true partners at all stages of planning, development and implementation and at all levels of management and evaluation of the programs. By giving them some meaningful responsibilities as technical people and decision makers/managers on projects and programs, they would develop a sense of commitment and ownership of such programs and projects with the added effect of ensuring sustainability even after donor countries have left. What has happened in the past is that often, when a development project in an LDC is ended and the foreign technical people have left, there is nobody responsible or knowledgeable enough about what took place or how things were done from the host country to pick up or sustain the process. We can not afford to continue to do things anymore in that inefficient and wasteful fashion.

For instance, it is estimated to cost about $200,000 to $250,000 a year to sustain a senior expatriate scientist as a field staff on a project in a typical developing country. In many of these LDCs today we have an abundance of well trained people, most of whom got their education from the best universities in this country. In countries where such trained men and women exist, it is more cost effective and more sustainable to use such qualified host country nationals for implementation of development projects as technical and managerial staff. The advantages of this approach are many fold. We will accomplish more with less

because for $200,000, we could secure the services of 6-8 of the most qualified scientists in any of those LDCs. There will be greater effectiveness because the participating nationals would more readily show a greater sense of commitment, closeness to the project, and ownership, and would, therefore, be in a suitable position to sustain the project when the external support is removed. Above all, a substantial part of the assistance money would be actually spent in the recipient country as a foreign capital which those countries desperately need for fueling their economy. As you are well aware, hardly any economic growth can be achieved in any of these LDCs without development money or foreign capital infusion, which ought to be spent in the recipient country.

I am convinced that in order to achieve more meaningful and lasting results and greater impacts in development assistance programs in a post cold war period, a new paradigm or model must be found for delivering or conducting such development assistance by the United States.

The CRSP model or concept is one that has been tried and found to be most effective and successful. It incorporates the various elements that bear on development success and sustainability, which as has been cited earlier, are lacking in other modes of project assistance.

In a typical CRSP project the developing country scientists participate as true partners with their American counterparts in problem identification and/or definition, project design and/or development, implementation, management and evaluation. Resources are made available directly to them for their activities. They are involved at various stages and levels of decision making that affect the CRSP activities. Any training that is conducted is always related to the particular CRSP needs. Such a model, without doubt, is more well suited than any other for responding to or meeting the development assistance goals of the USAID.

It is indeed inconceivable and quite ironic that in spite of the enormous successes of the existing CRSP projects, it is understood that the USAID plans to phase out many of them, including the P-CRSP. To me, such plans appear misguided and ill conceived.

With the cold war over, true foreign assistance, even within the already articulated framework of the foreign policy guidance in the Agency for International Development's programs focus --- democracy and governance, population, health and nutrition, environmental and natural resource management, economic growth and human resource development --- should be carried out primarily in the interest and to a greater extent for the benefit of people of the recipient countries, while still maintaining the foreign policy interest of the United States. This calls for a major change or realignment in the philosophy and approach to the way we have been doing these things in the past. Only by so doing can

the desired results and real improvements in the lives of the people we are trying to help in the Third World countries, particularly those in the Sub-Saharan African countries, be achieved.

29

Peanut Farmer Cooperatives In Belize

Anil K. Sinha[1]

INTRODUCTION

The Caribbean Agricultural Research and Development Institute (CARDI) is a regional organization which was established in 1975 to serve the agricultural research and development needs of the twelve (12) member states of the Caribbean Community. In Belize, CARDI initiated research and development work on peanut in 1979. CARDI is the collaborating institution for the Peanut Collaborative Research Support Program (Peanut CRSP) in the Caribbean region.

Belize is the only English speaking country on the Central American mainland and is located on its east coast. Mexico is in the north and western borders; Republic of Guatemala is on the south and south western borders, and the Caribbean Sea is on the east border. The area of the mainland and cays is approximately 22,963 km^2 (8,860 $miles^2$). Belize has the lowest population density in Central America and one of the lowest in the world. According to mid-year estimate in 1993, the country's population was 205,000, with a density of about nine persons per square kilometer (CSO, 1993).

Peanuts were one of the crops recommended for experimentation in Belize in the 1950's by British advisers (Robinson, 1985). The Tennessee Red gave the best results, and a small area of the crop was reported as being grown by Mennonite communities in the Belize Valley in the late 1960's (Department of Agriculture, 1968). In the early 1970's there seems to have a localized spread effect to non-Mennonite communities in the vicinity. Peanuts were first grown in San Antonio, Cayo, in 1977 following contacts with Mennonite communities. At that time a small amount of peanut was grown by two or three farmers as an experimental cash crop for marketing in roasted form in Belize City. Later due to CARDI's effort peanut became an important source of income for farmers of San Antonio and adjoining villages. Thus they formed into a number of groups which later registered as Cooperatives. In 1979 Belize imported about 20,000 kg of peanut in shell (US$58,000), and 21,000 kg of peanut butter (US$39,000.). By 1985, peanut production

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30

had increased to the level of self-sufficiency and surplus peanut is being exported to CARICOM countries.

CARDI'S SUPPORT THROUGH ITS RESEARCH AND DEVELOPMENT ACTIVITIES

CARDI initiated research and development efforts aimed at increasing peanut production in 1979. In 1980 CARDI conducted a survey of peanut production systems in the main peanut production area: San Antonio village in the Cayo District (CARDI, 1985). It was identified that farmers were planting by slash and burn system (MILPA) i.e., without any land preparation. The crop was not planted in rows and without using fertilizers and herbicides. The farmers lacked tools for proper land preparation, and for harvesting and drying the crop. CARDI had acted as a diffusion agency implementing a strategy to promote adoption of peanut growing. Its aim was to introduce improved technologies to increase production and productivity. A two-step flow strategy for diffusion of peanuts was adopted, seeking first to contact progressive farmers who would act as opinion leaders and persuade others to adopt. To this end CARDI had shown farmers the demonstration plots at the CARDI's Field Station and on farmer's fields, and also provided local extension workers with information on the growing of peanuts (Robinson, 1985).

In 1980 CARDI encouraged the formation of two cooperatives in the village of San Antonio to prepare projects for peanut production, and to apply for loans to meet costs of land clearing and cultivation of peanuts. Initially each cooperative had 33 members (Robinson, 1985).

In 1979 there were 38 ha under peanut cultivation. It was estimated that in 1979 about 28,310 kg of peanuts in shell was produced while in 1980 there was about 51,282 kg (Table 1). By 1985, peanut production had increased to the level that Belize was considered self sufficient in that commodity and surplus peanut is now being exported (Table 2).

51

Table 1. Production of peanut in Belize

Year	Amount (Kg)	Area (ha)
1979	28,310	38
1980	51,282	63
1981	150,000	122
1982	182,412	162
1983	331,056	363
1984	170,352	182
1985	174,090	200
1986	166,080	148
1987	255,068	182
1988	184,273	200
1989	139,795	150
1990	114,227	68
1991	158,318	101
1992	191,500	181
1993	233,800	224

Table 2. Export of peanut from Belize.

Year	Kg	US$ '000s
1984	2,561	10
1985	2,302	20
1989	7,938	10
1990	39,086	50
1991	94,794	121
1992	22,575	29
1993	79,379	103
1994	40,324	62

Under the Peanut CRSP emphasis was placed on investigating and identifying suitable methods for maintaining post harvest quality and reducing post production costs through improvements in harvesting, threshing, shelling, drying and storage operations. These were joint efforts of Peanut CRSP, CARDI and various Cooperatives.

FORMATION OF COOPERATIVE SYSTEMS

During the period 1978 to the early 1980's several cooperatives were registered as a result of a promotion campaign by the Government of Belize (Enriques, 1992). All of these cooperatives were formed by small farmers. Most of these farmers joined with the hope of improving their standard of living by improved and efficient production of agricultural produce. The Government provided land to these cooperatives (average about 20 ha per member) and also assisted in providing limited production credit through the Development Finance Corporation (DFC). A limited technical assistance was provided by CARDI on continuous basis as and when requested. Very little consideration was given for marketing of farmers produce on routine basis. Consequently cost of production was high, yields were low, and many times farmers could not sell their produce when they wanted to sell. After an in depth study jointly made by Cayo Cooperatives and Canadian Consultants, Cayo Cooperatives decided to undertake a marketing project which would also provide the administrative management skills, technical assistance, and financial resource required. These cooperatives formed the Belize Federation of Agricultural Cooperatives (BFAC) as a secondary cooperative society. Apart from primary cooperative members of BFAC which is operating in the Cayo District only, there is another Cooperative in the Stann Creek District engaged in peanut production. There are twenty (20) members in this cooperative. There is no regular support provided to this cooperative for technical assistance and administrative management and therefore, the cooperative is not moving forward as one could expect.

THE BELIZE FEDERATION OF AGRICULTURAL COOPERATIVES SOCIETY (BFAC)

BFAC was registered in 1984 but became operational in 1986. The Federation was established to provide marketing of their produce, and educational and technical assistance to its members.

BFAC has 14 primary cooperatives/affiliates. The organization has 464 members and over 3,000 direct beneficiaries (Table 3).

Table 3. Members of BFAC (1995)

#	Name of Cooperative	Year formed	Year joined BFAC
1	San Antonio Peanut And Grain Cooperative	1980	1984
2	Cristo Rey Farmers Coop.	1980	1984
3	Western Mopan Coop.	1980	1984
4	Cafetateros Benqueños Coop.	1982	1984
5	Santa Elena Farmers Coop.	1981	1984
6	Bullet Tree Falls Coop.	1980	1984
7	San Migeul Farmers Coop.	1980	1984
8	Santa Familia Grain and Vegetable Coop.	1985	1986
9	Valley of Peace Coop.	1986	1989
10	Belize River Valley Coop.	1981	1989
11	Las Flores Group.	1990	1991
12	San Marcos Group.	1988	1992
13	Cristo Rey Women Group.	1990	1990
14	Santa Familia Women Group.	1990	1990

BFAC'S MISSION

To assist cooperative farmers to improve their standard of living by increasing their income and for the cooperative to which they belong to become self sustainable.

In line with this mission statement BFAC provides the following services:

Marketing
Training and Education
Technical Assistance
Production Credit and Machinery Services
Women in Development
Youth Training
Cooperative Activities
Environmental Conservation
Advocacy and Representation

OBJECTIVES OF BFAC

1. To market the produce of members cooperatives locally and abroad.
2. To procure and store sufficient produce to influence the market in the interest of the members.
3. To increase the production and productivity of the cooperative farmers.
4. To provide and co-ordinate educational programs for members to improve the effectiveness of production.
5. To provide drying facilities to member cooperatives.
6. To assist member cooperatives to determine economically viable crops.
7. To provide a forum for member cooperatives to accumulate assets and to build security to generate income for the future.
8. To assist member cooperatives to improve Government Legislation of Cooperatives and of agricultural policies.
9. To facilitate member cooperatives to obtain maximum benefits offered by support agencies such as the National Development Foundation of Belize, Help for Progress, Belize Agency for Rural Development, and the Belize Enterprise for Sustained Technology.
10. To provide opportunity for members to gain experience and to develop the expertise in managing their own affairs.
11. To process as well as export products grown in Belize.
12. To develop self sufficiency at both the primary cooperative and the federation level.
13. The integration of women and youth into the cooperative movement.
14. To represent member cooperatives on issues pertinent to cooperative development.
15. To promote agricultural practices which are sustainable in the long terms.

ACHIEVEMENTS OF BFAC SPECIFICALLY IN PEANUT PRODUCTION

At the formation of BFAC there were 10 primary cooperatives as founding members and at the end of 1994 there were 9 cooperatives and five affiliates represented a total of 500 members (Table 3). Increased membership participation at the primary level and improvement in cooperative practices are evident. The Federation members handle peanuts, corn, Red Kidney Beans, potatoes, hot pepper, and other vegetables. BFAC's market share has increased and its share is on rise. BFAC sold about 50,000 kg of peanut to CARICOM and about 80,000 of beans in 1993 (Enriques, 1995). Only one (1) cooperative member of BFAC was planting peanut in 1986 and producing about 3,115 kg of peanut in shell while in 1993 there were 5 cooperative members producing 51,430 kg peanut in shell (Table 4). Over the years productivity of peanut has increased from 784 kg/ha to 1,232 kg/ha. The Federation has also been able to export 46,818 kg peanut in shell in 1992 and 50,000 kg in 1993. In 1994, the area under peanut has further increased and it is estimated that it will further increase in 1995.

Table 4. Production of peanut by BFAC members.

Year	# of BFAC Cooperatives Producing Peanut	Total Production (Kg)	Production (Kg)
1986	1	3115	784
1987	4	30260	-
1989	4	41730	10120
1990	4	13610	-
1991	4	52170	-
1992	6	54430	-
1993	5	51430	1120
1994	5	34000	1232

The technology for peanut production in Belize is developed by CARDI and commercialized by BFAC cooperatives. Members of BFAC are the biggest peanut producers in Belize. Most of the farmers raise peanut on 0.4 to 2 ha plots. However, a few farmers produce up to 8 ha of peanut.

A production credit scheme is in place with funds provided by the Canadian Cooperative Association. The farmer is given technical assistance, in-kind financing, a guaranteed market for his produce and a channel through which he can repay his loan through deduction from the crops sold through the cooperative.

In collaboration with CARDI/Peanut CRSP seven (7) Cooperatives have completed storage and drying facilities with an estimated capacity of about 90 metric tonnes of produce. These Cooperatives have acquired small farm equipment such as scales, testers, sheller, etc. through loans bearing an interest rate of 10% (Enriques, 1995).

Within the last two years, BFAC jointly with CARDI, about 300 days were concentrated on education, training, and technical assistance activities. BFAC has recently implemented a Management Assistant Program where the children of farmers are trained and employed to maintain cooperative records, and are also trained in other aspects of management. To date three young persons have been hired by three Cooperatives (Enriques, 1995).

Three major problems faced by cooperatives in peanut production are as follows:

1. Lack of technical assistance resulting in inappropriate management practices, high post harvest loss and high cost of production.

2. Lack of production credit due to farmers inability to meet banking criterion. As a result, the farmer cannot take advantage of the technical assistance offered nor the economies of scale.
3. Due to the unavailability of machinery the farmers chance of making a profit is greatly reduced. Time lines, reliability, and the cost of machinery services are essential factors which greatly influence profit or loss in an agricultural venture. Most of the farmers need to wait for owners of machinery to mechanize their lands. This practice has had negative effects on yields.
4. In most cases the infrastructure (roads, electricity, water, and storage) is non existent or in extremely poor condition to provide for adequate production practices.

MARKETING

BFAC produces and markets the Tennessee Red Variety Peanut. Major customers in Belize are the Mennonites of Spanish Lookout, the Piache Peanut Processing Plant and the local vendors. BFAC also export peanuts to Barbados. Peanuts are exported to the Caribbean in shell. The market demands that this product be free of foreign matter, disease, pest and has a moisture content of not more than 10%. The shipment must be accompanied by a phytosanitary certificate including certification of aflatoxin level below the tolerance level (20 ppb).

Because BFAC is owned by cooperative societies whose membership consist of small farmers, the various marketing activities are done at both the primary cooperative and BFAC levels. The primary cooperative collects, grades, buys and stores the peanut.

BFAC makes the marketing arrangements, collects the peanut from the cooperative, does final grading, packaging and ensures that the peanut reaches its final destination. BFAC also provides loans to the cooperatives so that they can give the farmer a first payment when he delivers his product.

A lot is to be desired in terms of the improvement that needs to be made in the marketing of peanut in Belize. Included are the following:

1. Market Information
2. Market Expertise
3. Financing
4. Infrastructure
5. Training and Education
6. Absence of coordination and long term commitment with producers and purchasers.

The lack of market information has been a major problem in Belize on the whole. Without market information, it is difficult for farmers to plan production and to take advantage of

the best available market. The market information should include available financing, technical assistance, and technological packages.

The need for Market Expertise, training, and education at all levels is evident in BFAC. This manifests itself when the cooperative allows farmers to deliver poor quality crop and collects premium prices. There should be coordination and understanding at all levels of the marketing process when it comes to market demand, prices, production cost, marketing process, collection and payment. The need to develop and establish linkages with the export market is also crucial, if farmers are to succeed in the international market.

Beside addressing the production credit needs, there is need to look at maximizing the use of credit so that the farmer can effectively compete locally and abroad. Training and education plays a vital role in this case.

CONCLUSION

Socio-economic development of the target areas in Belize, in overall terms, has been a spectacular success. The change in agriculture has brought a dramatic improvement in the standard of living.

The principal instruments of this transformation are:

I. The development and success of BFAC has provided dependable input supply and product marketing enabling farmers to enjoy steady incomes from commercial agriculture.
II. The successful intervention of CARDI in the development and transfer of new technology to farmers in the peanut growing areas in cooperation with BFAC, and their ability to utilize this technology in constructing a new, more efficient system of farming.

Farmers want more land to grow peanuts and other commercial crops and to merchandize other parts of their farming operation. The cost of production has still been the major economic constraints in making peanut profitable. The cost of the harvesting and post-harvest handling (threshing, drying, storage, and shelling) have been major components of the process requiring further improvements.

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Women Cooperatives in Peanut Processing in Thailand

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ABSTRACT

This research was conducted in 1991 and 1992 to investigate the transfer of peanut processing technology, along with business and marketing management, to farmers in Huay-Bong-Nua village, Prao district, Cheingmai province, northern Thailand. A pilot group of seven women farmers was formed and was trained the techniques for processing and quality control of peanut products (oil roasted peanut and ground roasted peanut). Those peanut products were marketed in downtown Cheingmai and Prao district markets. Consumer acceptability of both products was high and their quality were better than those of similar products in the markets. These results revealed that the women were well trained and understood the techniques in the processing peanut products. Improvement in socioeconomic status of the women farmers appears promising, although the project was conducted for only 6 months, which is a very short time for definitive change.

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Research on Appropriate Technology for Storage and Utilization of Peanut, funded by the Peanut CRSP, has been conducted in Thailand, as well as in other countries, for the last 10 years. Part of the Thai research has focused on improvement in quality of many traditional peanut products, along with development of some new ones. The program is maturing, and technologies developed by Peanut CRSP researchers are now being transferred to end users, that is, to small and mid-scale industries. This is the first project in transferring technology to a rural area, Huay-Bong-Nua village, Prao district, Cheingmai province, northern Thailand. This research was conducted in 1991 and 1992 to investigate the transfer of peanut processing technology, along with business and marketing management, to farmers in Huay-Bong-Nua village, Prao district, Cheingmai province, northern Thailand.

Huay-Bong-Nua village is in the northeastern part of Cheingmai province, about 90 km from downtown Cheingmai. The total area is 3,895 Rai. It is a newly developed village for poor farmers who previously had no land, designated by the country as an Agricultural Cooperative Park. Each family occupies about 10-20 Rai for living and for farming of crops, livestock, and fisheries. Almost all the area is used for the main crop, rice, in the rainy season. Peanut is the second crop, occupying about 80% of the total area throughout the growing season. In 1992 total population was 658 adult villagers, of which 316 were men and 342 were women; the total number of households was 193 families.

The Department of Product Development, Kasetsart University, joined with the Department of Agricultural Economics, Kasetsart University, and the Department of Food Science and Technology, Cheingmai University (with the cooperation of the Department of Food Science and Technology, The University of Georgia, USA) to conduct this research which the following objectives :

1. to investigate the transfer of peanut processing technology, along with business and marketing management, to women farmers in Huay-Bong-Nua village, Prao district, Cheingmai province, northern Thailand.
2. to study the effect of this technology on the socioeconomic status of these farmers.
3. to study the total cost, quality and shelf life of the products.
4. to study as a model that will be used for training to other group in the regions.

SOCIOECONOMIC AND MARKETING SURVEY

Before initiating the processing technology transfer study, socioeconomic status of 50 farm households in Huay-Bong-Nua village was surveyed using a direct interview questionnaire. Questions were asked in the following areas : general information, farming practices, economic status, and marketing status, especially for peanut.

41

A preliminary evaluation of the socioeconomic status of the group of seven women in the project was done by observation and by interviewing them at the end of the project (6 months) and after a year. Informal survey at several markets in Cheingmai was also conducted to identify the most popular peanut products. These products were purchased and analyzed for aflatoxin content. The aflatoxin content and other quality and shelf life factors of the processed peanut were than determined and compared with the existing products as a means of validating the group's learning of the processing technology. The survey was conducted on information from the 1990-1991 crop season.

Demographic information of 50 farm households in Huay-Bong-Nua village who grew peanuts is shown in Table 1. Three out of four people were farm workers. Both women and men were farmers, at a ratio of 1:1. Of the total population, 54.47% worked full-time on their own farms, and 39.84% worked part-time both on their own farms and in other jobs in the village; 5.69% did not work on the farm at all. About 88% of the households owned their own land.

Many different crops are grown in the village, including rice peanut, soybean, mungbean, blackpea, corn, and Chili. Figure 1 shows peanut in multiple-cropping systems year round.

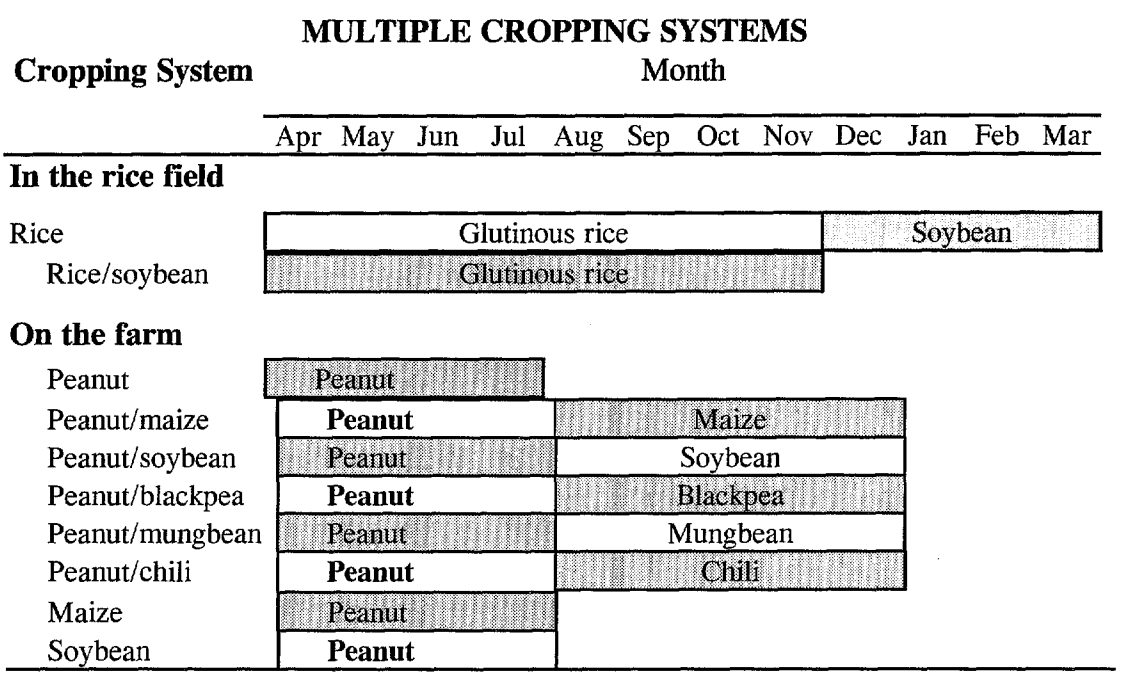
Land use for growing peanut was 5.76 Rai, which was about 45% of the total land per household. Each household earned about 6,388 Baths/year from selling peanut, which was about 33% of the total income of almost 19,500 Baths/year (Table 2). The greatest household expenditure was for food, just over 10,800 Baths/year, which was about 68% of the total expenses of almost 16,000 Baths/year (Table 2).

42

Table 1 Demography of selected peanut growers in Huay-Bong-Nua village, 1990-1991 crop season, before introducing peanut processing technology.

Item	Total	Male	Female
No. of farm households	50		
Age of head of household (years)	43.16		
Education (%)			
Illiterate	2		
Primary school (grade 1-4)	90		
Primary school (grade 5-6)	4		
Secondary school	4		
Family size (avg. no. of persons)	3.52	1.64	1.88
Full-time farm and non-farm workers in family (avg. no. of persons)	2.32	1.10	1.22
Part-time workers in family (avg. no. of persons)	0.08	0.02	0.06

Fig. 1 Multiple-cropping systems, most including peanut, year round in Huay-Bong-Nua village, Thailand, in 1990-1991.



43

Table 2 Cash farm income and expenses, per household, 1990-1991 crop year.

	Amount (Bath)[a]	% of Total
Income		
Peanut	6,387.71	32.91
Chili	6,246.60	11.58
Maize	1,453.08	7.49
Soybean	998.59	5.14
Blackpea	117.40	0.60
Mungbean	48.00	0.25
Hire labor (off-farm)	8,157.20	42.03
Total	**19,408.58**	**100.00**
Expenses		
Food	10,815.28	67.61
Clothing	1,271.80	7.95
Medicine	881.40	5.51
Festivals	1,024.80	6.41
Miscellaneous	2,003.40	12.52
Total	**15,996.68**	**100.00**

[a] 25 Bath = $1.00 in 1991.

Cost of peanut production per Rai was 2,050 Baths, of which 96% was for variable costs and 4% was for fixed costs; cash farm expense was 798 and noncash farm expense was 1,252 Baths/Rai, A Total of 72% of the farm expenses came from the farmers' savings and 28% was borrowed from the Cooperative and Agricultural Bank.

Table 3 shows average production cost and net income of peanut production per Rai at Huay-Bong-Nua village before this study. Production yield averaged 225 kg/Rai; selling price of the peanut was 9.39% Baths/kg. Therefore, net income averaged 2,117 Baths/Rai. Although net return was 145 Baths, net profit over cash farm expense was 1,319 Baths. The net profit of peanut and other crops, it is clear that peanut growing gave the highest net profit. These data also show that farm processing and sale of a value-added product is important for increasing farm income.

44

Table 3 Net investment and return of peanut production in Huay-Bong-Nua village, Thailand, 1990-1991 crop year.

	Value
Yield (kg peanut/Rai)	225.52
Average price (Baths/kg)	9.39
Income (Baths/Rai)	2117.63
Variable cost (Baths/Rai)	1971.70
Fixed cost (Baths/Rai)	77.88
Total cost (Baths/Rai)	2049.58
Total cash cost (Baths/Rai)	797.77
Net return (Baths/Rai)	145.93
Net profit over cash cost (Baths/Rai)	1319.86
Net Profit over total cost (Baths/Rai)	68.05

MARKETING STATUS OF PEANUT

In Thailand, as in developing countries, marketing of farm produce is a primary production problem. Farmers can not sell their products at a fair price. Total profit is shared among farmers and the various middlemen merchants involved in sales. Table 4 illustrates the marketing conditions for peanut in the village.

TECHNOLOGY TRANSFER PROCESSES

The technology transfer research was conducted in 1991 and 1992; this report was completed in October 1992.

A pilot group in the village was asked to form to join this research activity. The district home economist was invited to serve as group advisor.

46

Table 4 Peanut marketing conditions in Huay-Bong-Nua village, Thailand, 1990-1991 crop year.

	No. of farmers (N = 50)	% of Total
Selling form		
Fresh pod	0	0
Dried pod	50	100
Type of merchant		
Inside village	19	38
Outside village	31	62
Location of sales		
Inside village	50	100
Outside village	0	0
Marketing problem		
None	20	40
Low price	27	54
Low quality	3	6

A manual for processing the targeted peanut products was prepared by the Department of product Development, Kasetsart University. Information included methods for screening for good-quality peanut, grading, cleaning, blanching, frying, grinding, and packaging of both oil roasted and ground roasted peanut. Oil roasted peanut is partially dry roasted, them completed in hot oil; ground roasted peanut is dry roasted, then ground into flour. Fig.2 is a flow diagram of the processes involved.

Small equipment and materials were purchased and delivered to the village. This included a hand roaster of 20 kg capacity, an LPG gas burner as a source of energy, a set of frying pans, a grinder, a plastic sealer, scales, plastic pouches, labels, and trays.

Using the prepared manual and hands-on activities, training in processing techniques and marketing activities was conducted at the village. This took two days. After the group learned the techniques, they began their own production of oil roasted peanut from large peanut seeds and of ground roasted peanut from medium and small peanut seeds. The products were sent to the markets in downtown Cheingmai and in Prao district. The women were also taught to keep records of expenses and income.

Raw peanut
(var. Khon-Khaen 60-1)
↓
Shelling
at local shelling plant
↓
Grading
into large, medium, and small by hand operation
↓
Screening
rejecting poor-quality peanut by hand operation
↓
Raw material
good-quality peanut checked for aflatoxin

Large & Medium peanut	Small peanut
↓	↓
Roasting partially roasted at 165°C 20 min. for each 10 kg batch	Roasted fully roasted at 165°C 40 min. for each 10 kg batch
↓	↓
Blanching by hand	Grinding with a small grinder
↓	↓
Boiling in boiling water for 15 min.	Removing red skin with a win blowing action Draining
↓	↓
Frying at 160°C for 15 min. for each 2 kg batch	
↓	↓
Packing 100 g/pouch	Packing 500 g/pouch
↓	↓
Oil Roasted Peanut	Ground Roasted Peanut

Fig.2 Processes of oil roasted (left) and ground roasted (right) peanut

Researchers visited the site every month to observe the processing and to discuss and help solve any problems. One graduate of the Department of Product Development was stationed in downtown Cheingmai to cooperate with the group as required.

The following factors were evaluated

Quality. Samples of the products were taken for evaluation of quality by a student who had graduated from the Department of Product Development. Quality evaluation was performed in the laboratory at the Department of Food Science and Technology, Cheingmai University. Both microbial loads and aflatoxin content were measured,

Shelf life. Samples of oil roasted and ground roasted peanut were taken before marketing and were stored at room temperature for 2 months. Moisture content, water activity, and peroxide value of the products were analyzed every week. Analysis was performed in the laboratory at the Department of Food Science and Technology, Cheingmai University.

Consumer acceptance. Oil roasted peanut produced by the group was tested for acceptance by 100 consumers. Consumers were asked to rate the product on size, color, texture, and flavor using a 9-point hedonic scale. Because ground roasted peanut is used as an ingredient in several commercial Thai foods, we invited 47 caterers (30 males and 17 females) to evaluate the group's product.

MARKETING ALTERNATIVES

Farmers sold dried peanut in the shell to both village traders (38%) and outsider (62%). Although 40% of farmers said they had no problem marketing their crop, 54% wanted higher prices and only 6% said their products did not meet quality requirements. Nevertheless, the demand fox in-shell peanuts is small, and peanut is often overproduced. Processing peanut in the village would enable farmers to grow more peanuts to meet an increased demand. Also, income should increase by marketing a value-added product rather than raw peanut.

Alternatives for processed products included coconut- or coffee-coated peanut, dried roasted peanut with pods, steamed and dried peanut with pods, oil roasted peanut, and ground roasted peanut. Because the most popular consumer product in Cheingmai

province is oil roasted peanut and because ground roasted peanut is a popular ingredient in cooking many Thai dishes, we selected them for the technology transfer project.

COSTS OF THE PROCESSING TECHNOLOGY

Production costs for oil roasted and ground roasted peanut in this project are shown in Table 5 . For both techniques, the greatest expense was for the raw material (peanut). Selling price for the oil roasted peanut product was 100 Baths/kg and for the ground roasted peanut product 30 Baths/kg. Thus, profit of the oil roasted peanut was 36.56 Baths, or 84.16% of the cost; of the ground roasted peanut it was 6.8 Baths, or 39.53% of the cost.

Table 5 Processing costs of oil roasted and ground roasted peanut, Huay-Bong-Nua village, 1991-1992.

Item	Expense (Baths/kg)	% of Total
Oil roasted peanut		
Peanut	26.32	60.59
Fuel	1.23	2.83
Packaging, labeling	4.00	9.21
Edible oil for frying	1.37	3.15
Labor	10.52	24.22
Total	43.44	100.00
Ground roasted peanut		
Peanut	12.57	73.08
Fuel	1.07	6.22
Packaging, labeling	0.70	4.07
Labor	2.86	16.63
Total	17.20	100.00

QUALITY AND SHELF LIFE

A major problem in this area is the high level of aflatoxin contamination in ground roasted peanut sold in the Cheingmai markets: more than 90% of peanuts are contaminated with

49

high levels of aflatoxin that range from 0 in the Wa-Ro-Rod markets to 2039 ppb in the San-Pa-Koi markets. The average of peanut in 22 market locations in the province is 541 ppb of aflatoxin contamination. (Maximum aflatoxin allowed in US peanut is 20 ppb). Reduction of aflatoxin was considered as an essential part of the project.

Microbial quality and aflatoxin content of the oil roasted and ground roasted peanut from the group was either low or nonexistent (Table 6).

The results of the storage (shell-life) test of oil roasted peanut in plastic pouches are shown in Table 7, Moisture content and water activity were both low initially, but increased rapidly from 6 to 8 weeks; the average rate of moisture content increase was 0.034% per week. This greatly affected the crispness and rancidity of the processes peanut. The peroxide value (measure of rancidity) in the oil roasted peanut increased steadily over the entire period, with an average of 3.25 meq/kg oil per week. The rapid increase in peroxide value was due to the plastic pouch packaging, which did not prevent air from entering and to the extremely high temperatures in the market. Thus, the Shelf life of oil roasted peanut packed in plastic pouches in no longer than 6 weeks; after 6 weeks it is rejected by consumers due to rancidity.

This proved that the group could follow the procedures and understand the techniques very well.

Table 6 Quality of oil roasted and ground roasted peanut processed by farmers at Huay-Bong-Nua village, 1991-1992.

Quality factor	Oil roasted	Ground roasted
Microbial quality		
Total count (colonies/g)	420	750
Yeast and mold (colonies/g)	-	45
Coliform (MPN/g)	-	2
Aflatoxin	ND[a]	ND

[a] ND = not detected

60

The results of the storage test of ground roasted peanut in plastic pouches are also shown in Table 7. Moisture content and water activity increased rapidly at 3 weeks and continued to be high through 8 weeks; the average rate of moisture content increase was 0.028% per week. The peroxide value in the ground roasted peanut also increased steadily over the entire period, with an average of 4.0 meq/kg oil per week. Shelf life of ground roasted peanut is 4 weeks. Because ground roasted peanut is a wholesale product destined for food caterers, its market is more certain, so Shelf life does not appear to be a problem. Packed in bags of 500 g, the product is generally used within a week.

Table 7 Effect of storage time on moisture content, water activity, and peroxide value of oil roasted and ground roasted peanut.

	Time (weeks)								
Value	0	1	2	3	4	5	6	7	8
Oil roasted									
Moisture content (%)	1.22	1.29	1.31	1.28	1.29	1.32	1.43	1.41	1.49
Water activity	0.26	0.26	0.27	0.26	0.27	0.28	0.28	0.29	0.29
Peroxide value (meq/kg)	2	5	11	14	18	18	24	27	29
Ground roasted									
Moisture content (%)	2.26	2.28	2.33	2.44	2.42	2.43	2.46	2.58	2.59
Water activity	0.33	0.33	0.34	0.35	0.34	0.34	0.35	0.35	0.36
Peroxide value (meq/kg)	2	8	12	14	18	23	29	33	35

CONSUMER TEST

The results of a consumer test for oil roasted peanut at Cheingmai market near the end of the project. A total of 100 consumers, 42 male and 58 female, were interviewed. Most of them liked the peanut product due to its texture, taste, and aroma; sensory scores were moderately high to high, from 6.44 to 7.17. Highest score was for the crisp texture. (Fig.3)

6

Of the respondents, 55% accepted the product, 11% would not accept it, and 34% were unsure. A total of 88% considered the packaging size suitable, but 8% thought it was too small. About 89% thought the price of 5 Baths/50 g package was adequate. Some 41% of the consumers suggested adding a small amount of salt to improve the taste.

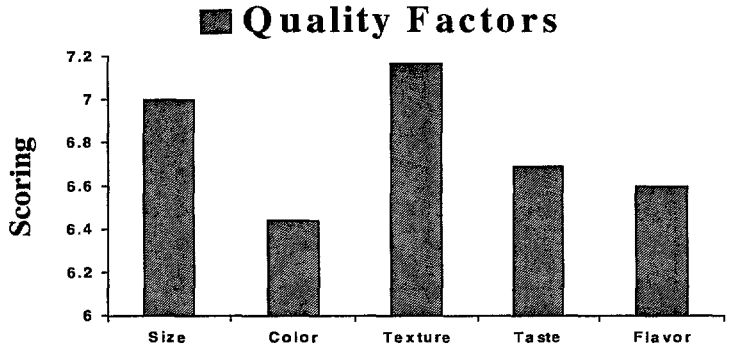


Fig. 3 Consumer rating (based on a 9-point hedonic scale) of oil roasted peanut produced by the farmer group at Huay-Bong-Nua village, 1990-1991.

The caterers who used the ground roasted peanut were also interviewed for their ratings. There were 30 males and 17 females, ranging from 20 to 50 years of age, with 45% of them over 40 years old. The foods for which they used ground roasted peanut included fried noodle and special sweet and sour noodle (i.e., Tom-Yam) 90%; satae sauce, 5%; and other foods, 5%. About 75% of them used from 500 to 1,000 g ground roasted peanut per day. About 7% of them preferred to buy the product rather than make it themselves. The caterers who made their own product were mostly concerned with freshness and cleanliness of the product, along with sanitary processing conditions; they did not trust the quality of the usual products sold in the markets. About 95% of the caterers accepted the color or the product, and 90% agreed with the packaging size. About 70% of the caterers considered the product suitable for sale in the markets.

CONCLUSION

This is a new and challenging project in technology transfer by the Peanut CRSP to a group of farmers in the rural area of Huay-Bong-Nua village, Prao district, Cheingmai province, Thailand. The project ran as a model to measure the socioeconomic impact of

62

such technology on a group of farmers who grow peanut as their second crop on their own lands and sell to markets in nearly districts. It is challenging to change the direction from selling raw and dried peanuts in the shell to selling a processed peanut product.

Using a marketing survey, we selected oil roasted and ground roasted peanut products. We trained a group of seven women farmers in the processing and marketing techniques, as well as in general business management. Products were placed in district and provincial markets.

Quality, Shelf life, and consumer acceptance of the products were all evaluated. Quality was good; the products were cleaner, safer, and more hygienic than products already in the market. This proved that the women were well trained and could understand the techniques in processing oil roasted and ground roasted peanut. Products became rancid after 6 weeks in the oil roasted and after 4 weeks in the ground roasted peanut; this short Shelf life was due to unsuitable packaging and high temperatures in the markets. Consumers considered the products good in quality and accepted them; the ground roasted peanut had higher quality than the already existing products on the market.

Researchers recommended that the women continue processing ground roasted peanut. Although its profitability was less than that of oil roasted peanut, ground roasted peanut had constant demand, a fast turnover rate, and better quality than the existing products. Moreover, up to 100 kg/day can be processed, compared to 30 kg/day for oil roasted peanut. This makes it, in the long run, a more suitable technology in Huay-Bong-Nua village.

The socioeconomic impact of this project on the households in the village was determined. It looks promising. The women learned techniques for processing peanut along with techniques for business and marketing management. This type of activity will help them learning techniques by themselves and also improving their quality of living. At the end of this project, October, 1992; the women earned a continuous profit of at least 1,088 Baths/month by working 2 days a week and selling ground roasted peanut at Prao district market.

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64

Quality Enhancement and Technology Transfer of Peanut-root Crop Food Products to Women Processing Groups in Leyte, Philippines

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INTRODUCTION

Root crops are important plants in the tropics because of their ecological adaptability and high yielding ability. Among the food items from root crops, focus has been made on bakery products since they are very popular among Filipinos and they contain the highest added value among food products in the market. At present, two bakery products (Cassa's Lacy Finger and Peanut-Sweet Potato Cookies) have shown market potential during the pilot testing stage. However, there is still a need to improve their sensory quality and nutritional value and to properly package them. Other ingredients such as peanut (Arachis's hypogaea L.), a major legume in the Philippines, may also be added in order to improve the flavor and add variety to root crop bakery products. There are existing small scale processors in Leyte who supply peanut products in Leyte and Cebu.

Women are major decision makers (Roa and Quevedo, 1992), but their actual activities or performance can be improved and their skills developed through appropriate training to make them more effective participants in any developmental endeavor. Understanding their socioeconomic characteristics, beliefs, and attitude would help policy makers and development workers design appropriate intervention schemes aimed at improving food

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65

processing conditions, promoting a more wholesome life, and increasing the availability of higher quality foods.

A study was then conducted of standardize the conditions and procedures for processing the raw materials (i.e. sweet potato flakes, peanuts, and cassava); optimize the formulation and process conditions for Lady Finger, Peanut-Sweet potato Cookies, and Peanut-Cheese products; increase the shelf-life of the products using appropriate packaging, storage, and marketing; obtain baseline socio-economic and demographic information of the cooperators; determine the marketability, adaptability and profitability of products developed at the level of women cooperators; and assess the impact of the technologies introduced and knowledge gained by women processors.

METHODOLOGY

1. Establishment of linkages and consultative meetings.
2. Identification of processing cooperators and profiting.
3. Socioeconomic baseline survey of cooperators.
4. Training of cooperators on processing and entrepreneurship.
5. Consumer survey and market testing.
6. Optimization of process and formulation.
7. Drying characterization of sweet potato flakes.
8. Packaging requirements and shelf-life studies on the different products.

RESULTS AND DISCUSSION

Women Cooperators

The Guadalupe Women's Association (GWA), a livelihood group organized through the ViSCA Tropical Ecology Project, is composed of housewives of upland farmers; it is situated less than a kilometer from ViSCA. The group was organized to provide an income to its members as an alternative to illegal logging and other activities which destroy the upland ecosystem. The Tropical Ecology Project provided support for the processing facility while the members contributed labor and some materials.

The other group, URIVIC, was organized by the Philippine National Red Cross (PNRC). Ormoc City Branch located about 45 kilometers north of ViSCA, in its drive to rehabilitate the flash flood victims of typhoon Uring.

CONSUMER SURVEY AND MARKET TESTING

Socioeconomic and Demographic Characteristics

Ninety-seven percent of the household respondents have females mostly middle-aged and the main decision makers in food buying (Table 1). Sources of income were primarily from private employment(46.7%) and government work (23.3%). In the households that had supplementary income, sidelines or remittances from children or relatives were important. The monthly family income ranged from P1,500 ($60) to P15,000 ($600) in Tacloban to P500 ($20) to P11,500 ($460) in Ormoc.

Nutrient content of food and price were considered very important (Table 2). When desegregated, the households in Tacloban were more critical of the nutrient factor while the price was more important with Ormoc residents. Households did not seem to be particularly concerned with convenience and packaging. This is partly explained by the fact that price is a catch-all variable that reflects both parameters. The food budget ranged from P500 ($20) to P9,000 ($360) per month; the snack budget from P2 ($0.09) to P50 ($2) per day. Respondents were generally attracted to taste and packaging with price as the balancing factor.

Table 1. Socio economics and demographic characteristics of sample households

Characteristics	Ormoc (n=110)	Tacloban (n=30)
Sex of respondents		
Male	2	4
Female	98	96
Respondents as decision makers		
Mainly	72.7	83.8
Partly	15.4	14.6
Not responding	11.9	1.6
Household size		
3-4	19.1	23.1
5-7	62.7	55.4
8-10	14.5	14.6
Over 10	3.7	6.9
Number of children		
1-2	30.9	22.3
3-4	40.9	46.9
5-6		
7-8	7.3	6.2
>8	4.5	2.3
Age of respondents		
16-25	5.4	10.0
26-35	31.8	25.4
36-45	33.6	32.3
46-55	18.2	16.2
56-65	8.3	23.2
>65	2.7	3.8
Sources of Income :Primary		

Sources of Income : Secondary		
None other	5.4	63.2
Sideline/remittances	11.8	35.4
Business	9.1	0.7
Private employment	2.7	0.7

Table 2. Factors affecting buying (percentage reporting importance).

Characteristics	Ormoc	Tacloban	Total
Nutrients			
Most important	18.2	75.4	49.2
Moderately important	18.2	10.8	14.2
Not important	2.7	0	4.2
No response	23.6	3.8	18.3
Price			
Most important	51.8	16.9	32.9
Moderately important	18.2	44.6	2.2
Not important	1.0	0	0.4
No response	12.7	37.7	26.2
Convenience			
Most important	17.3	0.7	8.4
Moderately important	41.8	2.3	20.4
Not important	0	0	0
No response	24.5	96.2	63.3
Packaging			
Most important	1.8	0.7	1.2
Moderately important	4.5	0.7	2.5
Not important	1.8	0.7	0.8
No response	42.7	90.7	68.3

Household members usually ate bread and banana for snacks because they were conveniently available (68%) and cheap (48%). The nearest store was the most common source of snack foods which were commonly consumed in the afternoon. The most preferred factors for sweet food were peanut, chocolate, and vanilla. Radio and television were the most common source of information about food products.

Consumer Preference

Between age classes, there were specific preferences for color, texture, flavor and liking of cookies. This implies that at different stages of maturity there were varying responses in a product. The buying attitude also was significantly affected by age of the respondent. Off-flavor was not significant meaning this sensory quality did not differ between age levels of respondents. When ages were collapsed into six classes no difference existed between classes. Both the plain Lady Finger and peanut-enriched Lady Finger were accepted; the latter was liked most. Peanut flavor enhanced the taste and smell of the product making it acceptable both for gift-giving and home use. Current packaging size was preferred to a larger one. Respondents were willing to pay up to P10 ($0.40) per package. The current retail price ranged from P5 to P7.50 ($0.20-$0.30) per package.

QUALITY ENHANCEMENT AND PROCESS/FORMULATION OPTIMIZATION

Optimization

Results from formula optimization studies on Peanut Sweet potato Cookies showed that formulas containing steamed sweet potato flakes were significantly less acceptable in terms of texture but had a significantly less prominent off-flavor than the formulas containing unsteamed sweet potato flakes that had not been steamed (Table 3).

Lady Finger processed from 100% cassava flour was found acceptable and was as nutritious as those processed from wheat flour. Observations also showed shorter shelf-life due to crumbling and loss of crispness especially once a package was opened and the product was exposed to air.

Peanut-enriched Lady Finger was found to be more acceptable and contained a higher percent crude protein than the control. However, since Lady Finger was pilot tested earlier without peanut the cooperators resisted in processing it as peanut-enriched since the

60

plain product was already acceptable. Another product, Peanut Lady Button was then developed which contained 25% peanuts. Initial results showed that a higher return of investment could be obtained from this product since breakage was lower because of its round rather than elongated shape as compared to Lady Finger.

Table 3. Mean taste panel scores of peanut-sweet potato cookies prepared using sweet potato flakes receiving various drying, steaming and toasting times.

Treatment [1]	External Color	Internal color	Texture[2]	Flavor	Off-flavor	Overall acceptance
T1	6.71	6.58	7.1a	6.39	5.08b	6.39
T2	6.64	6.61	5.64b	6.57	6.72a	6.25
T3	6.68	6.50	6.08b	6.89	7.08a	6.54
T4	6.75	6.75	6.32ab	6.86	7.08a	6.54
T5	6.82	6.54	6.46ab	6.67	7.22a	6.71

[1] T1 = dried immediately: T2 = steamed 3 min and dried: T3 = dried & toasted for 10 min:
T4 = steamed 6 min: T5=dried and toasted for 10 min.

[2] Mean values in columns followed by the same letter are not significantly different at 5% level of significance.

Increasing the levels of peanut and cocoa powder in Peanut Chocas did not significantly improve the quality of the product when subjected to sensory analysis (Table 4). There was no significant relationship between cocoa and peanut of Peanut Chocas at different levels in almost all sensory attributes evaluated except for color wherein a positive correlation existed or the scores increased as the level of cocoa was increased. However, regression analysis showed significance in color, flavor, and general acceptability. Furthermore, the response surface methodology showed acceptable products with scores ≥ (or like moderately in the Hedonic scale) at a lower cocoa level suggesting that the

formulation could reduce cocoa without effecting the desired quality to lower the production cost.

Table 4. Mean taste panel scores of Chocas with different levels of peanut butter and cocoa.

Treatments		Sensory Qualities			
Peanut (g)	Cocoa (g)	Color	Texture	Flavor	Overall Acceptance
0	0	6.00b	6.91	6.73	6.64
0	15	7.24a	7.27	7.31	7.33
0	30	7.53a	7.09	6.95	7.11
30	0	6.02b	6.95	6.81	6.77
30	15	7.44a	7.18	7.27	7.29
30	30	7.42a	5.80	6.71	6.75
60	0	5.93b	6.60	6.60	6.62
60	0	5.95b	6.60	6.60	6.62
60	15	7.16a	7.02	7.11	7.16
60	30	7.16a	7.00	7.11	7.11

[2] Mean values in columns followed by the same letter are not significantly different at 5% level of significance.

PACKAGING AND SHELF LIFE STUDIES

The adsorption isotherms of root crop-peanut bakery products (Lady Finger and Peanut-Sweet potato Cookies) using the procedure of Diamante et al. (1992) are shown in Table 5. The data were fitted with the various two-parameter isotherm equations (Chirife and Iglesias. 1973). The adsorption isotherms of Lady Finger at 30 degrees and 38 degrees were sigmoid and type II according to the BET classification (Brunauer et al., 1938). The sorption properties of Peanut-Sweet potato Cookies were very temperature sensitive compared to Lady Finger.

Table 5. Predicted shelf lives of Lady Finger and Peanut-Sweet Potato Cookies at accelerated conditions of 38°C and 90% RH using different packaging materials.

Packaging material	Thickness (inch)	WVTR ($g\ m^{-2}\ day^{-1}\ H_2O$)	Predicted shelf life (days)
a. Lady Finger			
Low Density Polyethylene	0.00246	11.6	1.96
High Density Polyethylene	0.00098	3.8	1.34
Polypropylene	0.00197	10.0	2.56
b. Peanut-Sweet potato Cookies			
Low Density Polyethylene	0.00246	11.6	2.07
High Density Polyethylene	0.00098	3.8	0.94
Polypropylene	0.00197	10.0	2.84

The critical moisture contents for loss of quality of Lady Finger and Peanut-Sweet potato Cookies were 2.28 and 3.56% (dry basis), respectively. Using the published data on the properties of selected packaging materials, the dimensions of the package, the adsorption isotherms at 30 degrees and the initial conditions of the products the predicted shelf life of both products were calculated using the packaging equation (Labuza, 1984). Results showed that the predicted shelf life using the packaging equation compared well with the actual shelf lives of the products. The existing thickness of polypropylene big (0.00216 inch) must be increased to 0.003999 inch in order to achieve a shelf life of 30 days for Lady Finger at ambient temperature (Table 6). However, the present thickness at 0.00374 inch of polypropylene bag for Peanut-Sweet potato Cookies is adequate since the required thickness is only 0.001364 inch. Using the commercially available thickness of 0.00974 inch and 0.00180 inch of polypropylene bags, the predicted shelf lives at ambient temperature were 27 days and 25 days only for Cassava Lady Finger and Peanut-Sweet potato Cookies, respectively.

Table 6. Packaging material thickness for a shelf life of 30 days for Lady Finger and Peanut-Sweet potato Cookies at ambient conditions.

Packaging Material	Required Packaging Material Thickness (inch)	
	Lady Finger	PS Cookies
Low Density Polyethylene	0.004639	0.001582
High Density Polyethylene	0.001519	0.000518
Polypropylene	0.003999	0.001364

TECHNOLOGY TRANSFER AND COMMERCIALIZATION STRATEGIES

Interdisciplinary Approach

The project staff, consisting of a food scientist, a food engineer, a statistician and a socio economist, made the technology transfer easier and proved to be a better approach to effective technology transfer.

Inventory of Skills and Facilities

After the establishment of linkages and consultative meetings, an inventory of skills and facilities followed. This was necessary to speed up the adoption process. The previous exposure of the members of ViSCA technologies enabled them to have a quick decision as to what product and technology to adopt.

Training

In the early phase of pilot testing of product technologies with the cooperators, a program on skills development other than processing was established. Aside from informal consultations with cooperators as part of the organizational build-up process, two 2-day sessions on entrepreneurship development training was conducted to enhance their capacities in managing and operating a food processing business. The Entrepreneurship Development Training (EDT) was designed on a stepwise basis to gradually introduce the skills in a simplified and pragmatic manner as housewives with very limited formal training are involved. Thus, the EDT's were planned as a series of three 1-day training workshops to suit their schedule.

61

The first EDT consisted of group dynamic sessions which were expected to strengthen the individual member's commitment to the group. The sessions were designed to build-up cohesion starting with self-knowledge and acceptance, the relationship of self to the group, group-enhancing attitudes and practices, and leadership rules and functions. The second session dealt with the basics in management and entrepreneurship, record keeping, and marketing. Resource persons gave the lectures. A field visit with pilot processing cooperators in Baybay enriched the training component through interaction with farmers and women cooperators concerned with the development of enterprises using root crop-based technology from ViSCA; a planning exercise for the respective groups was also conducted. A third level training will still be conducted and will focus more on stress and conflict management and how to improve business operations.

Training modules were important components of these activities. Recent observations showed that both groups need more training in marketing and improving their business operations. Recent consultation with members of both groups attempted to thresh out the problems in the operation such as improving processing team-up, incentive system, and output targets.

Sharing

Intergroup knowledge sharing was also encouraged. The URIVIC group was trained by a GWA member. This was done to encourage the groups to share techniques of processing and experiences in operating their respective enterprises.

MARKET EXPANSION

In addition to selling in the Barangay store which is really a limited market, GWA was assisted to get a stall and sell in the market of Baybay during market days (Tuesday and Saturday). They also sold and promoted the products from other ViSCA-assisted root crop processors. It was expected that in this way GWA could open a bigger market for the Peanut-Sweet potato Cookies, 'binangkal," and "polvoron" which have longer shelf lives. Their Peanut-Sweet potato Cookies and "polvoron" were also being promoted in Taelaban City.

In URIVIC, the market testing activities are on-going for the Cassava Lady Finger cookies and the newly introduced product, Cassava Lady Buttons, which is also a peanut enriched cassava flour. Assessment showed that the Cassava Lady Finger has already gained some market following since its introduction the previous year. The Cassava Lady Button, Peanut-Sweet potato Cookies, Cassava Cookies, and "Polvoron" still need further promotion.

Product Packaging

Packaging is an important component in product selling. To reduce the need for individual packaging materials to be used for every product and to off-set the minimum order rule imposed by the packaging manufacturer, multi-product packaging was used by both groups.

Product Scaling-Up Operation

The way to keep the group viable and make the venture profitable is to increase the product volume (Table 4), However, a corresponding market expansion has to be done. The number of product outlets in each business center was then increased. Instead of just Baybay and Ormoc for GWA and URIVIC, respectively, other areas were explored. To date, there are outlets in Ormoc, Taclaban, Cebu, Manila, and Los Baños, Laguna.

Feed-back Mechanism

A feed-back mechanism is being strengthened and the mechanism documented. This is one of the sources of information incorporated in our optimization in the laboratory and standardization activities at the cooperators processing centers.

Documentation of Production Constraints

A bi-monthly summary of production showed an irregular output for both groups, figuring relatively high in months with more orders for market testing activities. A major constraint was the lack of flour which limited the promotional efforts. It is noted that both groups are the forward links of the cassava flour processing cooperative in the south, a strategy to expand the market for root crop flour. Efforts are undertaken to stabilize the supply of cassava flour to sustain the market promotion.

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' Fleur 11' Impacts in Senegal

O. Ndoye,[1] O.D. Smith,[2] and A. Ba[1]

INTRODUCTION

Peanut research in Senegal started in the early 1920's at what was then a small research station now the National Center for Agricultural Research in Bambey. The early research focused on germplasm assembly and evaluation for adapted varieties. Later, in the 1940's, research focused on thematic aspects mainly agronomy and physiology.

It was later on that a true breeding program started. The peanut program has now numerous varieties that are released in Senegal and elsewhere in West Africa. Senegal became then, with Nigeria and Sudan, the peanut producing countries of Africa.

COLLABORATION WITH THE U.S.

The Senegalese peanut program has a long tradition of collaboration with researchers in the United States. As far back as in the 1960's Dr. Ray Hammons exchanged materials with breeders at Bambey. In that exchange, an edible peanut variety which was very adapted in the Central Peanut Basin was selected. Since 1964 GA1 19-20 has been grown; today it is the only edible peanut variety that is grown in Senegal.

The contact was maintained until the '80s when the Peanut CRSP Project started. Then what was an informal or non-official collaboration was brought into a dynamic and strong collaboration between Texas A&M University and ISRA (Senegalese Agricultural Research Institut).

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In 1984 Dr. Amadou Ba spent 3 months with Dr. Ruth A. TABER studying fungi and aspects pertaining to aflatoxin. Mr. Ibra Fall, a technician, was trained for one month, under Dr. Olin D. Smith, with hybridization and leafspot evaluation technics. In 1988, Mr. Ousmane Ndoye started a M. S. thesis work, with Dr. Smith, which was completed in 1988. Since then, he is in charge of the breeding project working on foliar disease and aflatoxin resistance and edible peanut.

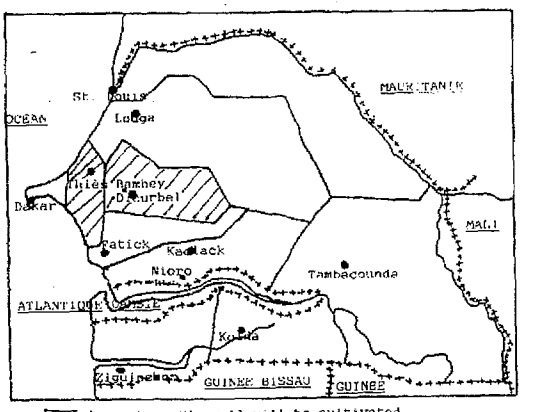
IMPACTS AND ACCOMPLISHMENTS

Over the years more than one hundred varieties and germplasm lines have been exchanged. Many of which are being used in breeding programs. Among them Chico which is one parent of a new variety GC8-35 with drought tolerance designed to be released in the northern part of Senegal.

The project also enables the exchange of materiels with other researchers or institutions.

'Fleur 11' was acquired under this scheme. 'Fleur 11' is originated from China. It was first introduced in Senegal in 1985 under the PI number 1174. After 3 years of trial in primary and secondary stations (SP and SS) it was entered in multilocational trials in 1988. In 1992 it was accepted as a new variety. 'Fleur 11 ' is intended to replace 55-437 in the regions of Diourbel and Thies. It might be grown in the Senegal river bank.

Map of Senegal showing thedifferent regions



Area where Fleur 11 will be cultivated

MERITS OF FLEUR 11

Compared to 55-437, Fleur 11 has some good attributes that makes it more fit for the above mentioned regions.

Plant stand

At emergence, plant stand is the same for the two varieties.

Yield potential

Haulm yield is equally important as pod yield for the Senegalese farmers. Haulm is used as animal feed; it increases farmers' income when sold, mainly in cities, during the dry season.

Fleur 11 pod yield is by far better than 55-437. On average Fleur 11 yields about 30% more than 55-437 on station. Haulm yield is similar for the two varieties.

Shelling percentage

55-437 has a little better shelling percentage than Fleur 11. This might be due to the fact that shells of Fleur 11 are a little thicker than those of 55-437.

Sound mature kernels

The SDK is not different for the two varieties. This is very important because Fleur 11 has bigger seed. In general, when two varieties have the same cycle, the one that has smaller seed is expected to have the higher SDK which is not the case here.

Hundred seed weight

Fleur 11 has better 100 seed weight than 55-437. Its seed size makes it an interesting variety for a company working with edible peanut which started seed multiplication.

Cycle

The two varieties have the same cycle which is about 90 days under our growing conditions. This is an advantage for Fleur 1 which can mature in areas where rainfall is very erratic despite its relatively big seeds.

Seed production

Seed is being increased during the rainy season and also during the dry season under irrigation in the Senegal river bank by a government owned company. Fleur 11 is expected to be released to farmers for the 1995 growing season. Farmers are asking for seed to be available the sooner possible because of the potential of this variety they observed during multi location trials.

In the two regions of Diourbel and Thies about 200,000 ha are under peanut cultivation for a production of about 59,600 tonnes. We have observed a 30% increase in experimental trials but we believe that we do a better than average job of peanut production. However, if we assume that growers will average 213 of the gain that we have observed, the annual benefit should equal 1.4 billion F CFA (approx. 2.5 million dollars) to the economy. Beyond the benefit of increased income is the greater assurance of food availability in areas where food supplies sometimes becomes limited.

Two promising lines have been tested in the southern part of the peanut basin. One is an oil-type peanut line (PC79-79), the other is a confectionary type peanut line (H75-0). Both are now on multi location trials since three years.

The most valuable accomplishments of this project is by far people trained and working for their country; I am a living example. When I first came to the US I hardly understood the language, it was difficult to speak a full sentence, now you can judge. The friendship developed with US scientists is also a valuable accomplishment.

PERSPECTIVE

'Fleur 11' could be the variety for Senegal, grown from North to South, if it were not the dormancy problem and its sensitivity to early leafspot. It is not an achieved variety, much is not known about aflatoxin contamination either. With the help of this project, we will work on these areas (dormancy, aflatoxin and leafspot) so that 'Fleur 11' can be cultivated in the south of the peanut basin. It has an advantage over the other varieties. Due to its seed size it can be used either as oil-type or confectionary type peanut.

Multi location trials will continue for the two lines PC79-79 and H75-0 to cover a wide range of soil types and environments in order to determine with accuracy their pod production potential.

Training for higher degree (Ph. D.) is needed since a doctorate degree is considered by most people as the necessary degree for good research.

ACRONYMS

SP= experiment station where research activities are important (as Bambey)

SS= experiment station of smaller importance (Louga, Thilmakha)

PP= farmers' fields

I= all cultural practices recommended in Senegal for peanut production are used in farmers' fields

72

CARDI-Payne Extension and Impacts in Jamaica

Joseph I. Lindsay[1]

INTRODUCTION

The peanut/groundnut has been grown for a long time in Jamaica. It has become established in the South Central parishes. Here the bulk of the local crop is produced in two growing seasons. The crop is predominantly rain fed and is the main crop in the farming systems of many small farmers. Whereas land preparation is mainly by hired tractors, the bulk of the activities in the production of peanuts is done by hand. These activities which are done manually include planting, weeding, molding, pesticide application, harvesting, stripping/threshing and drying.

Over the years attempts have been made to intervene in the production of peanuts. Through the Peanut-CRSP program varietal selection and post harvest aides have been highlighted.

THE PEANUT INDUSTRY IN JAMAICA - A SWOT ANALYSIS

A preliminary analysis of peanut production in Jamaica reveals the following strengths, weaknesses, opportunities and threats.

Strengths

The crop is well adapted to conditions in several agro-ecological zones in the Island.
There is greater local demand for the product than is currently produced.
Relatively cheap source of high quality protein and fat.
The production technology is available locally.
The reaped product can be stored for prolonged periods without deterioration in the quality.

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73

Weaknesses

Peanut production is chaotic at present.
There is the lack of an appropriate farmers organization for peanut farmers.
There is currently a lack of proper marketing channels.
The bulk of the crop is rain fed and hence production is seasonal and unpredictable.
Too few uses of peanut in the local diet compared to the potential.
Lack of selection according to quality divisions.
Inadequate availability of mechanical aids for production, harvesting and processing.
Lack of range of germplasm for different users.

Opportunities

Organize peanut producers association(s)/group(s).
Organize marketing including contract farming.
Develop sustainable campaign for increased use of peanuts in the local diet.
Training of key players in peanut processing and product development.
Encourage cottage industries based on the use of peanuts.
Potential for the production of peanut oil for cooking peanut flour and peanut cake for human and animal consumption.
Potential to increase output and reduce production costs.
Export of processed material to CARICOM states.

Threats

Cheaper produced peanuts flooding local market and destabilizing peanut farming.
Aflatoxin contamination and concomitant impacts.
Due to the removal of tariffs and the availability of more efficient factories, cheaper imports of processed materials from CARICOM states based on imported peanuts will adversely affect the local industry.
Escalating costs of inputs into the production of peanuts.
Local peanut has a high cost per unit of protein compared to protein substitutes.

74

CARDI-PAYNE

The CARDI-Payne variety was selected from a group of some 200 accessions from the United States and ICRISAT collections which were tested against the local variety. The CARDI-Payne (Tifrust 2 or ICG 7886) was considered to have superior yield and processing quality.

The major advantages	The major disadvantages
Higher yield.	Color not accepted by average consumer in its raw state.
Sweeter.	Some reluctance to purchase by some middlemen
Tolerance to leaf spot	Crop requires an additional 14 to 21 days to mature compared to the predominant Valencia variety
Resistance to rust	More difficult to thresh by hand.
Similar production procedure to main variety(Valencia).	
Higher oil content	
Market available through contract farming with main processors.	

PEANUT VARIETIES USED IN JAMAICA

Jamaican peanut industry is based predominantly on the use of the Valencia type peanut. There is very little selection and some processors have been complaining of the small size of the nuts. The Valencia variety, however has an excellent flavor to which the local consumers are familiar.

The variety also matures within 3 months and is adapted to the rain fed conditions on the majority of small farmers holdings.

There has been much interest in other varieties. There have been assessment of many varieties over the years. It was through this process that the CARDI-Payne was selected. An attempt was made to extend the production of CARDI-Payne through the provision of seeds to selected farmers. In one Coop seeds were given through a rotation system. In recent year the CARDI-Payne variety has been used as test crop in a fertilizer trial and this has resulted in more production of this variety. However, the expansion of the CARDI-Payne has not been maintained as previously expected. Among the reasons for non-expansion may the a number of the disadvantages of the CARDI-Payne shown above.

A larger seeded variety that has been successfully grown in commercial plot sizes with complete mechanization is the NC 2. This is a larger peanut which is suitable for the snack food sector. Currently several varieties including KIDANG, NC2, NC7, and ICG selections sourced out of Belize are being held for multiplication and further testing. The cultivars include several jumbo sized peanuts.

PRELIMINARY FINDINGS FROM SOCIO-ECONOMIC STUDY

The socio-economic survey was carried out in the parish of St. Elizabeth where the bulk of peanuts are produced. Interviews were carried out in 60 districts. The main objectives of the study were:

4) Assessment of resource (land, labor, capital) availability and utilization of off-farm income
2) Social and economic constraints at each stage of the production and post-harvest stages.
3) Costs of production, storage and disposal.
4) Levels of technical competence, actual use of different techniques.

Profile of St. Elizabeth peanut farmer

Seventy percent of the farmers are male. Some 70% of peanut farmers live within 1.5 km of their peanut farm where they travel mainly by walking. Some 40% of the farmers are over 50 years old and 33% are below 40 years old. Some 56% of farmers completed

primary school education, 27% did not complete primary school, 7% attended secondary school, and only 3% had a tertiary level education.

Farm labor

Labor shortage is a major problem as the majority of farming activities are done manually. The farmer is generally full time whereas 10-20% of relatives spend 1-3 days on the farm generally at critical times. Labor is generally hired to do critical operations such as: planting, molding, weeding, harvesting and threshing.

Land cultivated and land tenure

The amount of land cultivated by the farmers is summarized below:

Area(ha)	Percent
<0.40	10.0
0.4 - 0.8	46.5
0.8 - 2.0	30.4
2.0 - 4.0	9.0
>4.0	1.0

The data show that more than 80% of the farmers farmed less than 2 hectares of land. The small size of the farm is a serious limitation to potential income from crop protection.

In terms of land tenure 11.2% owned their land whereas 24.7 % occupied family land. Leased land from government accounted for 34.3%. Land leased from others accounted for 15.7% and rented land was 9%. There is hence no secure tenure for more than 80% of the land occupied by the farmers. there is further limitation to sustainable soil management.

77

Amount of land in peanuts

Area(ha)	Percent
<0.40	24.0
0.4 - 0.8	49.7
0.8 - 2.0	15.4
2.0 - 4.0	1.0

As shown in the data above more indicate that more than 70% of the peanut farmers have less than one hectare cultivated to peanut in any season. It is hence a typical subsistence crop.

Land clearing and soil tillage

Land clearing is done by hand particularly on small holdings. Hand tools for land clearing were used by 85.9% of the farmers whereas chemicals were used by 24.4%. It was surprising that power tools were used for land clearing by only 4.5% of farmers. Land clearing by tractors is considered low as generally the weeds would be buried during ploughing instead of being brush cut prior to land preparation.

Land preparation was done predominantly (74.7%) by tractor. However hand tools were used for tillage on 17.3% of the farms. Animal drawn equipment was used by 12.2% of the farmers. Farmers reported the use of the donkey and mule on 20.8% and 24.7% respectively on the farms. The cost of tillage varied from $120 to $6400. These costs are in contrast to those produced in a recent report from ILCA (1994) shown in Table 1.

Planting

The planting of peanut is invariably done by hand as there are few planters available to the farmers. Planting in rows was done by 66% of the farms whereas 23.7% broadcasted the seeds. Broadcasting is a faster operation as the covering of the seeds is done by the tractor in the final harrowing. In some locations branches were pulled over the soil to ensure seed coverage. Broadcasting however does not allow for molding and inter-row cultivation. It does not allow harvesting by a peanut lifter.

Of the tools used the farmer owned some 60.3% whereas groups held 9.9% and private contractors held a further 5.1%. Of the power tools, only 9.6% were owned by the farmer.

The survey also showed that some 28.5% of farmers considered that it takes one man-day to shell a bushel of peanuts by hand while some 18.9% considered the time to be 2 days. This is in contrast to the use of the electric sheller which took only 5 minutes to shell a bushel.

Seeds and varieties

Some 79.8% of farmers save their own seeds for planting. Of the remainder 9.9% obtained seeds from fellow farmers. Valencia was the variety planted on 79.5% of the farms whereas less than 1% of the farmers interviewed planted CARDI-Payne alone. Some planted both varieties. Some 14.4% of farmers knew of only the Valencia variety whereas 6.7% considered the ready availability of seeds of the Valencia and shorter growing season as other reasons for its use. Some characteristics of the Valencia and CARDI-Payne peanut varieties is shown in Table 2.

Farmers planting CARDI-Payne grew the crop because of its marketability through processors (37.8%) and the taste (7.7%). The major reason (71.2%) for planting peanuts was for the source of income it provided.

Fertilizer use:

Several types of fertilizer grades were used in the production of peanuts in St. Elizabeth shown below.

Some 73.7% of the farmers applied fertilizer to at least 0.2 ha of land. During the last crop grades 11-11-11; 14-28-14; 7-14-25 were used by 28.5%, 28.5% and 1.9% respectively. Organic matter was used by few farmers.

Table 1: Cost of production and returns from one hectare of peanuts 1994 (ILCA, 1994).

A: Gross income		1200kg @ $80 =	$96 000
Variable cost			
Land clearing	25md	$200	$5000
Forking	25md	$200	$5000
Draining	5md	$200	$1000
Direct planting	13md	$200	$2600
Fertilizer application	3md	$200	$600
Weed and mold	25md	$200	$5000
Weeding	25md	$200	$5000
Pesticide application	5md	$200	$1000
Harvesting	10md	$200	$2000
B: Total labor		136	$27 200
Input costs			
Seeds	112kg	$80	$8960
Fertilizer (NPK)	1000kg	$5 /kg	$5000
Insecticide	41itre	$400/l	$1600
Fungicide	7kg	$100	$700
C Total inputs			$16 260
D Total variable cost			$43 460
E Return to farmers			$52 540
US$1 = J$35			

Table 2: Characteristics of Valencia and CARDI-Payne peanut varieties grown in Jamaica

Descriptor	Variety	
	Valencia	CARDI-Payne
Market Type	Valencia	Spanish/Valencia
Growth habit	Bunch	Erect bunch
Testa color	Red	Cream
Seed size (g/100 seeds)	40-47	50-54
seeds/pod	3	3
Shell-out (%)	75	73
Seed oil content	Low	Moderate
Seed dormancy	None	None
Disease resistance		
Rust	Low	Good
Leaf spot	Low	Low
Yield potential(kg/ha)	2000-2500	2500-3000
Maturity period (days)	90-100	115-125
Market suitability	Snack nut	Processing
		(Adapted from Cooper 1993)

Fertilizer

Fertilizer grade	% farmers using grade
11-11 - 11	37.5
14-28-14	34.6
7-14-25	1.6
AmSul	1. 0
Organic manure	1. 0
6-18-27	0.6
11-22-22 + OM	0.3

81

Credit

Credit for peanut cultivation was not popular. Some 68.9% never use credit whereas 4.2% used it rarely and 19.2 % used credit only occasionally. Where credit was used 17.9% was obtained from a relative or friend. The amounts borrowed was between $100 and $5000.

Post-harvest activity

Some 94.2% of farmers harvested peanut by hand pulling. Threshing was done by hand by the majority of farmers (88.5%). Except for the two threshers operated by Peanut CRSP project, there is only one additional thresher on the island. Threshing was considered to be one of the most arduous task in the production of peanuts. Whereas the threshers are available they can only handle peanuts that have been partially dried. Due to problems with security it is not a very attractive proposition for the average farmer.

Drying was done in the field by some 52% of the farmers. Sheeting on the ground was used by 22.8% whereas bar-be-qua accounted for 3.2%. To reduce praedial larceny and other losses peanuts are generally reaped, threshed and taken home for drying where there is proper supervision.

Shelling

Shelling for planting is done by hand by many small farmers. From the survey 50.6% of farmers do some or all shelling by hand. However 27.6% of farmers used a motorized sheller and 1.6% used a hand operated sheller. Some 14% used a combination of hand and sheller. The sheller is either private or owned or shared by a group. Some farmers felt shellers were too far from their homes or farm. In fact about 50% complained of the unavailability of shellers as a problem and 13% considered unavailability on the farm as a problem. Some 3.5% considered the hand sheller to be difficult to operate. Some farmers refused to use the motorized sheller due to cracking of larger nuts including CARDI-Payne. The lack of electricity in some locations and the inadequate transportation system were also reported as limitations.

Farmers were asked specific questions about the Peanut-CRSP sheller and threshers. Some 24.4% knew about the motorized thresher and 9.3% knew of the pedal operated thresher. The hand sheller was familiar to 7% of farmers interviewed. However some 23.7% of the

farmers do not know about CARDI and 23% did not know about the peanut equipment being evaluated by CARDI. Farmers were willing to pay to have their peanuts threshed, 37.5% would use equipment if they are placed at a central point.

Storage

Bags were used for storage receptacles for peanuts on 80.4% of farms. Various places were used for storing peanuts. The percentages using different locations are shown below:

Place of storage	%using
Special store room	58.7
Kitchen	28.5
Under bed	0.3
Cellar	1.6
Community storage	1.0
Other	9.7

Post harvest problems:

The farmers interviewed reported a number of post harvest problems The main ones are listed as follows:

Marketing	33.3
Removal from field	17.0
Thresh and pick	12.5
Labor availability	9.0
Praedial larceny	4.2
Drying	4.2
Pests	3.5

Post harvest crop protection:

In the case of crop protection 5% of farmers took precautions against rats. Such precautions include the use of rat baits (64.4%) and keeping a cat (56.7%). Precautions against insects included proper drying 42.3%, removal of damage and infested material

83

(27.6%) and airing at intervals. Persons taking no special precautions made up 26.61. Removal of damaged pods was used to control molds.

Cooperatives:

The farmers were in general not too impressed with the idea of cooperatives. Although 24.7% considered cooperatives to be useful, some 4.5% believed that they never work and 6.7% considered that only some benefit. Marketing cooperatives were considered to be worthwhile by 1.3%.

FUTURE OUTLOOK

Market intelligence:

The peanut industry has been plagued by lack of a proper market structure. This has resulted in peaks and troughs with very wide fluctuations and uncertainties. In order to improve the efficiency of the industry it is necessary to develop a sustainable marketing system. In recent times, attempts have been made to establish contract agreements between producers and processors. These arrangements have proven difficult historically as the farmers tend not to live up to their obligations once they can obtain higher prices elsewhere. Table 3 below shows that there has been an increase in production during the past three years.

A recently formed cooperative has also been established for crop production in the main peanut growing area. Inputs are purchased in bulk and training is also done as a group. Collection and marketing of peanuts is an important activity. Members of the group are also interested in the processing and marketing of peanut products.

Product development:

In spite of the extended period that the peanut has been grown in Jamaica it is not widely used in food preparation. Peanut is traditionally consumed as a ball park snack food. Only recently has the peanut been used for a range of food products. Among the main products are: peanut butter, peanut paste, peanut brittle, Other products include ice cream topping, etc. It is currently being used as flavoring in a local weaning food for babies.

It is felt that for the industry to expand there must be greater use of peanuts in the diets of local people. A major deterrent is perhaps the high unit cost of the peanut. To have a sustainable increase in local consumption output will need to be increased. In addition there is the need to consider the following:

Establish link with home economics section of the Rural Agricultural Development Authority (RADA);

Develop packages of recipes for snacks, drinks and main food preparation;

Hold demonstrations and training sessions for farm household;

Dissemination of information through schools, churches other community organizations, the public information service.

CONCLUSION

Peanut is a popular crop grown traditionally by small farmers in Jamaica. It has the potential to give a return of J$50,000 per hectare. Unfortunately most farmers do not achieve this potential due to several limitations. Most farms are small (< 1 ha) and manual labor used is expensive and inefficiently used. The major strengths, weaknesses, opportunities and threats have been reviewed.

A recent socio-economic study has not shown much progress in production over the years. Recently however, peanut production has increased. Several constraints have been noted by the farmers. These include varieties, marketing, cost of inputs and cost and unavailability of mechanical aides. The potential envisaged with the introduction of CARDI-Payne variety have not resulted in meeting the targets previously envisaged.

There is still a future for peanuts in Jamaica if the most limiting of the constraints are addressed in a concerted manner. It is proposed that group production, marketing and ownership of mechanical aides be done to overcome constraints associated with the small size of the farms and the limited resources at the disposal of the farmers. Proposals have been made for improving quality, marketing and product development leading to greater

consumption of peanuts locally as possible avenues for improving efficiency in the industry.

Table 3 : Peanut production in Jamaica 1984-1994 inclusive

Year	Production (000 kg)
1984	2533
1985	3216
1986	2134
1987	2870
1988	1598
1989	2431
1990	1861
1991	2386
1992	4109
1993	4381
1994	4257

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New Varieties for U.S. Production

O. D. Smith[1]

INTRODUCTION

Thomas Jefferson said "The greatest service that can be rendered to any country is to add a useful plant to its culture". The development of new plants, improved varieties, is a principal focus of the Peanut CRSP breeding projects. However, for the addition of a new cultivar to a country's culture important criteria must be met. These criteria, in summary, are that the new candivar (candidate cultivar) be better than currently available cultivars in one or more important genetic traits, without producing undue risk of detriment in other characteristics. Often, the addition of useful new traits is not the most difficult aspect to attain; the difficulty is equaling current varieties in other aspects while adding the new trait.

Peanut CRSP has been a partner in the evaluation and release of four varieties in Texas and North Carolina since 1982. Initial efforts for the development of all four U.S. varieties selected, evaluated, and increased with the assistance of Peanut CRSP was initiated prior to 1982. Seldom can a peanut breeding effort initiate, develop, increase, and put into significant commercial use a variety in less than 12 years. An optimistic flow chart giving generations and years for the development of a new peanut variety might be visualized as follows:

[1] Texas A & M University, College Station, TX

Activity	Generations	Years
Parent selection	1+	1+
Hybridization & generation advance	2-4	2-3
Selection & evaluation	4-6	3-5
Seed increase and release	4	3

All of the activities listed, particularly the first three, are often extended. With good research, luck, and some risk, overlap of activities can be effected if lines appear with superior potential. Thus, the duration of Peanut CRSP is now entering the phase when significant payoff from cultivar development could be expected.

Criteria for the release of the aforementioned cultivars for each of the two states were as follows:

Texas

Tamrun 88 - high grade runner, rapid emergence, good yield.

Tamspan 90 - high yielding Spanish, useful resistance to sclerotinia blight and pythium pod rot.

North Carolina

NC 10C - Superior pod and seed traits, improved milling quality, longer shelf life, improved flavor, useful resistance to Cylindrocladium blackrot.

NCV-11 - High yield, high value per acre (3 - 11% greater than Florigiant, NC 7 and NC 9).

Example of the benefit from the release of these varieties can be demonstrated by the performance of the Spanish cultivar Tamspan 90. Tamspan 90 was released in 1990, some 13 years following the cross and 11 years following its initial selection. Yield data used in justifying its release included 22 test, three-year comparisons with the popular Spanish peanut cultivar "Starr". The basis for the average 11% increase in

98

value per acre for Tamspan 90 compared to Starr, using USDA peanut loan rates are shown in Figure 1. Of greater magnitude has been the benefit of Tamspan 90 in production areas plagued with sclerotinia blight caused by *Sclerotinia minor*.

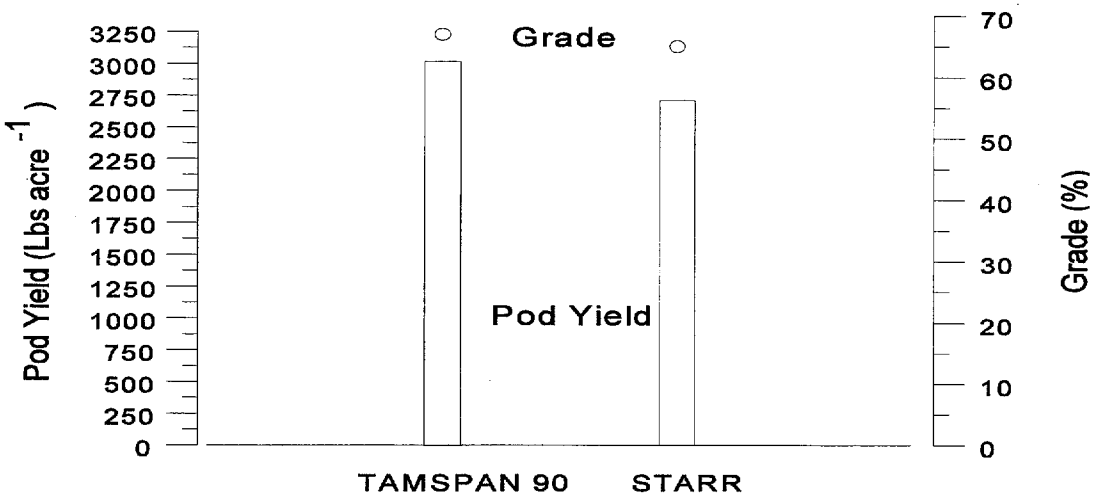

Figure 1. Tamspan 90 vs. Starr. 3 Years: 22 Tests.

Sclerotinia blight is a soilborne disease first recognized as an important production constraint in the Southwest U.S.A. production region in the mid-1980's. Once introduced into a soil, the organism persists for years and satisfactory means for its elimination is unknown. The fungus attacks pods, pegs, stems, and other plant parts in contact with the soil surface. The fungus is spread by infected plant tissue and small black colored sclerotia that are about the size of mouse feces. Sclerotia are found in abundance on plant part surfaces, inside and on pods and stems, and at low frequencies on or inside the seed. The persistence of the sclerotia are such that viable propagules can survive the digestive tracts of animals and birds that ingest the sclerotia through feeding. All commercial Spanish and runner cultivars, except Tamspan 90, available through 1994 were susceptible to the disease. Methods of chemical control are expensive and generally unsatisfactory. Crop losses to the disease in the Southwest region alone have totaled to millions of dollars annually.

In Figure 2 are shown comparative average pod yields and disease scores for Tamspan 90 and Florunner, one of the better performing runner varieties under disease pressure. Consistent yield and disease score differences are exemplified for each of the five trials represented. The impact

89

of the variety has been no less dramatic under commercial culture. Yield differences between Tamspan 90 and popular runner varieties of a ton/acre have been reported by reliable growers and agricultural extension personnel. An average yield advantage of 1,000 lbs./ac on sclerotinia infested land was projected by state extension agronomists in both Texas and Oklahoma. The impact of such yield differences is noteworthy.

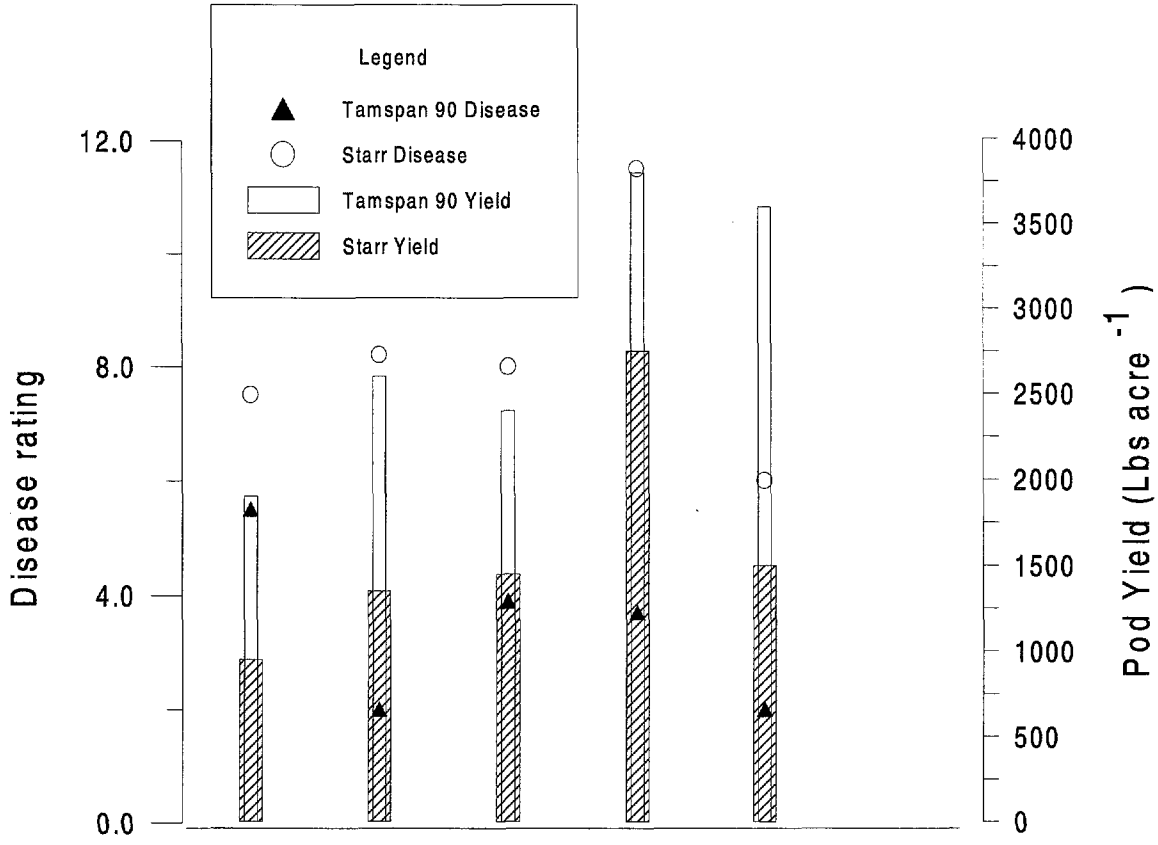

Figure 2. Tamspan 90 vs. Florunner. Sclerotinia Disease and Pod Yield. 3 Years : 5 Tests.

Agricultural extension service personnel in Texas and Oklahoma have derived estimates of production by variety in each of the two states. In Texas, Tamspan 90 was estimated to have been grown in 1994 on 31,600 acres, 43% of the Spanish acreage. An estimated 33% (35,000 acres) of the total 1994 Oklahoma peanut acreage was planted to the Spanish variety. Over 50,000 acres of the 60 to 70 thousand acres of sclerotinia infested land in the two states combined were planted to Tamspan 90 in 1994. To envision a conservative estimate of the impact of the variety for the most recent years, an average yield advantage

of 750 lbs. ac^{-1} for 50,000 acres at an average price of $650/ ton was calculated. The calculated impact from first point sales totaled in excess of $12 million for 1994. The multiplicative effect of the increased income to the states economy is beyond my expertise, but it is evident that the total effect is sizable. Additional benefit from the variety will continue to accrue until a better cultivar or other achievement is made to alleviate the loss from sclerotinia disease.

The results from the release of Tamrun 88 are less striking but nonetheless noteworthy. 15% of the 1994 Texas runner peanut acreage in 1994 was attributed to Tamrun 88. Using comparative yield test plot data, the increase in value per acre of production, based on USDA program rates, totaled to one million dollars.

Benefits for the other varieties could be projected. Hence, the investment in variety development has brought good dividends.

As noted earlier, parent selections and hybridizations for the aforementioned varieties were made prior to the inception of Peanut CRSP. The potential benefit from oncoming varieties is brighter than those of the past. I refer in Texas to the progress in development of runner-type varieties with useful resistance to sclerotinia blight and tomato spotted wilt virus. Comparative data on value per acre and disease scores for Florunner and promising runner-type breeding lines into which sclerotinia resistance has been incorporated from Tamspan 90 are shown in Table 1. Industry demand for runner peanuts greatly exceeds that of Spanish, and the sclerotinia infested acreage continues to increase. The potential impact of one or more of these lines, if approved for variety status, is evident. Significant impact can also be projected from the release of recently developed breeding lines with partial resistance to tomato spotted wilt virus. Major losses occurred in 1994 on some 30,000 acres of peanuts in South Texas from this virus, and spread of the virus to Central Texas and southeastern states continues. Partial resistance to the disease is available in the variety Southern Runner but industry acceptance of this variety has been poor. The yield benefits of selected lines in 1994 South Texas tests are shown in Tables 2 and 3. Seed increase has been initiated in prospect of release of one of the breeding -lines. Encouragement for rapid increase is strong among growers.

In summary, Peanut CRSP has been a positive force in the testing and release of four U.S. peanut varieties that have had significant economic impact for this country. Funds allocated to this effort have been a good investment. Optimism is high that the realized benefit will be much greater with the early release of candidate varieties that are now in late stages of development and seed increase.

Table 1. Data for selected entries under sclerotinia disease pressure at Stephenville, Texas - 1994.

Variety/Line	Pod Yield ($kg.\ ha^{-1}$)	TSMK (%)	Seed Weight (g/100)	Disease [1]
Tx901338-2	2384 a*	61 c	54.9 ab	0.3 c
Tx901269-2	2164 a	73 a	56.4 a	4.7 b
Tx901550-2	1765 b	70 ab	53.3 ab	4.3 b
Tamspan 90	1768 b	68 b	40.7 c	3.3 b
Florunner	1235 c	67 b	50.2 b	11.7 a

* Means within columns bordered by same letter are not different (P=0.5).

[1] Number of disease "hits" per plot.

Table 2. Data for selected breeding lines and checks in Frio County, Texas SWV#1 with spotted wilt virus - 1994.

Variety/Line	Pod Yield (kg. ha^{-1})	TSMK (%)	Disease (%)
Tx896100	1944 a *	75 ns	29 c
Tx901305	1538 bc	75	34 c
Tx901646	1453 bc	74	25 c
So.Runner	1335 bc	73	40 bc
Florunner	1282 bc	74	52 b
Tamrun 88	1116 c	74	73 a

* Means bordered by the same letter are not different (P=0.05).

Table 3. Data for selected breeding lines and checks in Frio County, Texas SWV#3 with spotted wilt virus - 1994.

Variety/Line	Pod Yield (kg. ha^{-1})	TSMK (%)	Disease (%)
Tx935389	2446 a*	76 ns	38 b
Tx935411	2335 ab	76	17 c
Tx935409	2115 a	77	18 c
So.Runner	1647 c	75	27 bc
Florunner	1606 c	73	56 a

*Means bordered by the same letter are not different (P=0.05).

93

Impact of Funding from Peanut CRSP on Technology Exchange and Management of Two Economically Important Peanut Viruses'

D. V. R. Reddy [1], J. W. Demski [2]

INTRODUCTION

In this paper we describe how funding from Peanut Collaborative Research Support Program (Peanut CRSP) has helped in achieving technology exchange and served as the base for research to formulate management practices for two economically important peanut virus diseases, groundnut rosette and peanut stripe.

The rosette disease of peanut was reported in 1907 from Tanzania. It is the most destructive disease of peanut in Africa. Many epidemics due to rosette have been reported from Africa. The major epidemic occurred in Nigeria in 1975, when rosette disease affected over 1 million hectares of groundnut and caused yield losses estimated at over 250 million U.S. dollars in Nigeria alone. Prior to 1982 precise nature of the causal agents of rosette disease was not known although involvement of more than one virus was suspected. Since most countries where rosette disease occurred did not have fully equipped virus laboratories and trained man power it was considered essential, for effective research on rosette disease, to establish cooperative links with plant virus research units in technically advanced countries where peanut was not grown. Therefore with support from the Peanut CRSP a meeting was held in 1983 in the University of Georgia at Griffin. It was attended by scientists representing Peanut CRSP, national agricultural research systems (NARS) in Africa, ICRISAT, and Germany. The main objective of the group meeting was to formulate a work plan for investigating the causal agents of rosette disease. Each group

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94

was given a specific aspect to investigate. The U. S. Scientists with funding from Peanut CRSP investigated the mechanical transmission of one of the causal agents of rosette disease.

They reported a consistent mechanical transmission of the symptoms - inducing component. Additionally, Peanut CRSP funds were used to assist the group in Germany in the identification of luteovirus particles from field collected diseased plants. The absence of luteovirus partially in mechanically transmitted plants confirmed the complex nature of etiology of rosette disease and laid the foundation for future research on groundnut rosette at the Scottish Crop Research Institute. Rosette disease has been shown to be caused by a complex of two viruses and a satellite RNA. Diagnostic aids have been produced for all components facilitating detailed epidemiological studies. This would facilitate identification of sources of infection from which the initial spread of the virus occurs and the determination of conditions favoring the multiplication and movement of the aphid vector. It would be possible to standardize methods for monitoring aphids for the presence of all the components of rosette disease involved in the etiology. Reports of the occurrence of rosette disease from Argentina, Philippines, India, Indonesia, Myanmar, and Fiji islands are now discounted as a result of progress made on the identification of the causal agents of rosette disease. It has now become feasible to evaluate the rosette resistant genotypes to all components involved in etiology. The need to identify sources resistant to the luteovirus is critical. Future research on breeding for rosette resistance will focus on the development of high-yield short-duration genotypes with rosette resistance preferably to the luteovirus component.

Peanut stripe virus (PStV) was first observed in 1982 in peanut germplasm imported into the U.S. from the People's Republic of China. It was indeed a fortuitous coincidence that funds from Peanut CRSP became available to undertake work on the newly discovered virus. We give below various aspects as a result of support from Peanut CRSP:

* PStV was fully characterized and diagnostic aids developed. Frequency of PStV seed transmission was determined and a non-destructive seed testing procedures developed.

* Distribution in the USA was studied and its presence in the major institutional productions was discovered.

* Diagnostic aids were used for surveys in south Asia and southeast Asia and as a result it was shown that PStV was by far the most widely distributed of all the peanut viruses.

* An international working group to coordinate research on PStV was formed in 1987. At the second meeting of this group, it was recommended that the group should coordinate research on all economically important viruses in the Asia-Pacific region.

* Supported all the meetings of the International Working Group on Peanut Viruses in the Asia-Pacific region, publication of proceedings of these meetings, and all technology transfer activities organized in conjunction with these meetings.

* Supported research which culminated into adoption or recommendation of series of measure to contain the spread of PStV. These included monitoring of breeding lines in institutional productions, training of personnel in plant quarantine, and rigorous testing of seed originating from countries where PStV is known to be endemic.

CONCLUSIONS

Peanut CRSP provided the impetus for the formation of the first International Working Group on Peanut Viruses in Africa and subsequently to the second Working Group on Peanut Viruses in the Asia-Pacific region. Peanut CRSP also took initiative, and provided technical and financial support to all major technology transfer activities undertaken till now, to the scientists in NARS, on the diagnosis and management of peanut viruses. Indeed the economic value of the outcome of funding provided by the Peanut CRSP is several fold greater than the funds provided.

Precise distribution of groundnut rosette disease is known. As a result of the availability of diagnostic aids it is now possible to monitor breeding lines for all the components

96

involved in the etiology of rosette disease and for studying the epidemiology. Various measures can now be suggested for the exchange, within and between countries, of peanut germplasm free of PStV. Additionally these measures are valuable for formulating guidelines for the import and export a virus-free germplasm and for preventing the virus spread within a country.

Peanut CRSP sponsored publication of many information bulletins and proceedings of the Working Group meetings. Significant ones among the publications are Information Bulletin on PStV and proceedings of meetings of three Working Groups, held in Dundee, Scotland in 1993.

The approach to find solutions to problems by the formation of Working Groups led to the identification of priorities, development of research techniques, identification of tasks to each of the teams based on their resources and technical skills, organization of technology transfer activities, and economy in utilization of resources avoid expensive duplication.

Accomplishments by the two international working groups on groundnut viruses have led to the formation of several such groups, for example the one on bacterial wilt of groundnut. McDonald and Gibbons (in this issue) described this concept as a "remarkable example of cooperative research". The impact made by the Working Groups was given its various publications sponsored by Peanut CRSP.

In the future, in addition to continuing the funding for the activities supported in the past, we expect that the following important activities will also receive support:

* To provide for the requirements to generate large scale production of diagnostic aids.

* To support research on epidemiology, targeted to provide integrated management practices.

* to support research on incorporation of resistance to viruses, especially by non-conventional methods.

Monitoring network to survey food products for aflatoxin in the Philippines

V. V. Garcia[1] and L. R. Beuchat[2]

INTRODUCTION

Rodents, insects and fungi cause immeasurable food losses in agricultural commodities in developing countries. Rodents and insects show the more obvious damage but the role of fungi in the loss of stored products cannot be ignored. Cereals and grain legumes must be stored dry to prevent the growth of fungi. If these commodities are not stored correctly (e.g., improperly dried, high temperature and humidity, inadequate protection, etc.), fungi will grow. The growth of fungi should be avoided for it will result in impairment of both food value and processing quality; and worst, the possible production of mycotoxins. Mycotoxins have attracted global attention because of their adverse effects on health and negative economic impact.

THE AFLATOXIN PROBLEM IN THE PHILIPPINES

Among the mycotoxins, aflatoxin has received the most attention in the Philippines. In 1967 Dr. R. W. Engel of Virginia Polytechnic Institute analyzed and found aflatoxin in peanuts and peanut butter produced in the Philippines. Through his efforts, the first aflatoxin laboratory was established at the Food and Nutrition Research Center (now FNRI) through a grant from the U.S. Agency for International Development (USAID). Dr. T. C. Campbell was assigned to the Philippines to assist in the establishment of the laboratory and the training of analysts.

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Aflatoxin surveillance and monitoring in food and feeds were conducted by the FNRI from 1967 to 1982 and by Santamaria et al. (1972) to determine which of the agricultural commodities were susceptible to aflatoxin contamination. The results showed that corn, peanuts, dry beans and copra (dried coconut meat) contain aflatoxin. Corn and peanut products contained high levels of aflatoxin with peanut butter containing as much as 8,600 ppb aflatoxin. Since 1987, researchers from IFST, U. P. Los Baños have been actively doing aflatoxin surveillance studies on peanuts and peanut products through a grant from the Peanut Collaborative Research Support Program (CRSP) administered by the University of Georgia (Table 1).

These results were validated/confirmed by the Bureau of Food and Drugs (BFAD), Department of Health. From August 1992 to January 1993, BFAD ordered nine (9) peanut butter manufacturers to withdraw/recall their products from the shelves. They were also ordered to suspend sales until the new batches of their products contained less than 20 ppb of aflatoxin. One company was reported to have shut down instead of complying with BFAD's consumer protection requirements.

Table 1. Aflatoxin surveillance of peanuts/products in the Philippines.

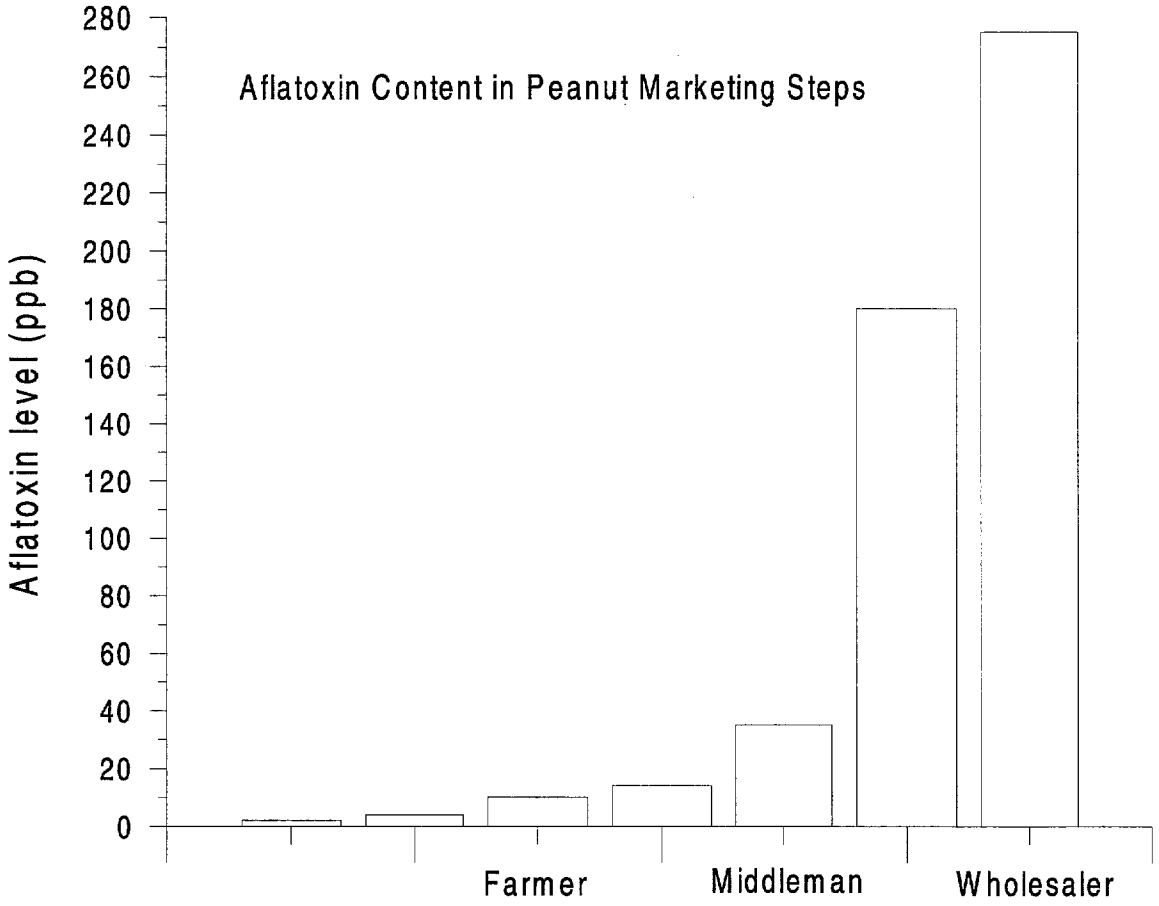
Sample	% of samples aflatoxin positive	Source
Peanuts seeds	80%	Campbell and Stoloff, 1974
Peanut Butter	91%	
Peanut Candies	78%	
Peanut/peanut products (1036)[1]	62%	FNRI aflatoxin surveillance (1967 - 1982)
Peanut seeds (57)	58%	UPLB - Peanut CRSP aflatoxin surveillance (1987-88)
Peanut products (82)	27%	
Peanut seeds (26)	36%	UPLB - Peanut CRSP aflatoxin surveillance (1988-90)
Peanut products (82)	27%	
Peanut products (66)	14%	
Peanut butter (15 brands, 3 samplings)	47%	UPLB - Peanut CRSP aflatoxin surveillance (1991-92)
Peanut products	27%	
Peanut candies	ND[2]	

()[1] - number of samples analyzed
ND - none detected

Studies at the National Postharvest Institute for Research and Extension (NAPHIRE) showed that peanuts at harvest contained very low levels of aflatoxin. Slow drying of peanuts in the field was responsible for the increase of aflatoxin. Because farmers do not dry peanuts adequately before they are stored or sold to the traders, aflatoxin increases significantly in the food marketing chain (Figure 1) (Quitco et al., 1989).

100

Figure 1. The evolution of aflatoxin contamination in Philippine peanuts.



ESTABLISHMENT OF THE PROPOSED NETWORK

Since aflatoxin contamination of cereals and grain legumes is a serious problem in the Philippines, there is a pressing need to educate/increase awareness among farmers, traders, processors, and consumers regarding aflatoxin and its health risk. Success in preventing aflatoxin contamination of agricultural commodities will result in safe-quality, processed foods and more economic benefits to farmers, processors and consumers. Each and every sector of society should cooperate with each other and the government in solving the aflatoxin problem.

At present, there are other government regulatory agencies which also perform monitoring and surveillance of aflatoxin on specific commodities. These include the Philippine Coconut Authority (PCA) on coconut products and its by-products; the National Food Authority (NFA) and the Bureau of Plant Industry (BPI) on cereals and legumes; and the Bureau of Animal Industry (BAI) on feeds.

Researchers from government agencies and academe also conduct studies on aflatoxin in peanuts, corn and copra (NAPHIRE, 1989; Garcia, 1992; UCAP, 1989); microbial control of aflatoxin (Mabesa, 1991; Divina, 1995); chemical detoxification (Mercado et al., 1991); and field test method development for aflatoxin (FNRI, 1992). Likewise, manufacturers of peanut butter and other peanut
and corn-based products monitor raw materials and processed foods for aflatoxin.

Inspite of the large amount of information on aflatoxigenic fungi and aflatoxin, the seriousness of the problem in agricultural crops and in foods and feeds have not been appreciated. There is a lack of awareness among farmers, traders, processors and consumers regarding aflatoxin and its potential risk to human and animal health. Regulatory controls cover only selected agricultural crops. In addition, research findings are not fully utilized because they are not well disseminated/tested even among researchers working on aflatoxin.

In February 1993, a National Seminar-Workshop on an Integrated Control Program for Fungi and Mycotoxins was held at University of the Philippines-Diliman, Philippines with the following objectives:

5. To provide a situational analysis of fungi/mycotoxin related activities in the Philippines,
6. To identify priority problems (R & D and research utilization) and
7. To identify mechanism(s) for an efficient coordination and information network among the public and private sectors who will be involved in implementation.

Two of the resolutions agreed upon by the participants in that workshops were:

1. To harmonize related researches/studies on aflatoxin and other mycotoxins; and

2. To formulate a national science based collaborative multi-disciplinary action program.

The participants recognized the need for networking as a mechanism to pursue more vigorous collaborative undertakings in aflatoxin related problems.

The proposed network will pursue three activities:

a. Monitoring and Regulation
b. Research and Development, and
c. Technology Transfer, Education, and Information

The networking will initially focus on aflatoxin. The network will involve the NFA, NAPHIRE, and BPI (all from the Department of Agriculture) which will monitor raw materials from the farmers field to the food manufacturers; the BFAD, in monitoring and regulatory activities of processed foods; and UPLB, in research and development activities (to include aflatoxin surveillance).

Department of Health (DOH), Agriculture (DA)
and Science and Technology (DOST)

INTER-AGENCY COMMITTEE ON AFLATOXIN
AND OTHER MYCOTOXINS

Technology Transfer, Education and Information	Research and Development (R&D)	Monitoring and Regulation (M&R)
FNRI/other	FNRI	BFAD (food)
DOST RDIs	NAPHIRE	NFA/BPI (grains)
UPLB/other SCUs	UPLB/other SCUs	BAI (feeds)
M&R agencies	M&R agencies	
Private Sector	Private Sector	Private Sector

Figure 2. Organizational Structure Of The Interagency Committee

103

The networking is needed for effective dissemination of information and training of personnel at the national level. The network must include the creation of a data base for documenting and dissemination of information. Inter- and intra-laboratory collaborative studies on aflatoxin should be a part of the quality assurance system to ensure confidence among consumers and buyers in the safety of raw materials and processed foods and also among laboratory personnel engaged in the analysis of mycotoxins. Training of personnel involved in control measures and analysts is needed at the national and regional levels.

ACKNOWLEDGMENT

The authors are especially grateful to the USAID supported Peanut Collaborative Research Support Program (CRSP), for the financial assistance granted to the food technology project being implemented by the University of the Philippines, Los Baños and the University of Georgia.

Appreciation is also extended to Dr. R. R. del Rosario. Dr. R. C. Mabesa and our research personnel, for their active participation in the implementation of the project.

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Detection and Detoxification of Aflatoxin-Contaminated Food Products

Timothy D. Phillips[1]

INTRODUCTION

Overview

Recent concerns about the quality and safety of foods have invoked a growing awareness of the significant dangers associated with food-borne poisons. Many of these poisons (including the aflatoxins, which are remarkably potent carcinogens), have been strongly implicated as chemical progenitors of disease and death in man and animals. Consequently, protection from these hazardous food chemicals is a critical issue. Following the discovery at Texas A&M University that diverse inorganic absorbents, including numerous clay and zeolitic minerals, could be utilized (and/or modified) to preferentially bind, detect and detoxify the aflatoxins, studies have been ongoing to: I) investigate chemical and biological mechanisms involved in this action, and ii) develop and characterize optimal clay-based technology for the reclamation of aflatoxin-contaminated grains and prevention of aflatoxicosis. Targeted research has resulted in the development of **two viable products:**

1) a simple, field-practical testing device for aflatoxins and/or complex mixtures of aflatoxins and other mycotoxins in food products and
2) a dietary additive (HSCAS) that protects animals against aflatoxins and greatly diminishes aflatoxin residues in food of animal origin.

Occurrence

The aflatoxins (B,, G,, B2 and G2), which are produced as frequent contaminants of foods by ubiquitous fungi of the genus *Aspergillus,* are the most potent, naturally-occurring carcinogens yet discovered (Figure 1); every year a significant percentage of the world's grain and oil seed supply is contaminated with these poisons (Council for Agricultural Science and Technology (CAST) (1989)).. Unfortunately, it is not always practical to discontinue the feeding of contaminated grain,

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especially in situations where alternate feedstuffs are not readily available. Thus, aflatoxins are frequently detected in animal feeds and result in major economic losses to the poultry and livestock industries. Unfortunately, the scope of the problem is much broader. Dairy animals can secrete carcinogenic aflatoxins (such as Aflvl,) in their milk following the ingestion of AfB, contaminated feed (van Egmond HP, 1994). Aflatoxins are heat stable and survive a variety of food processing procedures. They are commonly found as contaminants of food destined for human consumption, including peanut butter and other peanut products, breakfast cereals, cornmeal, dairy products, figs, various oilseeds, spices, and tortillas, etc. (CAST, 1989). In light of these findings, it is clear that practical and effective strategies for the rapid detection and detoxification of aflatoxin-contaminated foods are critically needed.

FIELD-PRACTICAL DETECTION OF AFLATOXINS

The development of simple, rapid and inexpensive screening tests for aflatoxins in crops (i.e., black light illumination, methods of thin-layer chromatography, minicolumn chromatography, and diverse immunoassays), has greatly facilitated their control via more effective monitoring and surveillance programs that allow for the diversion of contaminated food and feed (CAST, 1989). Currently, very sensitive and selective immunoaffinity assays are the most commonly used in the United States for regulating the aflatoxins. However, a major disadvantage of these immunoassays is that they are solely based on biological systems, and these systems are not stable in field situations that occur in many developing countries that greatly need this capability. Thus, one of our major objectives was to develop a chemically stable, field-practical assay for the rapid detection of aflatoxins.

CSID Assays: Research at Texas A&M University has led to the development of a novel diagnostic concept (Chemiselective Immobilization and Detection, CSID), based on the selective adsorption of aflatoxins at the surface of specially prepared solids. The aflatoxin detector device is constructed in a small tapered glass tube using a critical matrix of adsorbent materials that function to remove interfering substances, selectively immobilize aflatoxins (with high chemical selectivity) at targeted interfaces, and react at these interfaces to produce easily visualized fluorescent bands. The development of CSI detection technology has provided an inexpensive, technically simple, field-practical test that can be used for rapid preliminary screening of crops for the presence of aflatoxin or mixtures of

107

aflatoxins and other mycotoxins. The initial CSID assay for aflatoxins has been evaluated by the U.S. Federal Grain Inspection Service and approved as a screening method in the official FGIS inspection system along with five other aflatoxin test methods, including Afla-20-Cup, Aflatest, Agri-Screen, EZ-Screen, and Oxoid (Koeltzow and Tanner, 1990).

The concept of CSID is based on the separation of reactive (binding) interfaces by use of a non-competing (non-binding) interface. This separation of layers in essence destroys the continuum associated with what is normally considered to be chromatography. CSI detectors for aflatoxins have been developed and tested in collaboration with scientists from Rialdon Diagnostics, TerraTek, Inc. and Senegal, West Africa. The detector has been successfully used for aflatoxins in contaminated samples of peanut, corn, sorghum, wheat, soybean, rice, oats, barley, cottonseed, canola, and mixed feeds. In the current method, 50 g samples (finely ground) are placed into a blender jar, followed by the addition of 100 ml of 80% methanol/water. The jar is covered and the sample is blended at high speed for 1 min. Next, the lid is removed and the solution is allowed to clarify. One ml of clear top layer is transferred into a small vial followed by the addition of 3 ml of water and salt. Three ml of toluene are added, the vial is capped and gently inverted 10 times to mix. After the distinct separation of layers, 1 ml of top layer is added to the opening in the detector and eluted. Two ml of wash solution are then added to the column and eluted with a syringe. The test results are read with a UV lamp. The appearance of a blue fluorescent band at the target interface indicates a positive result (i.e., the sample is contaminated with aflatoxin at concentrations ~ 10-20 ppb, according to the amount of sample extracted) (Figure 2). The CSID-B, assay has been shown to be accurate, user-friendly, rapid (requiring a 15-30 min run time), sensitive, and chemically stable (it does not require refrigeration). These are attributes that make CSID particularly useful for field-screening of crops and assaying food products for aflatoxin contamination. We have recently developed a CSID for the detection of aflatoxin M, in milk at 0.5 ppb, which is the current action level in the U.S. (Cathey *et al.*, 1994). In the CSID-M, method, afM, is selectively adsorbed at the interface of a layer of neutral sand and a band of magnesium silicate packed in the tapered portion of a small glass minicolumn. The observed limit of detection for this assay (Table 1) was 0.2 ppb AfM', which was similar to the limit obtained using an immunoaffinity column (0.3 ppb AfM'). CSID-M1 was also accurate, with no false

positives or false negatives based on HPLC analysis of milk samples that were contaminated at, above or below the detection limit of 0.2 ppb (Table 2).

TABLE 1. Study of the detection limits of the CSID-M1 procedure, and an immunoaffinity column procedure [2].

AFM_1 Concentration	Method	
(ppb)	CSID-M_1 [3]	Immunoaffinity [3]
0.5	+	+
0.4	+	+
0.3	+	+
0.2	+	-
0.1	-	-
0	-	-

[3] Milk samples at .5, .4, .3, .2, and .1 ppb (parts per billion) were tested. Each sample was run in triplicate, and all 3 results agreed. Positive samples were detected by a blue fluorescence on the detection band.

[2] Vicam Aflatest-10 columns were used for the extraction step. All samples were run in triplicate, and all 3 results agreed.

[3] Results are reported as either positive (+) or negative (-) on the CSID-M1 minicolumn.

TABLE 2. Determination of the accuracy of the CSID-M1 minicolumn method for the detection of AFM1 in milk: comparison with an HPLC method.

Sample	HPLC 1 (ppb)	Minicolumn 2
1	.80	+
2	.30	+
3	.35	+
4	<.01	-
5	.20	+
6	<.01	-
7	.06	-
8	.01	-
9	.03	-
10	.02	-
11	<.01	-
12	.03	-
13	<.01	-
14	.30	+

1 Results are expressed in ppb (parts per billion).

2 Results are reported as either positive (+) or negative (-) for the CSID-M1 minicolumn.

DETOXIFICATION OF AFLATOXINS WITH CLAY

A variety of strategies for the reduction (or detoxification) of aflatoxins in grains and oilseeds have been reported in the scientific literature and recently reviewed (Phillips, Clement, and Park, 1994). These differ markedly in their practicality and effectiveness. A novel strategy, based on processed phyllosilicate clay (e.g., HSCAS) that selectively binds and inactivates aflatoxins in the gastrointestinal tract of animals, has been developed in my laboratory at Texas A&M University. Various applications of this clay-based technology have been evaluated in collaboration with scientists at Texas A&M University, USDA/ARS and in Senegal, West Africa.

Chemical Structure:

hyllosilicate clays (such as HSCAS) are composed of layer lattice silicates and chain silicates with repeating layers (or chains) of: 1) divalent or trivalent cations (e.g., aluminas) held in octahedral coordination with oxygens and hydroxyls, and 2) silicas that are tetrahedrally coordinated with oxygens and hydroxyls.

Other than structural morphology, these clays can be delineated by important functional properties including: surface density and swelling ability; cation exchange capacity; dominant exchangeable cation; pore volume and diameter; surface catalysis; and ligand binding.

Applications:

These and other clays (as well as chemically modified clays) have been used for a variety of purposes in agriculture and industry. Since earliest recorded history, the Chinese, Egyptians, Greeks and Romans were well-aware of the numerous properties of clay and zeolitic minerals. In many instances, animals and humans have been shown to eat clay (geophagy) and the reasons for this behavior are not readily apparent. Macaws in the Manu National Park in the Amazon region of Southeastern Peru have been reported to eat clay from a riverbank on an almost daily basis. Apparently, some of the seeds that are frequently eaten by the Macaws may contain toxic, bitter chemicals that are adsorbed and inactivated by the clay (Munn, 1994). Humans (particularly in southern regions of the U.S.) have been reported to eat clay during pregnancy (Loggi , Regenye, and Milles, 1992) and Indians in the high Andes use clay in their diet to counteract bitter wild potatoes (Munn, 1994). Many of these clays possess active binding sites that are capable of selectively and tightly adsorbing various molecules, including the aflatoxins.

Summary of Clay Research:

Our research has shown that HSCAS: 1) tightly binds (or, chemisorbs) aflatoxins in aqueous suspensions, including milk, 2) markedly decreases aflatoxin's uptake by the blood and distribution to target organs such as the liver, 3) protects against the adverse effects of aflatoxin in farm animals, including broiler chicks, turkey poults, lambs, goats, and pigs, and 4) reduces the transmission of aflatoxin M, in milk from lactating dairy goats and cattle (Phillips *et al.*, 1988; Smith *et al.*, 1994).

Capacity and ligand Specificity:

Studies were performed to assess the specificity of the aflatoxin binding process and to determine potential sites and mechanism(s) of chemisorption using methods previously established in our laboratory (Phillips *et al.*, 1988; Sarr, Clement, and Phillips, 1990). The capacity of HSCAS for aflatoxins was determined by adding varying concentrations of aflatoxin to clay in a disposable test tube, followed by mixing and centrifugation. The concentration of aflatoxin from an aliquot of the supernatant was determined with a UV-visible recording spectrophotometer. Maximum binding (BmaX) was determined by plotting the double reciprocal transformation of the following data: amount bound (nmoles of aflatoxin/mg HSCAS) versus concentration of aflatoxin (mM) in the supernatant. BmaX was derived from the calculated y-intercept of the linear regression line through the plot.

Our results indicated that HSCAS had a high capacity for the aflatoxins and binding was a saturable process. Interestingly, HSCAS exhibited more than 2.5 times the capacity for AfB, than AfM,, i.e., 420 nmol of AfB~ versus 156 nmol of AfM, were maximally bound per mg of HSCAS. The only structural difference between AfB, and AfM,, is a hydroxyl group at the 9a position in AfM,. However, this difference in AfM, causes a reduction in carcinogenicity (but not toxicity) by one to two orders of magnitude compared to parent AflB, (van Egmond, 1994). Based on these findings, our binding data with HSCAS are not unexpected. The difference in the capacities of HSCAS for these ligands might be explained by increased size of aflatoxin due to the addition of the hydroxyl group and exclusion from, or decreased access to, active binding sites in the interlayers of HSCAS. Also the hydroxyl group may be positioned to sterically hinder the docking or reaction of aflatoxin with binding sites in HSCAS.

In specificity studies, a variety of ligands containing at least one of three chemical functionalities associated with parent aflatoxin B, (i.e., a dihyrofurofuran, a coumarin, and a cyclopentenone) were tested with HSCAS. These included aflatoxins B,, G,, B2, G2, Q,, P, D,, coumarin, 4-methylumbelliferone, esculetin, xanthotoxin, aflatoxicol I and II, tetra-hydrodeoxyoflatoxin B, and MW compound 206 (from ammoniation). Also, 2 aflatoxin prototypes minus the dihydrofurofuran moiety (i.e., 5,7-dimethoxycyclopenteno[c]coumarin and 5,7-dimethoxycyclopentenon[2,3-c]coumarin) were chemically synthesized and included in the binding experiments (Figures 1, 3A and

112

3B). Test ligands were reacted with HSCAS in vitro and the extent of chemisorption was determined by high pressure liquid chromatographic analysis of extracts of the supernatants and desorbed HSCAS pellets, which were sequentially washed with a series of organic solvents. An index of chemisorption (Cα) was derived from the initial concentration of ligand, the concentration of ligand bound and the concentration of ligand desorbed. Results indicated that AfB, was strongly bound to HSCAS (with a Cα = 0.93). To put this in proper perspective, a Cα = 1.0 indicates total binding, with no desorption of ligand from the HSCAS pellet.

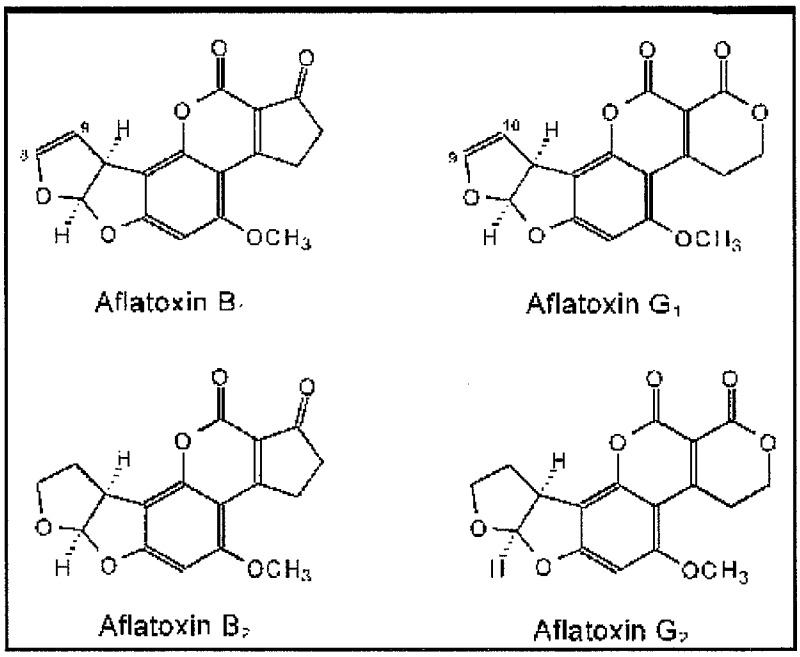

Figure 8:Chemical structures of aflatoxins B', B2, G' and G2

The Cαs for AfQ,, AfP,, AfB2, AfG,, AfG2, and 5,7-dimethyoxycyclopentenon[2,3-c]coumarin (DMC1) ranged from 0.79 to 0.89. Aflatoxicol I and 11, tetrahydrodeoxyaflatoxin B, and 5,7-dimethoxycyclopenteno[c]coumarin (DMC2) were initially bound by HSCAS, but were significantly desorbed by washing. Cαs ranged from 0.17 to 0.43. Aflatoxicol II was not bound as tightly as aflatoxicol 1. Coumarins (i.e., coumarin, 4-methylumbelliferone, esculetin and xanthotoxin) were initially bound, but almost entirely desorbed following washing. The ammoniation products (AfD, and MW 206) exhibited negligible binding to HSCAS (Figure 4). Based on structure-activity relationships, those ligands possessing an intact ,8-dicarbonyl system exhibited the tightest binding to HSCAS. Studies with the synthetic aflatoxin prototypes DMC1 and DMC2 supported these conclusions. DMC1 (which is a prototype of AfB,, minus the bisfuran)

contained the intact p-dicarbonyl system and was bound tightly to HSCAS (Coc = 0.89 vs. 0.93 for AfB,). However, DMC2 (which is a prototype of tetrahydrodeoxyaflatoxin B,, minus the bisfuran) contained only one carbonyl group and was bound less tightly to HSCAS (Coc = 0.17 vs. 0.23 for THDAfB,).

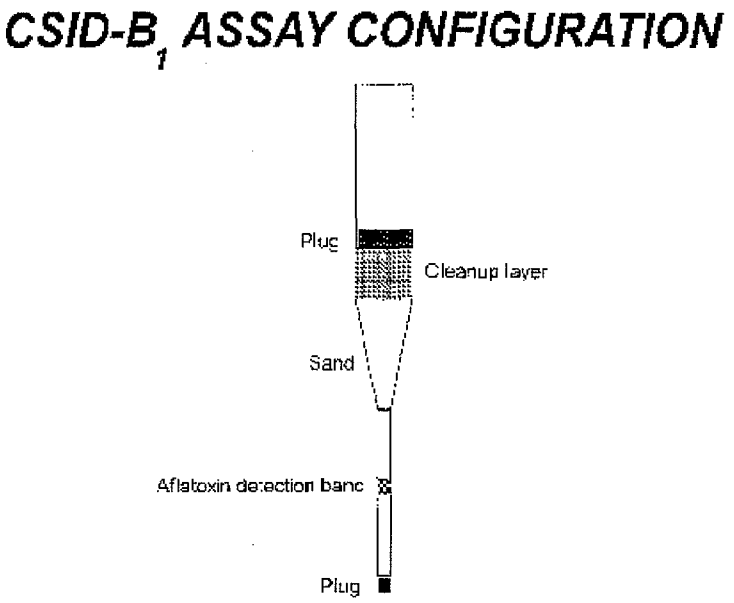

Figure 9: Diagram illustrating the basic configuration of the CSID-B ~ detector. Aflatoxin is visualized as a blue fluorescent band on the column.

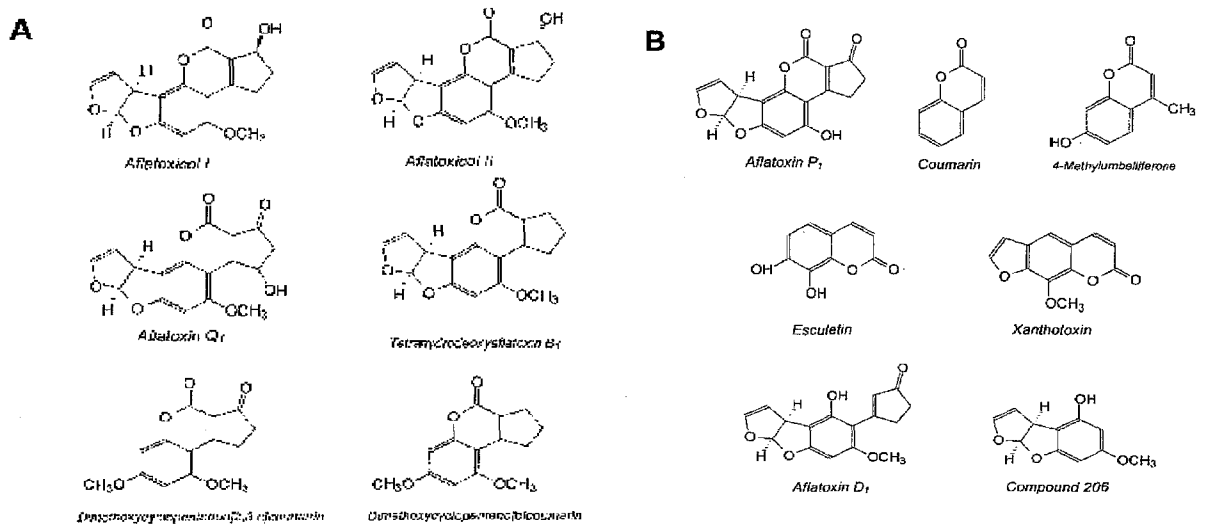

Figure 3: (A and B). Chemical structures of various test ligands used to determine the specificity and mechanism of aflatoxin adsorption by HSCAS.

Mechanism of chemisorption:

114

In further studies the mechanism of aflatoxin binding to HSCAS was investigated using Fourier-Transform (FT) infrared spectroscopy (FTIR). IR spectra were obtained from a direct comparison of "chemisorbed" ligands versus crystalline compounds that were uniformly coated onto the surface of HSCAS. Samples were prepared by blending 1 to 2% of sorbent or sorbent-aflatoxin complex with KCI (99.99% pure) in Sila-Mix (Perkin-Elmer). The powder was placed into the sample well of a diffuse reflectance device and the surface was gently leveled by tapping the well on a smooth surface. The DRIFTS (diffuse reflectance infrared Fouriertransform spectra) were recorded on a Perkin Elmer model 1620 FTIR. DRIFTS analysis yielded a spectrum similar to that of pure AfB,. A broad band between 3600 and 3000 cm^{-1} was attributed to intermolecular hydrogen bonded O-H stretches. An absorption band in the 1700 to 1750 cm~' region was characteristic of C=0 stretches. Upon reaction of AfB' with HSCAS the carbonyl stretching absorption bands disappeared and 2 new bands were observed in the region between 1600 and 1400 cm^{-1} . The disappearance of the carbonyl bands in AfB, following reaction with HSCAS and the appearance of new bands is an indication of the involvement of carbonyl groups in AfB, with the clay. Similar absorption bands in the same region with the formation of metal (Cu2+ Pd2+ or Al3+) acetylacetonates have been observed. It appears that metal ions in HSCAS reacted with the dicarbonyl system in AfB, to form metal chelates responsible for the new bands. The dicarbonyl system of AfB, consists of carbonyls from a lactone and cyclopentenone ring. It is an electron rich system that should readily form chelates with transition metals possessing unfilled d orbitals. Chelate rings formed by the p-dicarbonyl of acetylacetones and metal ions have been previously described as planar and symmetrical, providing strong evidence for the existence of a resonance stabilization of the binding complex (12). The strong binding of AfB, and related ligands (i.e., those containing intact, electron-rich dicarbonyl or dilactone moieties) to HSCAS appears to be related to the formation of a mononuclear (bidentate) chelate with transition metals in the clay. The stability of this complex is further enhanced by the possibility of resonance in the ring (Figure 5).

116

HSCAS - Aflatoxin B_1 Complex

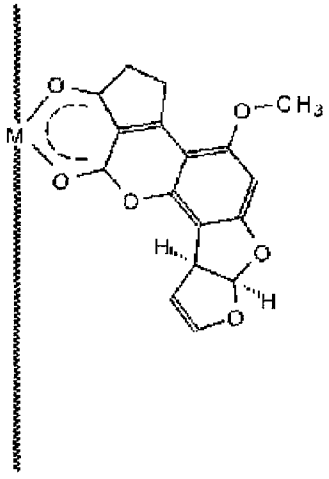

Figure 5 Chemisorption of aflatoxins and related ligands by HSCAS. A chemisorptionindex, or Ca (indicating the strength of binding to HSCAS) was plotted for each ligand (structures are shown in Figures 1, 3A and 3B). Values are equal to means (n = 3)

DISCUSSION

In conclusion, our findings have indicated that HSCAS has a propensity for compounds containing a D-ketolactone or a-bislactone (e.g., aflatoxins B and G series). A proposed mechanism of action of HSCASis the selective tight binding of aflatoxins in the Gl tract of animals resulting in a notable reduction in the bioavailability and toxicity of these poisons. A better understanding of the molecular mechanism(s) responsible for the chemisorption of aflatoxin by HSCAS may lead to the development of diverse clay-based absorbents to modulate the toxicity of mycotoxins and other hazardous food and feedborne chemicals. Further research is warranted to clearly delineate the safety, sites, potential interactions, and chemical mechanisms involved in the action of HSCAS and similar phyllosilicate clays.

116

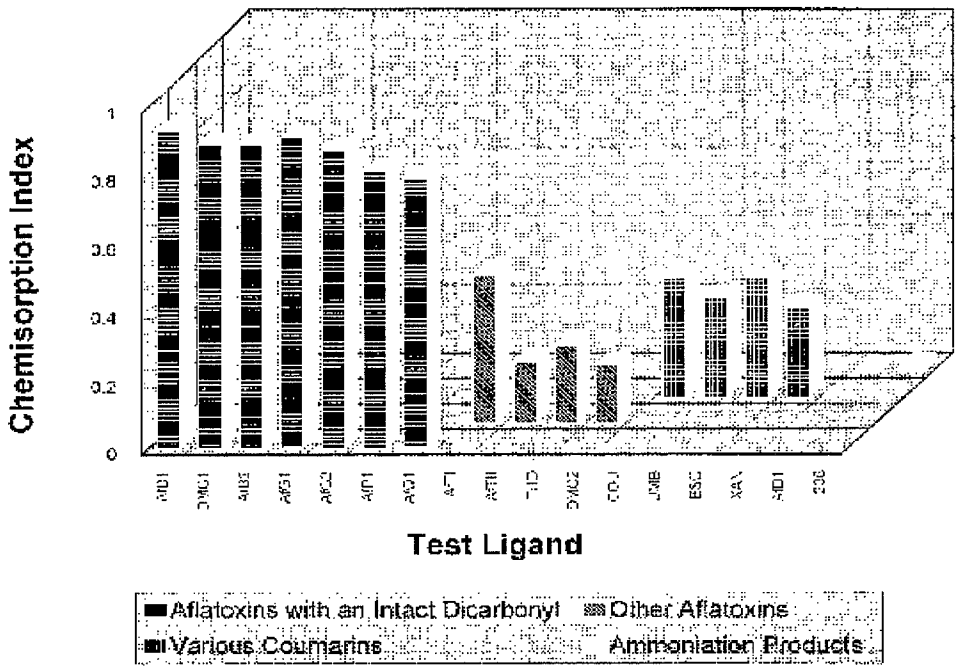

Figure 13 Proposed structure of the HSCAS-AfB, complex, suggesting the formation of a mononuclear, bidentate chelate.

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Breeding Peanuts for Pest Resistance

T.G. Isleib[1]

When uncontrolled in crops, pests such as diseases, nematodes, insects, and other arthropods may cause drastic reductions in yield, quality, and storability. When pests can be controlled through chemical applications, the cost of control directly reduces the grower's profitability. Use of pesticides may also pose a threat to the grower's health, to the environment, and to the desirability of the crop as a food for a pesticide-conscious consuming public. Some pests cannot be controlled by pesticides or cultural practices. For these reasons, resistance to pests is a common objective in plant breeding programs. Development of resistant crop cultivars may eliminate or reduce the need for chemical applications. Controls that are relatively ineffective when used with highly susceptible cultivars may work better with even a partially resistant cultivar. Because growers purchase new seed every year, there is usually no additional cost to the grower when he plants a pest-resistant cultivar. The technology is scale-neutral: small growers can utilize resistant cultivars as readily as larger growers.

In the case of peanuts *(Arachis hypogaea L.)* grown in the USA, few pest-resistant cultivars have been released. This is primarily the result of excellent performance by the private sector in providing growers with highly effective pesticides to control the most common pests in the crop. Another factor is the demand for a nearly perfect raw product in the domestic peanut market. Pods and seeds blemished, darkened or misshapen by disease or insect feeding are unacceptable to the sheller and processor or to the mainstream consumer of whole peanuts. As a result, control of diseases and insects in peanut currently is achieved primarily through intensive use of pesticides. Although there is growing antipathy among the consuming public toward pesticide use in food crops, there has been little willingness on the part of the shelling and processing industries or the consumer to trade perfect produce for reduced pesticide use.

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In order to eliminate pesticides entirely while subject to the regulatory conditions and market forces at play in the 1970's and '80s, the breeder must achieve levels of pest resistance that will provide the same level of pest control currently achieved with pesticides. This is extremely difficult, if not impossible. Pests and their crop hosts exist in a biological equilibrium that can be shifted in one direction or the other but which rarely permits the complete extermination of either pest or host. However, as changes in the regulatory environment and market forces increasingly encourage growers to use fewer pesticides, it may become easier for pest-resistant cultivars to find acceptance in the marketplace.

The pests of primary concern to peanut breeders in the USA have been those for which chemical or cultural control methods are unavailable, ineffective or expensive. These include the soil-borne fungal diseases Cylindrocladium black rot (CBR, C. *parasiticum* Crous, Wingefleld, et Alfenas), Sclerotinia blight *(Sclerotinia minor* Jagger), Southern stem rot *(Sclerotium rolisii* Sacc.), and toxigenic *Aspergillus* species *(A. flavus* Link and *A. parasiticus* Speare). Partial control of CBR is achieved by application of metam sodium, a volatile fumigant injected into the soil several weeks prior to planting. The new fungicide fluazinam promises excellent control of Sclerotinia blight, but fluazinam has not yet reached the market. Foliar diseases of significance in the USA include late leafspot *(Phaeoisariopsis personata.[Berk.* & M.A. Curtisl Arx, syn. *Cercosporidium personatum* [Berk. & M.A. Curtis] Deighton), early leafspot *(Cercospora arachidicola* Hori) and tomato spotted wilt virus (TSWV). Although leafspots are easily controlled by repeated application of fungicides, resistance to leafspots is still considered a worthwhile breeding objective because of the cost and effort required to achieve control with chemicals. There is no known chemical or cultural control for TSWV. Outbreaks of rust *(Puccinia arachidis* Speg.) are rare in the USA, and there is little incentive to breed for rust resistance.

Animal pests of peanut in the USA include nematodes, insects, and spider mites. Root-knot nematodes *(Meloidogyne arenaria* [Neal] Chitwood and *M. hapla* Chitwood) are the most widespread nematode problem. Pod-feeding insects such as southern corn rootworm *(Diabrotica undecimpunctata howardi* Barber), lesser cornstalk borer *(Elasmopalpus lignosellus* Zeller), and wireworms *(Conoderus* spp.) reduce quality more than they reduce

yield. Pods damaged by insect feeding are also more susceptible to infection by soil fungi. Foliar feeders such as tobacco thrips *(Frankliniella fusca* Hinds), potato leafhopper *(Empoasca fabae* Harris), corn earworm *(Helicoverpa zea* [Boddie]), fall armyworm *(Spodoptera frugiperda J.E.* Smith), and velvetbean caterpillar *(Aniicarsia gemmatalis* Hubner) may cause dramatic foliar symptoms or defoliation, but the economic thresholds for foliar damage are very high. Various species of thrips (Thysanoptera; Thripidae) cause early season stunting of seedlings and, more seriously, are vectors for tomato spotted wilt virus. Spider mites *(Tetranychus* spp.) may cause serious damage in dry seasons, but the effects of drought and spider mite injury may be difficult to separate.

Breeding for resistance to insects is generally considered by breeders to be more difficult than breeding for resistance to diseases. Resistance to insects takes three basic forms: tolerance, antibiosis, and nonpreference or "antixenosis" (Painter, 1951). "Tolerance" refers to the plants ability to withstand feeding or oviposition by the insect without suffering a significant decrease in economic yield. This sort of resistance is operative when the peanut plant produces the same pod yield in spite of foliar feeding by corn earworm. "Antibiosis" refers to a deleterious effect of the plant on the insect. This could be a reduction in fecundity or larval growth due to a toxic effect or nutrient deficiency from feeding, or it could be an adverse effect of the plant on some phase of the insect's life cycle, e.g., desiccation and death of eggs deposited on a pubescent leaf as opposed to a more glabrous leaf. "Nonpreference" refers to an effect of the host plant on insect behavior. Insects are highly mobile and may prefer certain host genotypes for feeding or oviposition. Resistance expressed in a breeding nursery that is due to nonpreference may break down when the insect is not given a choice among genotypes, as in a pure stand of a cultivar in a farmer's field.

The Peanut Collaborative Research Support Program (CRSP) of the U.S. Agency for International Development funds breeding efforts at two U.S. institutions: North Carolina State University (NCSU) and Texas A&M University (TAMU). The breeding programs at these institutions are charged with development of cultivars for two distinctly different production areas within the USA. NCSU's program breeds for the northern extreme of the U.S. peanut production area where large-seeded virginia-type cultivars are grown exclusively. This area includes parts of the coastal plains of Virginia, North Carolina, and

South Carolina, but production is concentrated in a few contiguous counties of southeastern Virginia and northeastern North Carolina. The vast majority of this area is cultivated without irrigation. TAMU's program breeds for the southwestern production region including Texas and Oklahoma. This area may be further broken into four smaller production zones. In south Texas, runner cultivars are grown in a mixture of irrigated and unirrigated fields. In west Texas, runner, spanish, and virginia cultivars are grown almost exclusively under irrigation on the high plains. In north-central Texas and Oklahoma, runner and spanish cultivars are grown under rainfed conditions with water supplies extended by limited irrigation. Peanuts in east Texas are almost exclusively rainfed. The southwestern production area traditionally grew spanish-type cultivars because their early maturity made them better suited to the often drouthy conditions. In the 1970s, production shifted to the higher yielding runner cultivars which predominate today.

Breeding for Pest Resistance at North Carolina State University

NCSU has released three pest-resistant cultivars. 'NC 6' is resistant to southern corn rootworm and other insects as well as being partially resistant to early leafspot (Campbell *et al.,* 1977). 'NC 8C' (Wynne and Beute, 1983) and 'NC 10C' (Wynne *et al.,* 1991) were released for their resistance to Cylindrocladium black rot. NC 10C was developed in part with funding from the Peanut CRSP.

The pest resistance breeding program at NCSU is a collaborative effort among faculty in the Departments of Crop Science, Plant Pathology, and Entomology. In Crop Science, T.G. Isleib conducts the conventional breeding project in *A. hypogaea,* while H.T. Stalker transfers desirable resistance from wild species of genus *Arachis,* and A.K. Weissinger utilizes plant transformation techniques to introduce resistance from unrelated organisms. M.K. Beute and B.B Shew provide the expertise in plant pathology to examine the nature of resistance. Drs. W.V. Campbell and R.L. Brandenburg have provided the final determinations of insect resistance.

The primary foci of disease resistance breeding at NCSU have been Cylindrocladium black rot and early leafspot. Numerous CBR-resistant breeding lines have been developed using conventional hybridization and selection procedures. However, the most resistant

selections have had characteristics such as thickened stems and leaves that made them dry slowly after digging and that resulted in poor acceptance from growers. Only NC 8C and NC 10C have qualified for release to growers. Neither cultivar has levels of CBR resistance as high as the resistant line NC 3033 (Beute *et al.,* 1976), and NC 8C was removed from the market because its pod and seed sizes were somewhat small for the virginia market type. Current efforts in breeding for CBR resistance include an accelerated selection program as well as evaluation of resistance in any advanced lines selected for reasons other than CBR resistance.

The accelerated breeding program makes use of a winter nursery at the USDA-ARS Tropical Agriculture Research Station at Mayaguez, Puerto Rico, to grow the F_1 and $F_{2:3}$ generations. F_2 and $F_{2:4}$ populations are planted at an infested site to allow single-plant selection for resistance and pod and seed characters. Resistance of $F_{4:5}$ families is evaluated in a replicated test on infested soil. Subsequent inbred generations are included in replicated trials for resistance and also in yield trials conducted at an uninfested site. Several high yielding resistant lines have been identified (Fig 1).

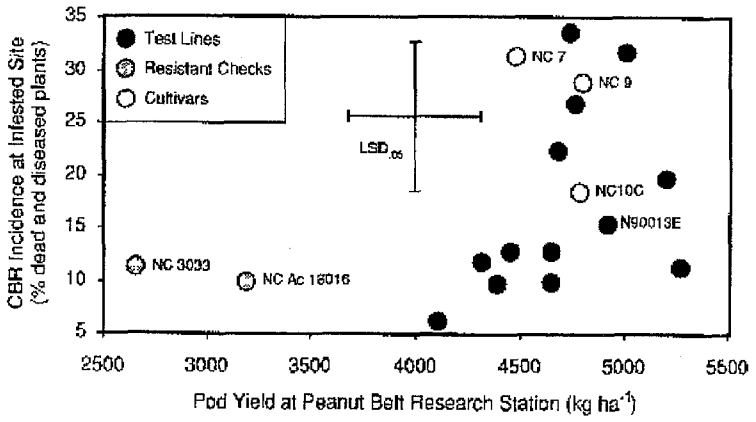

Figure 1. CBR incidence in an infested field at Trap, NC, versus pod yield measured at the Peanut Belt Research Station, Lewiston, N.C., in 1993 and 1994.

124

The practice of screening all advanced lines for their CBR reactions has identified unexpected partial resistance in several lines derived from a cross between the susceptible cultivars NC 7 and NC 9. Foremost among these selections is N90013E (Fig. 2), a candidate for release in 1995. The original sources of the CBR resistance most commonly used in the NCSU breeding program have been NC 3033 and NC Ac 03139 through their descendants, NC Ac 18016 and NC Ac 18229. Alternative sources of resistance have been identified among accessions of A. *monticola* and in the peanut core collection (Holbrook *et al.*, 1993).

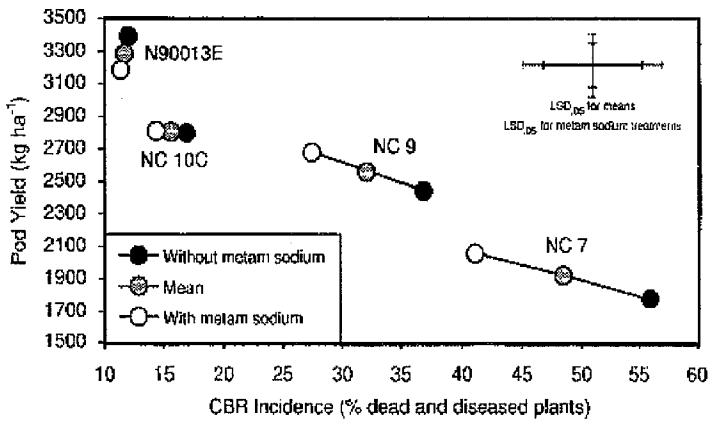

Figure 2. Pod yield versus CBR incidence in plots with and without metam sodium fumigant. Means across five tests conducted over three years in Bertie County, N.C.

The wild species of section *Arachis* contain levels of leafspot resistance superior to those found in the cultigen. Although the transfer of resistance is difficult due to differences in ploidy between the diploid wild species and the tetraploid cultigen, resistance has been transferred into tetraploid lines that cross readily with cultivated peanuts. Four such resistant lines were released as germplasm in 1994 (Stalker and Beute, 1993). Lines derived from the wild species exhibit more leafspot resistance than any other lines tested in the NCSU program, but they tend to have low yields and small seed sizes. The NCSU program has utilized resistance sources within A. *hypogaea* as well as wild species to

improve virginia-type germplasm (Fig. 3). Most of the resistant germplasm with virginia-type pod and seed attributes traces to PI 121067 through its descendants, GP-NC 343 and NC 6. GP-NC 343 is an insect- and leafspot-resistant line selected from a cross of PI 121067 with NC Bunch in 1947 (Campbell *et al.,* 1971). Other sources of resistance, including PIs 109839, 269645, and 270806, have been used as parents in the leafspot resistance breeding program, but their progeny have not had sufficiently large pod and seed size to consistently grade within the virginia market class.

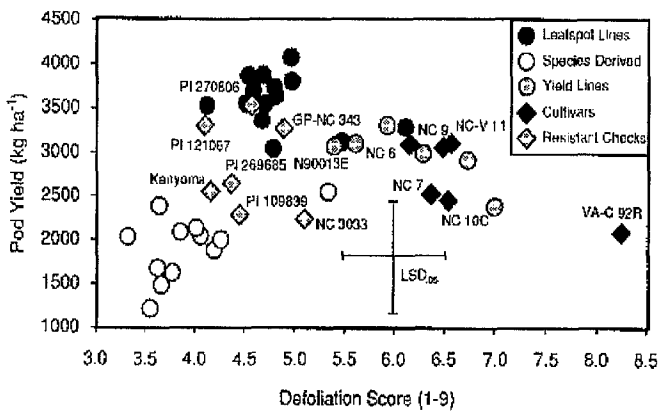

Figure 3. Pod yield versus defoliation in plots without chemical control of early leafspot *(Cercospora arachidicola* Hori). Means across two tests conducted in 1993 and 1994.

Most of the insect-resistant germplasm in the NCSU program again derives from GPNC 343. Other sources of insect resistance include mutants selected from a population irradiated with gamma rays (Campbell *et al.,* 1975). These mutants have altered leaf surfaces that make them less suitable for movement and feeding by leafhoppers. NCSU radiation mutants also have been used in the insect-resistance breeding program at ICRISAT (Dwivedi *et al.,* 1994).

Tomato spotted wilt virus had not been found in extensive portions of the North CarolinaVirginia peanut production area until 1994. 'NC-V 11' (Wynne *et al.,* 1991b), developed with partial funding from the Peanut CRSP, has been reported to carry some

126

resistance to TSWV although it was never subjected to selection for TSWV resistance (A.K. Culbreath, pers. commun.). There has been very little conventional breeding at NCSU for TSWV resistance, but crosses between reportedly resistant lines and large-seeded cultivars were made in 1993. The best chance for high-level resistance to TSWV lies in transforming peanut with genes for the TSWV coat protein. Research of this nature is being performed at NCSU in A.K. Weissinger's project and by plant transformation projects at other institutions.

Breeding for Pest Resistance at Texas A&M University

Efforts at Texas A&M Univ. (TAMU) includes conventional breeding within the cultivated species, A. *hypogaea,* by O.D. Smith as well as transfer of resistance from wild species native to South America by C.E. Simpson. The program is focused on the soil-borne fungal diseases' Sclerotinia blight, root-knot nematodes, and tomato spotted wilt virus.

Sclerotinia blight is spread through much of north Texas and has been identified in a few locations in southern Texas. Estimates of infected area in the Southwestern U.S. production area are 10,000 ha in Texas and 14,000 ha in Oklahoma. The TAMU program of breeding for resistance to Sclerotinia blight includes field screening of segregating populations followed by seed increase in the greenhouse to prevent spread of the pathogen through infected seed. The program has advanced to the point where off-station performance testing is necessary. Advanced selections are tested under varying levels of disease pressure (Tables la,b). Because the shelling and processing industries have expressed a desire to keep the number of cultivars on the market as low as possible, resistant cultivars also must perform reasonably well in fields where Sclerotinia blight is absent. While none of the advanced selections are immune to *Sclerotinia,* their performance is far superior to the check cultivars 'Florunner' and 'Tamrun 88' in the presence of the disease. When the disease is absent, the selections' performance is very similar to that of the checks.

Table la. Performance of lines resistant to Sclerotinia blight under low and high disease incidence. Means across two tests in central Texas.

	Pod Yield			Sound Mature Kernels			100-Seed Weight			Disease
Identity	Low	High	Red.	Low	High	Red.	Low	High	Red.	Rating
	kg ha^{-1}		%		%		g		%	units
Tamrun 88	4980	497	90.0	74	56	24.3	58	47	19.0	8.7
Florunner	5221	1488	71.5	72	71	1.4	60	54	10.0	5.7
Tx901417	4752	2971	37.5	74	71	4.1	61	55	9.8	2.3
Tx901305	4681	1612	65.6	72	70	2.8	59	53	10.2	4.7

Table lb. Performance of lines resistant to Sclerotinia blight under medium disease incidence. Means across two tests in central Texas

	Pod Yield			Sound Mature Kernels			100-Seed Weight			Disease
Identity	Low	High	Red.	Low	High	Red.	Low	High	Red.	Rating
	kg ha^{-1}		%		%		g		%	units
Tamrun 88	3049	1654	45.8	67	72	-	55	58	5.8	5.7
Florunner	5340	3896	27.0	73	74	-	56	58	-	2.4
Tx901417	5882	4768	19.0	61	68	-	56	58	-	0.1
Tx901305	4355	4034	7.4	70	77	-	53	58	-	2.2

Much of central Texas and some fields in south Texas are infested with root-knot nematodes. Chemical control is both expensive and a source of environmental concern.

The source of nematode resistance in the TAMU breeding program is TxAG-6. TxAG-6 is a tetraploid breeding line selected from a complex interspecific hybrid with ancestry from three diploid wild species native to South America: A. *diogoi* Krapov. & W.C. Gregory, syn. A. *chacoense* Krapov. & W.C. Gregory *nom. nud.,* A. *batizocoi* Krapov. & W.C. Gregory, and A. *cardenasii* Krapov. & W.C. Gregory (Simpson *et al., 1993).* The procedures used in transferring genes from diploid wild species into the tetraploid cultigen are described elsewhere (see H.T. Stalker's chapter). TxAG-7, a nematode-resistant selection from a cross of TxAG-6 with Florunner (Simpson *et al.,* 1993), was crossed with commercially acceptable cultivars (Florunner, Tamspan 90, Tamnut 74, NC 7, and Agratech VC-1), and the resistant plants have been backcrossed six times to the commercially acceptable parents. The backcross progeny from the fifth cycle have been compared with the susceptible recurrent parents. High levels of resistance have persisted through the cycles of backcrossing. In greenhouse tests, the most susceptible of the backcross progeny reduced the reproductive rate of the nematode by 86 to 99% (Table 2). Resistance to M. *arenaria* derived from A. *cardenasii is* conditioned by at least by one dominant gene.

Table 2. Egg production by *Meloidogyne arenaria* on resistant plants derived by backcrossing commercial cultivars to TxAG-7.

	Egg Production				
	Recurrent	Range in BC_5F_2		Reduction	
	Parent	Best	Worst	Best	Worst
	eggs (g of root)$^{-1}$			%	
Florunner	2910	0	266	100.0	90.9
Tamnut 74	1855	0	266	100.0	85.7
Tamspan 90	7890	49	191	99.4	97.6
NC 7	--	6	32	--	--
Agratech VC-1	7310	14	72	99.8	99.0
TxAG-7	32				

In south Texas, TSWV has caused heavy yield losses, and many fields have been dug prematurely because of dying plants. Significant losses have occurred in south central Texas and isolated foci of infection have been found in north Texas. No effective control for TSWV has been identified, making host-plant resistance the last hope of the grower. Specialists at TAMU recommend that growers complete their planting within a narrow time-frame designed to reduce disease incidence, probably by minimizing the spread by thrips feeding. Following ten years of selection, advanced lines with TSWV resistance have been tested in replicated trials in south Texas. Each plot in each test was bordered on one side by a row of 'Tamrun 88', a susceptible cultivar. Selections developed fewer symptoms of viral infection and yielded substantially more than the check cultivars (Table 3).

Summary

Host-plant resistance to diseases and insect pests of peanut is a common objective of the two U.S. peanut breeding programs funded by the Peanut CRSP. Although there has been considerable progress made in breeding for pest resistance in both projects, only two resistant cultivars have been released to growers. This seems inefficient until one realizes that the duration of the CRSP projects has been approximately 12 to 13 years, about the time expected for the development of a new cultivar from initial cross to release. In fact, the Peanut CRSP has supported efforts initially undertaken without CRSP funding. CRSP researchers have been very successful in transferring useful resistances from the diploid wild species of *Arachis* into the cultigen. Some of these resistances are in lines close to cultivar release; others remain in breeding lines expressing deleterious characteristics of the wild progenitors. Changing attitudes with respect to pesticide use and a changing regulatory environment may cause rapid changes in growers' acceptance of pest-resistant cultivars in the future.

Table 3. Performance of lines selected for resistance to tomato spotted wilt virus (TSWV) at Texas A&M University.

Identity	Pod Yield	Sound Mature Kernels	100-Seed Weight	Disease Incidence
	kg ha^{-1}	%	g	%
Test 1				
Florunner	3725	73	59	47
Tamrun 88	2844	71	53	80
Southern Runner	3770	71	58	34
Tx896100	5119	71	64	29
Tx901305	4275	74	60	39
Test 2				
Florunner	3250	77	59	59
Tx935014	5179	79	62	33
Tx935402	5197	77	60	33
Test 3				
Florunner	3963	73	58	56
Southern Runner	4065	75	55	27
Tx935389	6036	76	63	38
Tx935411	5763	79	61	17

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Pilot Program for IPM in Thailand

Manochai Keerati-Kasikorn[1]

INTRODUCTION

In Thailand the arthropod complex that feeds continuously on peanut consists of insects and spider mites. They attack foliage, stems and pods and also transmits important viruses to peanuts. In general, foliage feeders cause only minor problems in Thailand. Sucking insects which transmit the important viruses can cause major constraints to peanut production. In addition, the pod feeding insects are major pests. While foliage feeding and sucking insects have registered chemical control methods in Thailand, the development of effective control methods for soil pests has been very difficult. In tropical areas, pests occur in overlapping life cycles which attack the crop at the same time. This is more difficult to access their damage potential. A list of the major insect pests of peanuts are shown in Table 1. The most susceptible time for damage by the pests refers to the synchronization of the pests with the plant development. The goal of this research is to reduce the constraints of insect damage and insect transmitted viruses on peanut production and yield by developing a pest management program compatible with existing cultural practices and farming systems. This report summarizes the work done on thresholds, cultural practices, natural enemies, host plant resistance, and chemical control.

Sampling techniques for insect pests

Techniques that are used to sample for pests, monitor pests and access damage are included for leafhopper, thrips and defoliators of the following.

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Leafhoppers: Use a standard insect sweep net and record the number of leafhopper nymphs and adults per 10 sweeps. For leafhopper damage. remove 25 leaves at random and count the number of hopper burned leaflets equal to 100 leaflets.

Thrips: Select 10 unopened terminal leaves, dip leaves in alcohol to remove thrips, then pour the liquid through filter paper and count the number of thrips. For thrips damage, take 25 leaves at random, and count the number of thrips damaged leaflets. Each leaflet represents 1%. If damage is severe, count the number of severely stunted plants.

Defoliators: Remove 25 leaves at random. Use a grid or pictures to estimate percentage of defoliation. A visual estimate is also used when the field is large.

Pheromones: Pheromones are available for Heliothis and Spodoptera, which impregnated rubber septa placed in sticky trap are efficient at attracting and capturing specific pests for monitoring.

Sticky traps (No-Bait): Sticky traps are not selective but are effective in capturing small insects such as thrips and leafhoppers.

Water pans: Yellow pans with water are used to collect aphids

Table 1. Insect of peanuts in Thailand.

	Pest Species	Most susceptible plant age	Importance
A.	**Foliage Feeders**		
1.	Leaf Miner *Apoaerema modicella*	21-100	Minor and frequent
2.	Leaf Roller *Archips micaceana*	30-80	Minor
3.	Bollworm *Heliothis armigera*	40-70	Minor
4.	Cut Worm *Spodoptera litura*	45-80	Minor
B.	**Sucking Insects**		
5.	Thrips *Frankliniella sp.*	15-90	Major and frequent
6.	*Scirtothrips dorsalis*		
7.	*Caliothrips indicus*		
8.	Leaf Hopper *Empoasca sp.*	21-90	Minor and frequent
9.	Aphids *Aphis craccivora*	21-70	Minor
C.	**Pod Feeders**		
10.	Subterranean ants	49-100	Major in some locations

Cultural practices

No-tillage: Peanuts planted in rice stubble conserve moisture, labor and gave yields which were not significantly different from peanuts planted in a conventionally cultivated field. Leafhopper and thrips are less abundant and peanuts have more or less the same damage in no-tillage and conventionally planted peanuts. Pod damage from the subterranean ant is also less.

Spacing: Peanut crops planted with close spacing produced higher yields than when planted with wide spacings. Three common insects found in the crop were leaf miners, leafhopper and thrips. The insect populations were not much different among the different plant spacings. (Keerati-Kasikorn, M. 1990).

Planting date: Peanut planted early have less leaf miner, leafhopper and thrips damage than peanuts planted late. Other defoliators presented depending on the surrounding vegetation and climatic factors in each year. Early planting peanuts usually produced a higher yield than late planting peanuts.

Natural enemies: The common natural enemies found in the farmers' fields are predators, parasites and pathogen, include:

Predators: Ladybird beetles occur in the dry season crop where peanuts are planted after rice. They feed on aphids and leafhopper nymphs that they keep peanut pests at low level. Predaceous bugs attack the larvae of Heliothis armigera and Spodoptera litura, but high number of this predator occur only once every 3-4 years.

Parasites: There are several parasitic hymenopterans such as Apanteles sp. Tetrastichus sp., Sympiesis sp., Stenomesins japonica and Elasmus sp. that attacked leaf miner larvae. Pupae are also attacked by Brachymeria lasus, B. minuta and Eucepsis sp. (Phisitkul, 1985). The tachinid fly lays eggs on Heliothis armigera larvae.

Pathogen: Nuclear polyhedrosis virus also infect Heliothis armigera larvae. They are effective natural enemies to the pest in some locations when environments are favorable to the pathogen (Ketnuti, 1991).

Table 2. Natural enemies found in the peanut plots in Thailand.

	Natural enemies		
	Species	**Host Species**	**Importance**
A.	**Predators**		
1.	Ladybird beetle	*Aphis craccivora*	major, frequent
2.	Predaceous bug	*Heliothis armigera* *Spodoptera litura*	minor, frequent
3.	Reduviid bug	*Heliothis armigera* *Spodoptera litura*	minor
4.	Big ey bug	small young insects	minor
B.	**Parasites**		
5.	*Apanteles sp.*	*Aproaerema modicella* larvae	minor, frequent
6.	*Tetrastichus sp.*	*Aproaerema modicalla* larvae	minor
7.	*Brachymeria lasus*	*Aproaerema modicella* pupae	minor
C.	**Pathogen**		
8.	NPV.	*Heliothis armigera*	minor, frequent

Host plant resistance

Three groups of peanut germplasm have been evaluated for pest resistance. These lines were collected from ICRISAT, NCSU and the collaborative insect resistance evaluation

137

project among the entomologists of NCSU, Philippines and Thailand. All tests were done under natural infestation and damages were assessed for the individual insects. Lines adapted to local environment and producing good quality seeds were selected for re-evaluation in the subsequent year while those producing poor quality seeds were discarded. Numerous genotypes have been identified with multiple pest resistance. The performance of some genotypes in Thailand is shown in Table 3. (Keerati-Kasikorn and Sueb-pimai, 1994). These lines have been tested for several seasons shown remarkable stability in performance against multiple pests. The lines with NC 7 and GP-NC 343 usually showed a high level of resistance to both defoliators and sucking insects.

Table 3. Some lines of insect resistant peanut in screening tests in Thailand.

Peanut Lines	**Leaf Damage per 20 plants**		**Yield**
	Thrips	**Leafhopper**	**t/ha**
NC 7 x NC 15745	6	28	2.63
NC 7 x GP-NC 343	7	18	2.89
Manfredi 68 x GP-NP 343	9	20	1.85
Robut 33-1 x GP-NC 343	5	19	2.06
Robut 33-1 x NC 2214	3	6	2.50
NC 7 x NC 301	9	33	2.89
NC 7 x NC 10247			3.17
Mini Pintar x [Robut 33-1 x NC Ac 2232	2	9	2.03
GP-NC 334 x Nc 6	6	22	1.79
Tainan 9 (check)	19	27	1.51

Chemical control

Peanuts are attacked by many insects which may damage any part of the plant. Methods of controlling pests vary due to location, weather conditions and other factors. Some peanut insects may be controlled by cultural practices and some are manipulated by host plant resistance while many of them are controlled by pesticides. It is important to consider that methods of application' maximum dosage and proper time interval are applied with care and consciousness. Recommendations for insecticide applications are to prevent economic loss when the numbers of insect pests reach the economic threshold. This is only a guideline for farmers to make decisions. Insecticides recommended by the Division of Entomology and Zoology to control the leafhopper are carbosulfan, omethoate, carbaryl and monocrotophos 2-3 times at 10 day intervals or when the number of leafhoppers reach 6 insects per leaves. Sirisingh et al. (1986) reported that carbosulfan, prothiophos, triazophos, monocrotophos, alphomethrin and fenvalerate gave the effective control of thrips. However thrips' feeding usually causes little yield loss to the crop, but severe crop loss is caused by virus disease. To prevent crop loss caused by thrips, early sprayings must be applied, especially the plot had been infected by virus-disease before.

Crop loss caused by leafminers were reported by Keerati-Kasikorn et al. (1987) and Sirisingh et al.. (1987). Leafminers caused crop loss at different level such as 36% (Keerati-Kasikorn et al.. (1987) 40% (Keerati-Kasikorn and Singha, 1986) and 54% (Sirisingh et al..' 1987). However this pest is easily controlled by several insecticides such as monocrotophos, triazophos, methamidophos, omethoate, endosulfan and carbosulfan (Bumrungsri, et al.., 1986). Aphids were present at the early and flowering stages which caused severe damage in the dry season with shortage of irrigation. Crop loss occurred when aphids transmitted the virus disease to the crop. Insecticides such as monocrotoptios, carbosulfan and chorpyriphos gave a good control. Boll worm (Heliothis armigera) has shown some resistance to monocrotophos (Keerati-Kasikorn, et al.., 1988). Since this insect is a major pest of cotton in Thailand, insecticides were heavily used to suppress its population. Subterranean ants live underground and feed on the young seed of peanut pod. Attempts to use a coconut meat as a bait to lure monitor their population having some success but the control of this pest by insecticides gave a limited success, since the ant is mobile and can travel approximately 2 kilometers per day (Keerati-Kasikorn and Singha, 1989).

Integrated Pest Management

Integrated Pest Management (IPM) is a concept that utilizes all suitable methods to suppress the pest population under the economic threshold. The objective of IPM is to help growers produce the most profitable crop; When insects are managed using the thresholds and pesticide rates for the preventive program, it gave a significantly higher yield. This is probably due to additive of effects which includes cultural practice, biological control, and insect resistant cultivar. They are all needed for sustainable agriculture.

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Strengthening Research Capacity

Peanut CRSP Human Resource Development

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INTRODUCTION

In order to help attain the goals of the Title XII Program of the U.S., programs for improving the research capability of both developing countries and U.S. institutions by the Peanut Collaborative Research Support Program (Peanut CRSP) are in progress. Among the many problems affecting sustainable production and utilization of peanut are inadequate transfer of technology and a lack of enough trained researchers and support personnel. Increasing research capabilities by supporting selected students to attend university academic degree programs in the U.S. is one of the strategies being attempted. Under the Peanut CRSP auspices, a number of students have been and are being trained at four universities: North Carolina State University, the University of Georgia, Alabama A&M, and Texas A&M.

This is a report on a study of the socioeconomic impacts of the Peanut CRSP graduate training efforts to date utilizing an international mail survey of graduate students who were sponsored by the Peanut CRSP in degree programs at the four U.S. universities. The Peanut CRSP, initiated in 1982, is designed to address a number of constraints to sustainable production and utilization such as low yields due to unadapted cultivars and yield losses due to infestations of insects, diseases and nematodes. Among the other constraints addressed by the program are inadequate transfer of technology and insufficient numbers of trained researchers and support personnel. Efforts to relieve the latter two constraints have been implemented through the CRSP graduate training program. The CRSP seeks to generate solutions to current problems and improve

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research capabilities for effectively addressing future problems. While increasing research capabilities through degree training is an integral part of this effort, U.S. scientists also gain knowledge and acquire important elements such as germplasm, from other countries through this program.

Sommers (1967) has suggested that efforts for improving human development have ranged in scope from attempts to develop human beings and attempts to develop peoples' resources to attempts to develop manpower. Programs to improve human beings are the broadest and include concerns of social science for areas such as education, training, health, and human environments. Manpower development is the narrowest and involves policies or programs "...that increase the worker's productivity or increase his mobility so that he makes a greater productive contribution in the labor market and at the same time increases his own earnings and welfare" (Sommers, 1967). Today we refer to manpower development as human resource development. The Peanut CRSP graduate student support effort is a program for human resource development.

Investigations such as the present one are rare. Studies which follow students after graduation to determine outcomes are generally referred to as "tracer" studies. References to only four tracer studies could be found in the literature (Institute Teknologi Mara, 1980; Sullivan, 1981; USAID, 1977; USAID, 1981). Only two of these appear to be even somewhat similar to the present study (USAID, 1977 and USAID, 1981). The *Tracer Study Guidelines* (1983) prepared by George Psacharopoulas for the Education Department of The World Bank proved valuable in the design of the survey instrument used in this study.

This report studies the extent of CRSP impacts on human resource development, especially through the training of U.S. and foreign research scientists at the cooperating CRSP institutions in the U.S.. At the time of this study, the Peanut CRSP had supported 101 graduate students most of whom are foreign nationals recruited through the Peanut CRSP contacts with professionals in participating countries. Some students in this study were still completing their educations. Most have completed their educations and have returned to their home countries. Part or all of their education and research has been funded through the program. This study is based on a survey designed to assess the

CRSP program's impacts on the students' educational and professional experiences, and subsequent contributions to agricultural research and development efforts, both here and abroad.

In order to help attain the goals of the Title XII Program of the U.S., programs for improving the research capability of both developing countries and U.S. institutions by the Peanut Collaborative Research Support Program (Peanut CRSP) are in progress. Among the many problems affecting sustainable production and utilization of peanut are inadequate technology, poor transfer of technology and a lack of enough trained researchers and support personnel in developing countries. Efforts to relieve these constraints have been implemented through the CRSP which seeks to generate solutions to current problems and improve research capabilities for effectively addressing future problems. Under the auspices of the Peanut CRSP graduate training program a number of students have been and are being trained at four universities: North Carolina State University, the University of Georgia, Alabama A&M, and Texas A&M.

While increasing research capabilities through degree training is an integral part of this effort, U.S. scientists also gain knowledge and acquire important benefits such as germplasm, from other countries through this program.

Sommers (1967) has suggested that development efforts have ranged in scope from attempts to develop human beings and attempts to develop peoples' resources to attempts to develop manpower. Programs to improve human beings are the broadest and include concerns of social science for areas such as education, training, health, and human environments. Manpower development is the narrowest and involves policies or programs "...that increase the worker's productivity or increase his mobility so that he makes a greater productive contribution in the labor market and at the same time increases his own earnings and welfare" (Sommers, 1967). Today we refer to manpower development as human resource development. The Peanut CRSP graduate student support effort is a program for human resource development. At the time of this study, the Peanut CRSP had supported 101 graduate students most of whom are foreign nationals recruited through the Peanut CRSP contacts with professionals in participating countries. Some students in this study were still completing their educations. Most have

completed their educations and have returned to their home countries. Part or all of their education and research has been funded through the program. This study is based on a survey designed to assess the CRSP program's impacts on the students' educational and professional experiences, and subsequent contributions to agricultural research and development efforts, both here and abroad.

This is a report on the socioeconomic impacts of the Peanut CRSP graduate training efforts to date utilizing an international mail survey of graduate students who were sponsored by the Peanut CRSP in degree programs at the four U.S. universities. Investigations such as the present one are rare. Studies which follow students after graduation to determine outcomes are generally referred to as "tracer" studies. References to only four tracer studies could be found in the literature (Institute Teknologi Mara, 1980; Sullivan, 1981; USAID, 1977; USAID, 1981). Only two of these appear to be even somewhat similar to the present study (USAID, 1977 and USAID, 1981). The *Tracer Study Guidelines* (1983) prepared by George Psacharopoulas for the Education Department of The World Bank proved valuable in the design of the survey instrument used in this study.

RESEARCH PROCEDURES

The population of this research included all the graduate students who had been sponsored by the Peanut CRSP Program in degree programs. Almost all of these had completed at least one degree, although some masters students are continuing to work towards a Ph.D. This population sample does not include CRSP students in other support categories (Post Doctoral, Sabbatical, or short-term training).

Since a complete list of the student participants was not available, the sampling frame had to be compiled from various CRSP sources. The sources include the annual CRSP reports of the four participating universities (North Carolina State University, University of Georgia, Texas A & M, and Alabama A & M), the departments in which these students majored, and the Management Entity Office of the Peanut CRSP located at the University of Georgia. The sampling frame consisted of 101 names of students who had been enrolled in degree programs through the Fall of 1989. Of these, 68 personal current addresses were known by the CRSP Program or were discoverable by the

146

research team. Two foreign university institutional addresses were added bringing the total sampling frame to seventy addresses.

The mail survey was considered an appropriate method of data collection given the international geographic dispersion, thus making phone calls expensive or impossible. The high education levels of the respondents suggested high written survey response capabilities. The survey was constructed to determine the demographic characteristics of the students going into the CRSP sponsored training, the nature of their training, their status after the CRSP sponsored training, and the impacts on productivity and dissemination of their CRSP training and research activities. Both open-ended and closed questions (multiple choice) were included in the survey to collect qualitative and quantitative data. Three mailings and selected follow-up phone calls where feasible were used in an effort to keep the return rate as high as possible.

Given the relatively small population size, we did not draw a sample from the sampling frame. Every address available was sent a survey. To the extent, therefore, that our sampling frame matches the population, we have conducted a population, rather than a sample, study.

One month after the first mailing we distributed the second mailing and the response rate from the first two mailings is sixty-four percent (25 nonrespondents). Six of the 25 nonrespondents were subsequently identified by the Management Entity Office of the Peanut CRSP as well-known participants in the program whose current addresses were available. A follow-up effort was conducted to solicit their returns. All 6 returned their completed surveys shortly thereafter, bringing the total number of returns to 51 (a 73% return rate).[1] Based on state-of-the-art techniques, survey methodology experts indicate that a well-done U.S. survey should yield a response rate of about 70% (Dillman, 1978). Given the added international mail difficulties, a lack of complete addresses for some,

[1] Since these 6 respondents received an additional mailing, they were analyzed separately in an effort to detect possible bias. Where no differences in trends between these six returns and the larger sample of 45 were detected, all 51 cases were included in the tables.

and lack of ability to make follow-up phone contacts with all the respondents, 73% represents a reasonably good response rate.

The survey instrument contained 37 questions including 28 multiple choice or short answer questions. Examples, of short answer questions are: "Age?", "Name of Employer?", and "Title of present position?". The remaining 9 questions were open-ended allowing the respondents to give as much information as they chose. Examples, of the latter questions are: "What problems, if any, did you have in obtaining employment after graduation?", "What applications of the thesis, if any, were made in your home country?", and "How was the technology associated with CRSP training modified, if at all, for local conditions?".

Multiple choice questions and those which were quantifiable are reported here. Only the questions which were deemed directly related to the impact of the CRSP on students and their subsequent activities are analyzed for this report. Other questions will be used later in multivariate sociological analyses that will attempt to take into account factors affecting individual differences in outcomes among students (e.g., "size of community", "gender", and "current socioeconomic status").

MAIN SURVEY FINDINGS

The respondents' average age is 33.4 and they spent an average of 31 months doing graduate work supported by CRSP. For those who are no longer students, it had been 2.3 years on average since completing their degrees at the time of this survey.

Fifteen of the CRSP-trained respondents were continuing their education rather than taking jobs. The latter is a somewhat limiting factor for this study, since the post-graduate impacts through subsequent employment activities cannot be assessed for these respondents. Of course the impact of their masters thesis, research while at the university, and other activities at the masters level are still relevant even though they may be continuing their Ph.D. work. Thirty-two respondents listed completed theses.

Seventeen countries are represented. The country represented most often besides the U.S. (37%) was Thailand with 8 students (15.7%). The Philippines was the third

148

country with 7 (13.7%). Fourteen other countries had at least one student in the CRSP program. Only 14 students (27.5%) came to the U.S. via CRSP sponsorship. All six respondents who received the last mailing came to the U.S. on CRSP sponsorship. One possible reason why relatively few students were brought to the U.S. under CRSP sponsorship is that 19 are from the U.S. and were already here. The CRSP program also recruited some foreign students while they were here in the United States.

A surprising 47.1% of the sample are female students. This is unusual given the general difficulty which women in many underdeveloped countries have in obtaining various types of equality, including education equality (Moxley and Wien, 1969). With regard to students' primary specialization in graduate school, Food Science (29.4%) was the main specialization. Breeding/Genetics was second with 23.5%. Crop Science and Microbiology were the next most popular choices with 13.7% and 11.5%, respectively. Toxicology was next, followed by Entomology, Biotechnology, and Plant Pathology.

Queries on students' current employment status, reveal that "university employee" is the category indicated by 29.4% (n=15) with an equal number indicating that they are "students". In third place is "private employment" followed by "government employment." (Fifteen respondents remain as full time students and 2 are currently unemployed.) With regard to employed students' professional time, most of them spend the majority of their time doing research. Teaching activities are second followed by administrative activities, service, extension, and finally policy activities.

Table 1. Indicators of Direct Impacts on Individuals.

	Percent
A. Degree Completed (n = 36):	
MS	47%
Ph.D.	53%
B. Usefulness of education to present employment of graduates (34 employed)	
Response: "very useful"	85%
1. Positive	
Impact on present position income ("yes")	44%
2. Positive	
Impacts on present position promotion ("yes")	56%
3. Positive	
Impacts on present position productivity ("yes")	56%

In Table 1, one notes that among those who are not currently "students," 47% received the MS Degree, while over half (53%) received the Ph.D. Overwhelmingly they thought their university education was "very useful" for current employment (85%). Only one respondent gave a negative response to this question.

Slightly over half of those employed said that their CRSP training had positive impacts on their promotions (56%) and productivity (58%). Slightly less than half (44%) said their CRSP training had a positive impact on their income.

150

Table 2. Indicators of thesis research impacts (Base Number = 36 degrees completed).

		Percent
A.	Application of thesis to home country? ("yes")	75%
B.	Give Examples of thesis applications	61%
C.	Examples of thesis research applied to U.S., (including incomplete theses N = 44)	73%

As shown in Table 2, over 75% of the employed respondents indicate that there was an application of their "thesis" or "dissertation" in their home country. Over sixty percent (61%) were able to give at least one specific example of an application. Almost three-fourth (73%) of the respondents could give a specific example of the use of their "thesis research" which had been applied in the United States.

Table 3. Indicators of Impacts Through Diffusion of CRSP Training.

		Percent
A.	Give potential uses in U.S. or home (N = 51 students)	89%
B.	Training shared with others (N = 51 students). Examples given: through coworkers (78%), training programs (12%), conferences (67%), publications (80%), other agencies (16%). (Percents do not equal 100 since multiple answers are possible.)	92%
C.	Technology obtained through CRSP training modified for local use (N = 34 employed).	29%

As can be seen in Table 3, an overwhelming portion of respondents (89%) were able to give an example of a potential use of their CRSP training for the U.S. and their home country (Question A). Another question (B) asks in what ways the respondents CRSP

training has been shared. Almost all of the respondents (92%) had shared their resources with others. The most frequent indication of sharing is through publications (80%). The second most often mentioned method of sharing is through co-workers (78%), followed by sharing through conferences (68%). Other agencies and training programs together constitute 28%. The last category © indicates that twenty-nine percent had experience with modifying technology obtained for local use.

Table 4. Research Projects and Publications (All 51 Respondents).

		Publishing Percent
A.	Reporting journal articles, book chapters, etc[a]	51%
B.	Reporting abstracts and other reports[b]	71%
C.	Reporting research projects worked on[c]	84%

[a]94 Articles and book chapters
[b]119 Reports and abstracts
[c]168 Research projects

Table 4 reveals over one-half of the respondents (51%) reported publications. A count of all the publications listed yields an average production rate of 1.84 per respondent. Additionally, over 70% reported abstracts or reports published during or since their training. A count of reports and abstracts listed indicates an average production rate of 2.3 per respondent. Finally, 84% of the respondents have participated in active research projects.

SUMMARY OF ANSWERS TO OPEN-ENDED QUESTIONS

The following section describes the general nature of the responses to open-ended questions in the survey. Respondents showed great variation in the amount of information and detail given, but the overall quantity and quality of responses was impressive, since the questionnaire could easily take one hour to complete.

162

The first open-ended question asked students which subjects studied in graduate school were most useful in reference to their present employment. There were 37 respondents and 74 responses. Considering their modal specializations were in food science and breeding/genetics, it is surprising that the subject most often mentioned as "most useful" was "statistics" (11 responses). This may indicate that statistics is a more basic (less specialized skill) with wider applications than other courses taken. "Plant breeding" was the second most often mentioned course (8 responses).

Another question requested that students list the topic of their thesis. Nine of the theses dealt with nutritional uses of peanut. Most of the remaining theses involved basic research on the peanut plant itself with three focusing on plant breeding and ten on plant diseases. Others dealt with a variety of basic research and applied research topics related to the plant itself, or growing and harvesting conditions of peanut.

Another question asked about technology associated with CRSP training which has been modified for local use. A total of 18 responses were received to this question. Some said that this question does not apply to their current situation. Others claimed that the technology is already appropriate for local use and no modification is needed, but a number of others did give examples of how the technology has been modified. Three examples of the types of modifications are: (1) "instead of using artificial shade, actual tree shade is being used in the Philippines," (2) "processing without sterilization because the university cannot afford to buy glass bottles (using plastic)," and (3) "the use of a simple and inexpensive package and simple technique to measure stability of roasted peanuts."

A question regarding "Applications of Thesis/Dissertation in the U.S." has one of the higher response rates. There were 33 examples given. Several examples refer to the general application of peanut breeding in the United States. Most of the other responses are more detailed. Examples of detailed applications include: (1) "manipulation of Laitr Acid Bacteria," (2) "screening of peanut breeding lines for A. Flavus resistance," (3) "development of Chemisorbents for Aflatoxin," (4) "interspecific hybrids used to develop breeding populations with disease and insect resistance," (5) "evaluation of toxicities of

biological control agents," and (6) "help set up IPM strategies for peanut insect pests in Georgia."

A question regarding the respondents' perceptions of potential use of CRSP training for the U.S. and home applications is relevant to both foreign and American students. Therefore, it is not surprising that this question received the highest response rate (41 responses). Eight of the responses regarding applications which seem to differ from any of the previous answers are: (1) "how to supervise workers or technicians," (2) "using consumer research techniques to develop products to meet the needs of consumers," (3) "teaching and advising graduate students from overseas," (4) "technology development and transfer to peanut growers," (5) "professional skills and status needed to carry out projects in Niger in a high level government position," (6) "increase plant productivity and food quality," (7) "ways to get more funds and money for research," and (8) "optimum timing of insecticide application and action threshold of thrips on peanut."

Another question deals with the weaknesses of the CRSP training program and suggestions for improvement (Question 36). There were 36 responses to this question. The most frequent theme is the students' lack of knowledge of the Peanut CRSP Program. Many of the respondents claim that they do not know much about the Peanut CRSP. There are indications that there has not been enough communication between the program and the students who are involved. Also expressed is a desire for more interaction among those students who are supported by CRSP and also with the university professionals who are involved with CRSP. One respondent says that they themselves did not realize they were sponsored by CRSP until they received this survey. A few other respondents feel that the financial policy of CRSP poses some problems. Some feel that the funding is not enough to sustain minimum expenses.

The remaining weaknesses were not mentioned by more than one respondent. Nevertheless, some of these seem worth consideration in order to help improve future efforts. One respondent felt that CRSP overly emphasizes technical aspects of training and ignores the important aspects of socioeconomic understanding and socialization. This person suggests that some of the professors need to improve their human relationships, especially with foreign students. Another respondent felt that the monetary

funds were too limited to cover expenses involved in conducting and developing IPM strategies. Another respondent stated that there was a lack of adequate equipment to conduct research such as a leaf area meter, computer, control chamber, etc. Finally, it should be kept in mind that 41% could think of no single criticism or suggestion to improve the program.

A final question asks about major strengths of CRSP training and the CRSP program. There were 39 positive responses. This was the second highest response rate of any of the open-ended questions. This is more impressive since this is the last question in a time-consuming questionnaire, the point at which the fatigue factor should curtail responses. Even more striking is the length of various responses to this question. One of the responses ran 15 typed lines. The total lines of response to this question for all respondents is easily double the lines of response for any of the other open-ended questions. In technical terms, the quantity (34 responses), the direction of response (positive), and the intensity (number of lines written) suggest that respondents are overwhelmingly satisfied with the CRSP program. The strengths listed overlapped extensively. Included were statements about the enhanced possibilities for collaboration, professional growth, and direct contact with participants in the program.

As mentioned earlier in this report, six of the 25 nonrespondents (24%) were identified by the Management Entity Office of the Peanut CRSP as important participants and they were sent an additional mailing. All six of these participants submitted completed questionnaires. We initially compared this group with the original 45 respondents to make sure that they were not significantly different before including them in the final tables.

These six respondents were similar to the first 45 respondents on most of the responses. They differed substantially from the original group only in terms of responses to 6 questions: (1) their method of recruitment to CRSP, (2) their degree received under CRSP funding, (3) their present jobs, (4) the perceived impact of their training on productivity, (5) their satisfaction with CRSP, and (6) their publications. In particular, these six respondents were more likely to be brought to the U.S. under CRSP sponsorship (100% versus 18% for the original 45 respondents), receive the Ph.D.

(100% versus 33%), spend more of their current professional time teaching (35% of time versus 10%), perceive an impact on their own productivity (83% versus 50%) and on their coworkers' productivity (50% versus 25%), be "very much satisfied" with their CRSP training (100% versus 54%), list more publications and reports (an average of 2.7 versus 1.7 and 4.3 versus 2.1, respectively), and more likely to list both weaknesses and strengths of the CRSP program (83% versus 51% and 83% versus 78%, respectively.) On all the other 31 variables, this group was indistinguishable from the original 45 respondents.

As in any survey, evaluation of the results is tempered by the consideration of nonrespondents (19 participants did not respond). Inclusion of data from these 19 (27% of the sampling frame) could have produced slightly different findings from those reported here. In addition, while many of the findings are impressive (e.g., the high productivity levels), the lack of a matched comparison group of individuals with similar characteristics and without CRSP support prevents an approximation to the experimental design type of assessment. Of course, the latter approach would have required a substantially greater investment in research funding.

SUMMARY AND CONCLUSIONS

The study contains a number of indications of socioeconomic impacts. Evidence based on this survey indicates increased worker mobility, earnings, and welfare. Also, there has been a high degree of research productivity of former students given the short time graduates have been working (2.3 years) and the number who are continuing their studies (29%). These 51 students have produced or collaborated on 94 publications, 119 reports or abstracts, and 168 research projects. Fifty-six percent report that the CRSP sponsored training positively impacted their productivity, 56% their promotions, and 44% their income. There is a virtual consensus among former students (85%) that their university education was "very useful for their employment."

Program participants were mostly foreign (63%), students who majored in food science (29%) and breeding/genetics (24%). The male/female proportions were not significantly different (53/47%). Over seventy percent (71%) have completed their academic training

156

and spend most of their professional time doing research in government or university settings.

The Peanut CRSP program has been effective in terms of human resource development and subsequent research applications. Applications of thesis research were reported to have occurred in their home country by 82%. From a low of 67% to a high of 80% they indicated indirect impacts of their training through the sharing of their knowledge in a variety of activities such as working with co-workers, conferences, and publications.

The U.S. is also a major beneficiary of this CRSP effort. For example, 73% reported examples of thesis research applied here. Examples of applications of their training for the U.S. and/or their home country were given by 89%. Almost all of the students worked on U.S. projects while studying here.

The areas identified by respondents as needing some attention by the CRSP program are communications about the CRSP program to the students, communication and contact between and among CRSP sponsored students, and faculty, and more attention to possible feelings of inadequate funding in certain areas among sponsored students. Other than these areas of needed improvement, the evidence indicates that the Peanut CRSP program has been very successful in terms of human resource development goals. There is also strong evidence that the students' research and training is already being applied in both the home country of foreign nationals and in the United States. More than 70% of the participants reported application of their university CRSP training.

The open-ended questions suggest even stronger evidence of support by former and current students. The lack of criticisms and the quantity, length, and intensity of written responses suggest that the respondents are not just satisfied, but grateful for the CRSP program.

Finally, an unusual characteristic of this particular higher education program is the absence of the "brain drain" phenomenon. All of those foreign students (100%) with completed degrees had returned and remained in their home countries at the time of this study. This is especially impressive given the high percentage of female graduates of the

CRSP training, a group that previous literature (Cortes and Perez, 1970) has identified as highly susceptible to the "brain drain" effect.

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168

National Peanut Program Development in Thailand

Aran Patanothai[1]

Peanut research in Thailand is organized as a coordinated program between the Department of Agriculture (DOA) of the Ministry of Agriculture and Cooperatives, Khon Kaen University (KKU), and Kasetsart University (KU). The program was formulated in 1981, and has been collaborating with the Peanut CRSP since the beginning. Under this collaborative program, financial and technical supports are provided by the Peanut CRSP to the three Thai institutes. KKU and KU also received financial supports from the International Development Research Centre (IDRC) of Canada from 1982 up to the end of 1988. The organization of research as a coordinated program and the supports from the Peanut CRSP and IDRC have greatly strengthened peanut research in Thailand. This paper describes the formulation and development of the Coordinated Peanut Program in Thailand.

Peanut Production in Thailand

Peanut is an important food legume and oil crop of Thailand. It is grown by small farmers in all parts of the country, not only providing a significant source of cash income but also being an important source of protein for the rural people. The crop is consumed in various forms: as an ingredient to a variety of dishes, as boiled, boiled-dried, and roasted peanut, and in confectioneries of different kinds. It is a major source of edible oil and of protein for animal feed, and also plays an important role in the maintenance of soil fertility. However, despite its importance, peanut is considered a secondary crop because of its smaller area compared with those of crops like rice or maize.

Slightly more than 100,000 ha of peanut is planted to peanut annually, with an annual production of about 140,000 tons. Planted area, however, has varied to some extent from year to year, and has declined slightly in recent years. Average national yields have been about 1.4 tons/ha.

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The crop is grown in upland areas in the rainy season, in the paddy fields following rice in the dry season, and in the draw-down areas along the river banks in the post rainy season. Upland areas cover about 61%, paddy areas about 37%, and draw-down areas about 2% of total peanut acreage. In upland areas, peanut is grown under rain fed conditions. Cropping systems include monocropping, double cropping, and intercropping, these systems occupying 27%, 32%, and 2% of overall peanut acreage, respectively. In double cropping systems, peanut is grown both as the first crop and as the second crop, almost equally. Most of the paddy field production is irrigated, while a small portion (3% of total area) is unirrigated but has a high sub-surface water table in the dry season. Crops grown in the draw-down area depend on residual soil moisture after the water receded.

The major growing regions are the North, the Northeast, and the Central Plain. In the South, isolated fields of peanut are grown for local consumption, mainly in young rubber plantations.

Most of the nuts produced (> 98%) are used domestically, and very little (< 2%) is exported as shelled and boiled-dried peanut. However, Thailand imports a considerable amount of peanut cake for animal feed. The demand for peanut is anticipated to increase if peanut quality is improved and consumed products are more diversified.

Major constraints in peanut production are drought (for rain fed crops), low soil fertility, insects, diseases, and weeds. Most farmers are poor and cannot afford high inputs to address these constraints. High labor requirements are also a limiting factor for peanut production, as most of the operations are done manually. Consequently, peanut yields in Thailand are rather low compared with those of the developed countries, even when grown under irrigation. Aflatoxin is another important problem that restricts the use of peanut, both for human consumption and for animal feed. Research is needed to remove these constraints, particularly by technologies appropriate to the different cropping systems and to the available resources of the capital-deficient small farmers.

Peanut Research Prior to 1981

Before 1981, Peanut research in Thailand had been done mostly by the Department of Agriculture, Ministry of Agriculture and Cooperatives, and three agricultural universities (Khon Kaen, Kasetsart, and Chiang Mai). Having the overall responsibility, research of the Department of Agriculture covered all aspects of production technology. At Khon Kaen University, peanut research was a part of the IDRC-funded Semi-Arid Crops Project that emphasized the improvement of peanut for Northeast Thailand. Some work was also done in the closely related Cropping Systems Project. Similarly, peanut research at Kasetsart University was part of the Oil Crops Project. Though research was initiated in several areas, little work had been done at that time. There was no organized research project on peanut at Chiang Mai University, however, peanut research was an integral part of some projects, particularly the Multiple Cropping Project and the Highland Project. Emphasis was on the Chiang Mai Valley and the hilly areas in the North.

Linkage among the various agencies had been on a personal basis, and through conferences, meetings, and exchange of research reports. Work plans had never been discussed among institutes. This had led to fragmentation of research that, often, was not complimentary, and progress had been slow. Though several institutes were working on peanut, each had limited personnel and resources, and many researchers did not work full-time on peanut.

Formulation of a Coordinated Peanut Program

Realizing that with the existing structure progress in research would not be fast enough to support the growing demand for the crop, a coordinated peanut improvement program was formed to combine the strengths of the individual institutes.

The first step in organizing the coordinated peanut program was the peanut workshop held at Khon Kaen University on October 28-30, 1981. In the workshop, production and marketing problems and prospects were examined, past research was reviewed, and future research needs were discussed. The principle of a coordinated peanut program was also agreed upon, with the Department of Agriculture being the core institute and the three universities (Khon Kaen, Kasetsart, and Chiang Mai) being the participating

institutes in the network. Outlines of coordinated research were specified in certain fields, and a working group was formed to serve as a coordinating body.

Following the workshop, further discussions were held, and outlines of future research and scope of work for the individual institutes were specified. Chiang Mai University was not included in the program mainly because there was no organized peanut program as such, though they did have some work on peanut as an integral part of various projects, but cooperation has been sought to ensure overall coordination. The coordinated peanut program between the Department of Agriculture, Khon Kaen University, and Kasetsart University was documented and submitted to IDRC and the USAID-Peanut CRSP for their support. Both donors agreed to support the program in 1982, with IDRC being the main supporter for Khon Kaen University and Kasetsart University and the Peanut CRSP being the main supporter for the Department of Agriculture. Funds from the Peanut CRSP were also made available to Khon Kaen and Kasetsart Universities as well. Later, after the IDRC support ended in 1988, the Peanut CRSP became the sole external supporter for the three institutes.

Coordination Activities

In the Thailand Coordinated Peanut Program, there are three levels of coordinators: the national coordinator, the institute coordinators, and the discipline coordinators. The national coordinator is the Director of the Field Crops Research Institute of the Department of Agriculture or the person he designated (normally the Director of the Khon Kaen Field Crops Research Center where peanut is a mandate crop). He is also the coordinator of the DOA program. Other institute coordinators are project leaders of the KKU and KU programs. The discipline coordinators are key researchers in the different disciplines designated by their respective groups. This organization, however, is formed informally, and coordination is done voluntarily.

The main coordination activity is the national peanut meeting which is held annually. All organizations working on peanut, including the extension agencies, are invited to participate. In some years, selected personnel from the private sector have also been invited. The location is rotated among the participating institutes. The meeting normally starts with presentations on the current situation on production and marketing, followed

162

by reports of progress of research in the past year. This is structured by disciplines, and ends with group discussion on future research plans for the individual disciplines. Sometimes, a panel discussion was organized on a specific topic. In the early years progress of research was reported by each institute in all disciplines. In later years, this was changed to reporting by discipline across institutes, and organized into themes. The members of the disciplinary groups, thus, have to meet before the meeting, normally at night, to coordinate their presentation. This kind of arrangement has helped fostering more coordination of research among institutes. The proceedings of the meetings were published and distributed to participants, concerned organizations (particularly extension), libraries of agricultural universities and colleges, and interested persons.

Up to 1995, 11 meetings were held. Number of participants ranged from 47 to 112, normally around 60-70, and number of institutes involved varied from 7-12. The most important one was the 9th National Peanut Meeting held in 1990 that was a review meeting. This was done by assigning to key researchers in each discipline (one year ahead) the task of reviewing past research in their field. The reviewers, then, presented their reviews and recommendations for future research to all participants in the meeting, followed by group discussion to comment on the presentations. Based on the comments, each report was later revised before being published in the proceedings.

Apart from the regular annual national meeting, the individual disciplinary groups are also encouraged to meet and discuss their work whenever opportunity permits. In practice, some groups met more often than the others. Another opportunity to discuss work plans is when the US collaborators visit our program. These visits were also done regularly, mostly once a year.

Collaboration with the Peanut CRSP

Collaboration between the Thai Peanut Program and The Peanut CRSP was agreed upon in 1982, but actually began in 1983. Phase I of the Peanut CRSP support covered the period from 1983 to 30 June 1987, Phase II from 1 July 1987 to 30 June 1990, and Phase III from 1 July 1990 to 30 June 1995.

During Phase I, areas of collaborative research included breeding and pathology, soil microbiology (rhizobium and mycorrhiza), and utilization. North Carolina State University collaborated with the three Thai institutes (DOA, KKU, and KU) on breeding and pathological research, and with the DOA and KKU on entomological and rhizobial research, while Texas A&M University collaborated with the DOA on mycorrhizal research, and the University of Georgia collaborated with KU on peanut utilization research. These collaborations were done under four Peanut CRSP projects:

(1) Peanut Varietal Improvement for Thailand and Philippines (NCS/BPC/TP),
(2) Management of Arthropods on Peanut in Southeast Asia - Thailand and Philippines (NCS/IM/TP),
(3) Influences of Rhizobia and Mycorrhizae on Nitrogen Fixation and Growth of Peanuts in Thailand and Philippines (NCS-TX/SM/TP), and
(4) Appropriate Technology for Storage/Utilization of Peanut - Thailand and Philippines (GA/FT/TP).

During Phase II and III, there were some changes in scope of work and participating institutes. KU dropped out from breeding work but still participated in pathological research. The project on rhizobia and mycorrhizae was ended. Research on peanut virus diseases was expanded, particularly on peanut stripe virus, for which KKU collaborated with the University of Georgia. Collaboration was done under the Peanut CRSP Project :

Peanut Viruses: Etiology, Epidemiology, and Nature of Resistance (GA/PV/N, TP).

These collaborations and support have enabled the Thai program to expand its research substantially, and have greatly help strengthened the capabilities of Thai peanut researchers.

Impacts and Future Plan

The organization of research into a coordinated program and a series of coordinating activities over the years have encouraged the work plans of the participating institutes to be more integrated. Close personal relationships among researchers have also been developed, leading to good cooperation among institutes. Consequently, research has been progressing at a faster rate than the period before the program was formulated.

164

This, of course, was partly because of the supports from the Peanut CRSP and IDRC, but the integration of work plan resulting from the coordinated program contributed to a considerable extent.

In future, more emphasis will be given to technology transfer, particularly the training of extension personnel on the production practices for large-seeded peanut. A pilot program will also be needed to fit the newly released large-seeded cultivar Khon Kaen 60-3 and the boiling-type cultivar Khon Kaen 60-2 into the existing seed circulation systems of farmers in different areas, and to establish linkage between production and marketing/utilization of the large-seeded cultivar. The program now is able to play a regional role, particularly in assisting the neighboring countries. This is in line with the policy of the Thai government, and some discussions have been done with ICRISAT on this. Certainly, ongoing research will need to be continued, including the role of peanut in sustainable agriculture.

Strategic and Applied Research Advances

166

Strengthening Applied Research In Countries Hosting The Peanut CRSP Program: *The case of the University of Ouagadougou, Burkina Faso*

Dr. Alfred S. Traore[1]

INTRODUCTION

Burkina Faso is a landlocked country in the heart of West Africa. It is a developing country which is among the least developed countries of the world with a per capita income of ca. US $400. Farming (i.e. agriculture and cattle rearing) is the main occupation of its inhabitants (10,000,000 on 274,000 square kilometers).

Burkina Faso has only one university, which is located in Ouagadougou, the capital city. The student population is about 10,000 with 7 to 10% of foreign students.

The University of Ouagadougou is very actively engaged in international, inter-university cooperation. This cooperation is conceived of as a means of enhancing the internal development of the university and of reinforcing its contribution to the development of Burkina Faso. Several USA universities are among the cooperating partners of the University of Ouagadougou. Those which cooperate in the sciences are engaged in three types of projects:

* SECID Project
* Peanut CRSP Project
* Specific projects with some universities such as the University of Georgia, Iowa, etc...

[1] University of Ouagadougou, Burkina Faso

Whatever the type of project engaged in, the key features of the cooperation have always been the training of human resources and the strengthening of applied research with the aim at improving the standards of living of the population.

IMPACT OF THE SECID PROJECT ON THE STRENGTHENING OF THE U. O.

Short presentation of Institute of Rural Development (IDR)

The IDR has been created in 1973. It trains engineers of rural development in three options (Tables 1 and 2).

* Agronomy
* Water and forestry sciences
* Animal breeding

So far, 750 diploma have been delivered in these three sections. The impact of cooperation with the USA universities was determining to obtain such a good result. This cooperation was built up through SECID Project at the beginning.

The objective of the SECID Project

The main objective of the SECID (Human and Agricultural Resource Development) project, which was initiated in 1977, was the improvement of the theoretical and practical training of the Institute of Rural Development (IDR), one of the nine schools of the University of Ouagadougou.

A number of activities have thus been engaged, the main ones being:

a. the strengthening of the teaching staff of IDR through support for the training in the USA, in Master's and PH.D. programs, of a good number of graduates of IDR. Eight of them are now members of the teaching staff of IDR.
b. the qualitative strengthening of the teaching provided at IDR by sending experimented American professors and teachers.
c. the upgrading of training programs at IDR. This included the revision of existing programs and the introduction of new, indispensable, subjects such as rural sociology and project management.

d. the opening of an experimental research station at Gampela (in the outskirts of Ouagadougou) in which field work could be conducted and practical training offered to students of IDR.
e. the equipment of the experimental station with agricultural material and machines, laboratories, motor vehicles, etc. Support for running costs was also provided.
f. the equipment of a computer room with micro-computers and appropriate software.
g. the organization of study visits to the USA for teaching staff, and other technical workers of IDR.

We can conclude that the contribution of this project to the development of IDR, of the University of Ouagadougou and of Burkina Faso as a whole has been considerable.

IMPACT OF THE PEANUT CRSP PROJECT ON THE DEVELOPMENT OF THE U.O..
The Peanut CRSP Project started its activities in 1982 in the areas of entomology and phytopathology. Another component was added in 1988, viz. Food Technology. From then on the University of Ouagadougou has been a reference in francophone Africa for the CRSP project. The good functioning of the project in spite of the economic crisis and the numerous student strikes which paralyzed the other universities of the subregion of West Africa has made of the University of Ouagadougou the favorite training center for foreign students. Their number has kept going up those past three years to the point that today there are about 20 nationalities represented at the UO. Student strikes have not so far been so disruptive as to compromise the academic year, as is frequently the case in the universities of francophone West Africa.

The impact of the CRSP project for the development of our university is considerable. It can be analyzed along the following three lines:

* the strengthening of applied research
* the impact of the CRSP project in the area of training
* the socioeconomic impact of the CRSP project

THE STRENGTHENING OF APPLIED RESEARCH THROUGH THE PEANUT CRSP PROJECT

Several types of interventions under the CRSP program have strongly contributed to its impact on the strengthening of applied research. The following points need special mention:

a. The equipment of the laboratories of entomology, phytopathology and food technology.
b. The provision of appliance for *in situ* observations, which are essential and indispensable for entomological and phytopathological studies.
c. The allocation of a budget to cover the running costs of the afore mentioned laboratories and the execution of the research programs.
d. The financial support provided to researchers to participate in regional or international seminars/colloquia on research on peanut.
e. The development of a network of scientific connections between the University of Ouagadougou, other research institutions (INERA/CNRST/ICRISAT, etc.), American Universities (universities of Georgia, Texas A&M, Alabama A&M, etc.), and even individual researchers.

THE IMPACT OF THE CRSP PROJECT IN THE AREA OF TRAINING

The CRSP project has supported the training of students at undergraduate, graduate, and postgraduate levels.

The support at the undergraduate and graduate levels has been more or less direct but real: it has consisted in the improvement of the production of teaching materials using the facilities that the project has made available, and in the financial support provided to graduate students for the preparation of their memoirs.

Thirteen students from Burkina Faso or from foreign countries (Tchad, Niger, etc) have had financial support for the preparation of their memoirs in agronomy with Dr. Albert P. Ouedraogo, responsible for the Entomology section of the project.

The panel of Phytopathology conducted by Mr. Philippe Sankara supported nine national or foreign students for the preparation of their memoirs.

But the support of the CRSP project has been even more considerable for postgraduate ("3d cycle") students.

In the area of Entomology, one student from Tchad is completing his dissertation under the supervision of Dr. Albert P. Ouedraogo.

In the area of Phytopathology one national female student is completing her master degree dissertation.

In food technology, which is under the responsibility of Dr. Alfred S. Traore, a training program for engineers of food sciences has been set up which uses the equipment and material provided by the project. About twenty students from Burkina Faso, Togo, Tchad or Congo, have been trained since 1989, three other students have been able to prepare their doctoral dissertations since, then; two of them (P. Nikiema and R. Simde) have successfully defended their theses and are now members of the teaching staff of the department of biochemistry and microbiology. The third student, S. Nanema, is about to defend his dissertation. He already takes part in the teaching activities of the department.

It thus appears that the Peanut CRSP Project has contributed to the training of more than 40 national or foreign students; about a dozen among them take part in the teaching and research activities of the University of Ouagadougou.

THE SOCIO-ECONOMIC IMPACT OF THE CRSP-PEANUT PROJECT

By the high quality of the results achieved, the Peanut CRSP Project has clearly contributed to the enhancement of the scientific image of the University of Ouagadougou in West Africa. The relevance of the subject treated with respect to the needs of the population and to the national economy amply justify the keen interest shown by the university and by the political authorities of Burkina Faso in this project.

The scientific results achieved by the project with respect to the production and the technological transformation of the peanut, which is a very important product in the economy of Burkina Faso, have contributed to the improvement of the conditions of

production, presentation and consumption of peanut-based products. Those findings have made it possible to pay particular attention to peanut diseases, insects that may contaminate the gains, and more importantly the aflatoxin that may render it inapt to consumption.

PERSPECTIVES IF THE CRSP PROJECT IS EXTENDED

Several determining actions based on the results of the research undertaken within the CRSP project and aiming at the socioeconomic development of Burkina Faso and of other satellite countries had been envisioned in case the project is extended for another five years:

3. Regional cooperation to further develop research on the peanut to improve its production. This research would now lay emphasis on the study of varieties that resist the diseases and the attacks by insects;
4. The development of postharvest preservation techniques so as to prevent aflatoxin contamination;
3. Sensitizing consumers to pay more attention to the hygienic aspects of the handling of peanut-based products so as to improve their conditions of preservation for marketing;
4. Closer contacts between USA researchers and peanut production companies (SOFIVAR) or companies using the peanut as raw material, so as to favor the emergence of a true local industry of this legume;
5. Strengthening and intensifying the training of trainers with the collaboration of our American partners, so as to answer the growing needs of our various departments at the University of Ouagadougou for qualified teaching and research personnel.

Given such high hopes as described above, we are anxious about the risk that the project may not be extended while the USAID mission in Ouagadougou is closing. The consequences would be.

a. A decrease in the intensity of the cooperation between our university and American universities;
b. A decrease in the level of exchange between burkinabe and American scientists as a result of the reallocation at the local level of USAID support;

c. A slowing up of the training of trainers at the University of Ouagadougou. It can be predicted that the students working with the support of the project will face many difficulties in completing their training if the project was to come to an end at this phase.

CONCLUDING REMARKS

The cooperation between the University of Ouagadougou and USA universities since 1977, as well as with USAID has been a very positive and happy experience. It has contributed to:

- the development and the strengthening of relations between burkinabe and American researchers;
- the training of several engineers of rural development and of doctoral students;
- the strengthening of applied research at the University of Ouagadougou and in the country as a whole. Indeed researchers from the American and the burkinabe side have come to know each other through the SECID and the Peanut CRSP projects and as a result several other projects have been initiated (SANREM CRSP Project, etc.).

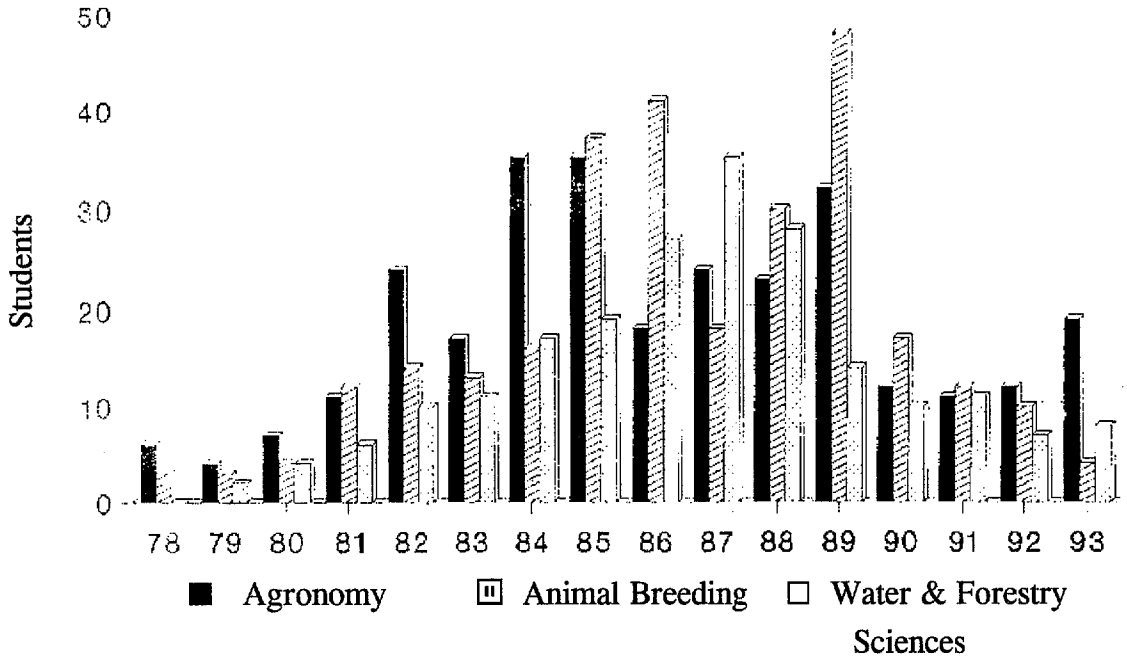

Table 1: Number of Rural Development Engineers trained in IDR from 1978 to 1993 (long term training: 5 years)

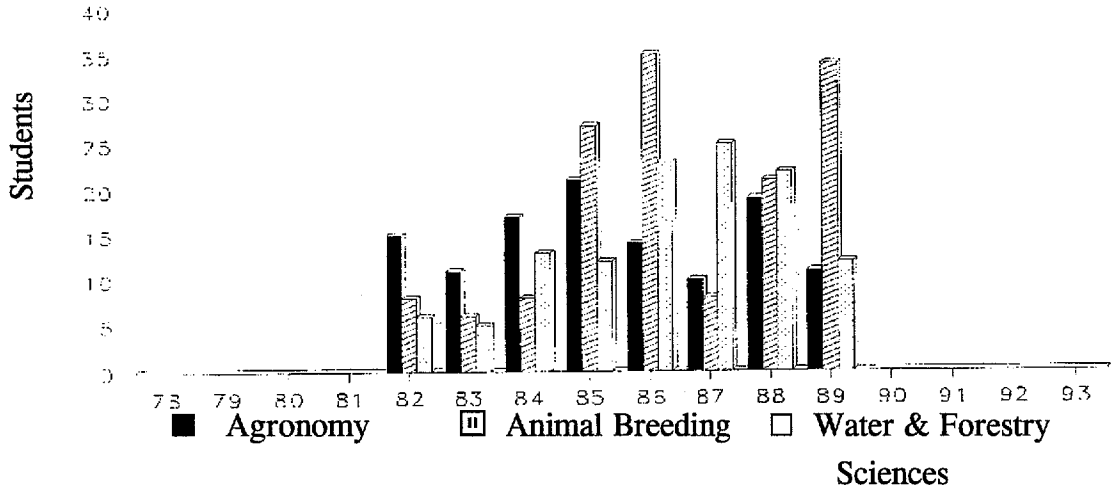

Table 2: Number of Rural Development Engineers trained in IDR from 1978 to 1993 (short term training: 3 years)

174

Networks and Linkages with Regional and International Agricultural Research Centers

D. McDonald[1], R.W. Gibbons[2]

INTRODUCTION

Even from the planning stage Peanut CRSP has sought, and developed, close cooperation with regional and international organizations engaged in peanut research. Reasons for this close cooperation are many, but among the most important is the relative paucity of qualified, full time, peanut researchers on a global basis and perhaps, more importantly, is the need to avoid duplication of research because of limited availability of funds. The cooperation developed has, however, never been at the expense of the close relationship that Peanut CRSP has always maintained with the scientists and organizations of the national programs with which it has worked.

The linkages developed have been various and include direct research cooperation, organization of training, workshops and conferences and also the production of reports and proceedings of scientific meetings. Some cooperation has developed informally, while others have been more formal and have resulted in memorandums of agreement being developed.

Cooperation with Regional and International Organizations

CARDI

Peanut CRSP has developed cooperation with the Caribbean Agricultural Research and Development Institute (CARDI) to develop and extend technology. CARDI is supported

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1 Former Peanut CRSP Board Member and Director of the Legumes Program, ICRISAT, India (from 1992)

2 Former Peanut CRSP Board Member and Executive Director ICRISAT Sahelian Center and West African Programs (until 1992)

by CARICOM (Caribbean Community) which comprises twelve English-speaking countries.

Peanut CRSP has worked in Trinidad, Jamaica, Belize, St. Vincent and Antigua with CARDI. From 1982-87 initial emphasis was on breeding and cultural practices and peanut utilization in food systems. The breeding project identified two suitable cultivars - Kidang in Belize and CARDI-PAYNE in Jamaica. A graduate trainee received a Ph.D. in Food Science under the guidance of Dr. Bharat Singh, Alabama A&M University.

Later a new project was initiated with CARDI involving post harvest handling systems for small scale producers. Achievements have included human resource development, the introduction of threshers in Jamaica and Belize, the improvement of drying and storage operations, the introduction of a pedal powered sheller in Belize, and the production of detailed shop drawings for fabrication of threshers by local machine shops.

French and Francophone Organizations

CIRAD-CA

CIRAD-CA (The French Center for International Agricultural Research and Development, Annual Crops Program) is international but the CRSP relationship is with the peanut section that is mainly concerned with francophone West Africa. CIRAD-CA is the successor body to IHRO (Institute for Oils and Oilseeds Research) and its scientists are located in Montpellier, France and francophone West Africa. Peanut CRSP and CIRAD-CA have a formal memorandum of agreement in Burkina Faso. There is also common interest in the aflatoxin problem and virus diseases.

CORAF

CORAF (Conference des responsables Africains et Francais de la recherche agronomique) is a recently organized network of France and ten former French colonies mainly in West Africa (Burkina Faso, Cameroon, Chad, Congo, Cote d'Ivoire, Guinea, Madagascar, Mali, Niger and Senegal) and is funded by the European Community (EEC) and France. The network headquarters is Bambey (Senegal) which is the Senegal Site for a Peanut CRSP (Texas A&M) breeding project. CORAF is becoming recognized and

accepted more widely in Africa and may become a strong coordinating group for the Region.

IDRC

IDRC (The International Development Research Center, Canada) has worked with Peanut CRSP in Thailand. Projects involved the department of Agriculture (DOA), Kasetsart University (KU) and Khon Kaen University (KKU) were jointly financed. While Peanut CRSP supported all three, IDRC supported the two universities. Projects involved pests, diseases, genetic enhancement and biological nitrogen fixation (BNF).

ACIAR

ACIAR (The Australian Center for International Agricultural Research) and Peanut CRSP developed a program in S.E. Asia mainly on peanut stripe virus which was once perceived as a potential threat to US peanut production. Research took place mainly in Thailand, the Philippines and Indonesia. At regional meetings held in Indonesia research priorities were determined, and further cooperation approved on the use of acid tolerant cultivars developed by the Philippines and Peanut CRSP, in the ACIAR supported acid soil programs in Indonesia and Malaysia.

ICRISAT

Peanut CRSP and ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) have had a long and synergistic relationship. ICRISAT has a global mandate for peanut improvement and is headquartered in Hyderabad, India. It also has smaller research teams based at Lilongwe, Malawi and at the ICRISAT Sahelian Center in Niamey, Niger.

Research Planning and Management

In 1980 Drs. Jackson and Cummins presented their proposed program at the first ICRISAT International Workshop on Groundnuts at Hyderabad, India (Jackson and Cummins, 1980) to an international audience from all major peanut producing countries. In the same year ICRISAT was represented on the planning grant advisory panel by R.W. Gibbons, the ICRISAT Groundnut Program Leader. In 1982 Gibbons was elected as a member of the CRSP Board of Directors. He served until 1992 when he retired

from ICRISAT. He was replaced by D. McDonald, the ICRISAT Director of the Legumes Program. This membership allowed close cooperation between the two organizations and prevented any duplication of research.

Sabbatic Leave

ICRISAT researchers have spent sabbatic leaves in the USA working closely with Peanut CRSP Principal Investigators on their projects.

North Carolina State University
R.W. Gibbons - Program Leader
S.N. Nigam - Principal Breeder
J.P. Moss - Principal Cytogeneticist

University of Georgia
D.V.R. Reddy - Principal Virologist

Texas A&M University
P. Subrahmanyam - Principal Pathologist

Alabama A&M University
Umaid Singh - Senior Biochemist

Dr. V.K. Mehan, Senior Pathologist, spent his sabbatic in Senegal working on aflatoxin in association with the Texas A&M project.

Training

During the early years of Peanut CRSP technicians from Thailand and the Philippines were sponsored by Peanut CRSP to receive their training at the ICRISAT Center in Hyderabad. This training was very cost effective and practical. National Scientists were also sponsored to attend training workshops in S.E. Asia run jointly by Peanut CRSP and ICRISAT. Dr. W. Anderson (NCSU) who completed a post doctoral fellowship at Khon Kaen (Thailand) received genetic materials from ICRISAT and joint publications were published from this cooperation.

Newsletters

Peanut CRSP cooperates with the ICRISAT Center to produce the "International Arachis Newsletter." The newsletter is distributed worldwide to communicate research results to all levels of peanut researchers. The newsletter is published from Hyderabad by ICRISAT and carries the joint logos of the two organizations, and an acknowledgment of the source of the CRSP's funding from grant no. DAN-4048-G-00-0041-00 for the publication of the newsletter.

Publications

Peanut CRSP and ICRISAT have produced many joint publications including journal articles, guides and translations. A few examples are cited.

ICRISAT combined with Peanut CRSP to translate a large report by Morris (1992) into French thus making it much more accessible to francophone readers, as four of the five countries concerned in the report were French speaking.

ICRISAT, Peanut CRSP, and CIRAD also produced a very useful handbook on "Field Diagnosis of Groundnut Diseases" in French and English versions with 75 color plates (P. Subrahmanyam et al, 1992). Authors were from ICRISAT, the University of Georgia, and Khon Kaen University. The handbook is small enough to be used in the field.

Another useful bulletin was produced on Bud Necrosis Virus, the diagnosis of which had previously caused many problems in correct identification of the causal agent (Reddy et al, 1991).

Workshops and Conferences

Peanut CRSP has cooperated with a number of organizations in holding workshops and conferences, both regional and international. One of the largest was the co-sponsorship of the second international workshop on groundnuts at ICRISAT, India. CIRAD was another co-sponsor of this workshop. The proceedings were published as "Groundnut - a Global Perspective" by ICRISAT (1992). Often Peanut CRSP co-sponsored regional workshops with ICRISAT in West and Southern Africa and Southeast Asia, and funded

Principal Investigators from the USA and host counties to attend and present research results. One major accomplishment of these workshops was to enable national researchers to meet and discus common problems with their peers, as very often national budgets were not sufficient to enable researchers to travel to other countries. This stimulated cooperation and encouraged the exchange of information and genetic materials.

Research Cooperation

ICRISAT and Peanut CRSP have cooperated fully in many aspects of peanut research. Breeding materials and germplasm have been exchanged and screened in the USA, India, S.E. Asia and Africa. Many pest resistant lines were identified and are now being used in domestic breeding programs in the USA. Joint breeding projects have been initiated and other areas of cooperative research include biological nitrogen fixation, aflatoxins, viruses and agronomy.

By joint planning duplication has been avoided and individual strengths have been properly utilized. ICRISAT, for example, has done little work on food science and has utilized Peanut CRSP's expertise. ICRISAT has no full time entomologist in West Africa and has fully utilized the services of the Peanut CRSP entomologist from the University of Georgia who works mainly with the Burkina Faso national program. He has regularly visited the ICRISAT Sahelian Center when traveling to West Africa.

Another example of complementarily is research on aflatoxin. Peanut CRSP has paid much attention to the use of absorbent clays to reduce contamination while ICRISAT has concentrated on genetic resistance to the invasion by the fungus.

Multinational Virus Group

In 1983 a planning conference was held at Griffin, Georgia between virus researchers from Peanut CRSP, ICRISAT, Ahmadu Bell University (Nigeria) and the German Virus Institute at Braunshweig to coordinate research on Groundnut Rosette Virus (GRV) which can be devastating in Africa south of the Sahara. Collaborative work on rosette was expanded to include the Scottish Crops Research Institute and a further meeting was held in Cambridge, England in 1985.

190

As Scotland and Germany are not peanut growing countries, live virus specimens were allowed to be imported and for the first time in approximately 70 years GRV was fully categorized. It was shown to have three different viruses involved, one of them being an assistor virus. This was a remarkable example of cooperative research.

The Asian virus group was thus set up to investigate Peanut Stripe Virus (PSV) and cooperating agencies included Khon Kaen University, Thailand, CIRAD (France), ACIAR (Australia), Peanut CRSP and ICRISAT. Meetings were held in 1987, and in 1989 at the ICRISAT Center in India. China and India were also represented at this meeting.

In 1993 the Africa Group, the Asian Group and a Biotechnology Group met together in Dundee, Scotland to review research and coordinate future endeavors. "Working Together on Groundnut Virus Diseases" (ICRISAT 1994) was published from the Dundee meeting.

The working group concept provides

- Priority problem identification and strategies
- Economy in resource utilization by pooling resources
- Development of cooperating teams of scientists
- Stimulus for improved technology exchange

SUMMARY

Peanut CRSP has developed close working relationships with many regional and international organizations that increase research capabilities, maximizes economy of funding and thus increases the capabilities and expertise of national programs.

The External Evaluation Report of Peanut CRSP in 1989 commended Peanut CRSP's relationships with international organizations and stated "they will long be remembered."

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192

Strategic and Applied Research Advances

183

Aspects of Peanut Processing, Packaging and Utilization the Semi Arid Tropics Of Africa: The Case of Burkina Faso

M. Elena Castell-Perez[1], B. Onuma Okezie[2]

INTRODUCTION

The peanut *(Arachis hypogaea L.) is* one of the most widespread legumes in Burkina Faso (approximately 100,000 tons/year) and other countries in the Semi Arid Tropics (SAT) of Africa. It is used as a food source in a variety of forms and it is a means of economic empowerment (Wheelock et al., 1989). However, the role of peanuts as earner of foreign exchange or a cash crop in these countries has declined due to losses in quality brought about especially by mycotoxins. This has created an urgent need to enhance the competitive value and quality of peanuts and to improve the long-term sustainability and profitability of the local agriculture.

The incidence of protein malnutrition is still high in the region and increased attention has been focused on oilseeds as alternative sources of food proteins (Traore and Singh, 1991).

Thus, in the midst of rising concerns over health and nutrition of the world's population, the nature of peanuts - high protein content and popular taste - renders such a commodity particularly appealing for innovative and more effective uses. Peanuts, highly abundant and easily available in the region are consumed in many forms - as roasted seeds, peanut paste, peanut oil and raw or boiled seeds. The high protein content (40-60%) of peanuts makes them best choice for protein fortification in these countries (Singh and Singh,

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1991; Singh, 1992). However, this has not been easy to accomplish because the major constraint in increasing peanut utilization in the Semi Arid Tropics of Africa is the unavailability of peanuts in processed forms. In addition, contamination with insects, rodents, molds and mycotoxins further limits their utility for human consumption. The challenge has been accepted by food scientists and engineers who took the necessary steps to review and upgrade the existing processing methods and quality of traditional peanut products in the region and to investigate ways to improve methods of storage and packaging, processing and product development. These scientists quickly realized that this was not an easy task because new product development implies changes in formulation, processing and packaging that pose constant challenges to food manufacturers, particularly as properties change in response to ingredients used, processing and storage conditions.

Recently, Americans have become very health conscious and there has been considerable increase in the demand for nutritious food items. In the case of peanut, the fat intake is a major concern and research has focused on the development of reduced-fat peanut products and alternative peanut-based food items.

This paper presents specific examples on the application of food technology principles to improve, develop and expand the use of peanuts in the SAT region. It is based on research conducted under the Peanut Collaborative Research Support Program (Peanut CRSP) in Burkina Faso and the United States. Emphasis is given to four major aspects: (1) improvement of staple foods, (2) post-harvest technology methods, (3) safety considerations (aflatoxins), and (4) development of new food items.

FOOD TECHNOLOGY FOR IMPROVED PEANUT UTILIZATION

(1) Improvement of Staple Foods

The major focus has been the enhanced utilization of peanuts by using it as a source of required nutrients in common food items in the diet of the local population. In other words, supplementation of indigenous foods with peanuts to increase the nutrient content thereby having a significant impact on the health and nutritional status of the population. A good example is Toe, a stiff porridge made from sorghum, corn or millet flour. It is the predominant and most consumed food in West Africa, especially in Burkina Faso. It

185

is prepared in a variety of ways to be eaten alone or with a stew and is consumed by almost everyone, from three months old babies to adults of all ages. However, "Toe" is quantitatively and qualitatively poor in proteins. Thus, nutritional improvement of this staple food was attempted by implementing the use of composite flour technology. This has been done with other staple foods such as the sorghum based kisra (Ahmed et al., 1987), cassava-based gari (Singh, 1992) and rice-based idli (Castell-Perez and Mishra, 1995).

Peanut flour was produced - and defatted - locally in Burkina Faso with a proximate composition of 18-20% fat and 43-60% protein. Three cereal flours (sorghum, corn and millet) were supplemented with up to 30% defatted peanut flour (DPF) for preparation of "Toe". The effect of supplementation on processing parameters (temperature and boiling time), chemical, and sensory properties was investigated and results indicated that protein (15-25%) and fat (0.91.6%) contents increased while total sugar and energy levels decreased with supplementation. Sensory studies with locals indicated that the protein enriched "Toe" was acceptable to consumers at 10-20% levels of DPF (Traore, 1993).

IMPACT

Currently, four types of flour for use in infant foods exist in Burkina Faso (MISSOLA, KASONA, DEN-MUGU and VITALINE). Peanut-fortified flours were compared with locally available blends in terms of nutritional value and cost. The purpose was to determine the feasibility of introducing and marketing the new, improved flours for "Toe" manufacture and also for use as weaning foods. It was found that the developed peanut-supplemented flours were cheaper (average cost of $0.10/50g versus $0.25/50g) and more nutritious. Thus, development and marketing of organoleptically acceptable and nutritionally improved flours for preparation of staple and weaning foods are already a reality in Burkina Faso. Also, the traditional flours come from small-scale production centers with distribution and quality control being supervised by the Ministry of Health through nutrition centers. However, appropriate quality control procedures are lacking. Further research is still needed because fortification of cereals affects the nutritional, sensory and rheological properties of the resultant composite flour and an understanding

of its properties is critical for optimization of product and process development efforts and for final product quality.

(2) Post-Harvest Technology

Roasted peanuts, commonly known as "marba-tigue", are widely marketed in Burkina Faso. This product also constitutes the major source of income for a large number of women. However, variation in processing methods among the women processors and inadequate postharvest technology procedures usually result in decreased nutrient quality and stability of the roasted peanuts during storage.

Common problems encountered with roasting procedures are the undesirable brownish color, high nutrient losses and high moisture contents (>20%) which lead to rapid deterioration and consequent economic losses (Traore, 1993). A study was undertaken by the Food Technology

Group at the Universite de Ouagadougou in Burkina Faso to determine proper processing parameters to improve the quality of "marba-tigue". It was noted that the aforementioned quality problems were mainly due to the inappropriate roasting method (temperature and time) and long soaking time (more than three hours), respectively. As a result, the effect of soaking methods (hot versus cold water) and roasting time and temperature (120°C, 150°C and 180C° for up to 10 minutes) on the product nutritional quality was investigated. Soaking the peanut kernels in water at 80°C (pH 8.0) caused an 8% decrease on water soluble proteins as compared to a soaking treatment with water at 27°C which produced minimum losses. Lysine losses were higher (31%) for the high temperature- long time roasting methods. Protein digestibility decreased as a function of degree of roasting and the best results were obtained with peanut kernels roasted on clay at 150°C for 6 minutes (Table 1) (Traore, 1993).

Improvement of quality during storage was also studied. Preliminary work was undertaken to determine a way to inactivate the enzyme peroxidase, responsible for oxidative reactions in the food items. Soaking the peanut kernels in water at 27°C for 2 hours and then in water at 90°C for 5 minutes (blanching) was tested and results showed that the activity of peroxidase decreased from 9.68 p/min/g to 0.61 p/min/g (Traore, 1993). An innovative approach to the problem of quality degradation during storage was

187

the addition of garlic extracts (0, 0.2, 0.25, 0.3, 0.4, 0.5%) to the soaking water previous to blanching. The premise was that the extracts would enhance the flavor of the product as well as improve storage stability of the roasted peanuts. Thiobarbaturic acid (TBA) values were considerably lower for roasted peanuts soaked with 0.5% garlic extract (9.5 mg/kg) than the control samples - 0% extract - (18 mg/kg) after 6 months of storage (Traore, 1993). Peanut paste processing and packaging is another example of the impact of implementation of proper post-harvest technology procedures. CITEC-HUILERIE is a factory located in BoboDioulasso, Burkina Faso, which manufactures oil from peanut kernels and cotton seeds. It also manufactures peanut paste for local distribution. Since November 1992, this factory stopped production of peanut paste because of the high cost of the packaging material which was imported from France (tin cans of 0.5, 1, 5 and 20 kg). Also, the cans size was not satisfactory to the daily requirements of an average family of 10 persons.

Table 1.Effect of Processing Method (Time and Temperature) on the Protein Digestibility of Roasted Peanuts

Roasting Parameters		Protein Digestibility mg/ml
Temperature (C)	Time (min)	
120	12.0	3.0
	16.0	3.0
	10.0	2.9
150	12.0	3.0
	16.0	4.2
	10.0	1.5
180	12.0	1.5
	16.0	1.2
	10.0	0.5

The Food Technology Group at the Universite de Ouagadougou collaborated with the factory personnel to find a solution to this critical problem. Initial experiments to find an alternative package were conducted using a simple plastic bag or can manufactured by a local factory, FASOPLAST. Results showed that the simple plastic bag was unsuitable because high acidity and lipid oxidation occurred rapidly on samples stored up to 5 months. Plastic cans (polyethylene) seem to be the best choice for packaging of the peanut paste. It was also observed that product stability was a problem (oil separation) and research in this area of peanut paste processing and packaging is currently in progress.

IMPACT

Women are very actively involved in the processing, distribution and selling of peanut products in Burkina Faso and other countries in the region. The women (processors) provide the products to the sellers at different locations in the cities - shops, markets, hotels, etc. -. Surveys addressing the problematic issues confronting rural women processors have identified the major obstacles to produce a good quality product. The women have been informed about the results from the aforementioned studies and a process is being established for the development and acquisition of a technical knowledge base among the women for both the production of quality products and for their economic empowerment. Improvement of peanut paste processing and packaging will certainly lead to the betterment of the local economy as well as the understanding of the application of food technology principles to improve product quality and process efficiency.

(3) Safety Considerations (The Aflatoxin Problem)

Aflatoxins are considered a potential hazard to food safety and public health and human beings and animals are exposed to aflatoxin due to contaminated food (Wood, 1989). The most challenging aspect of this problem is that it cannot be totally eliminated by prevailing methods. Assessment of aflatoxin contamination of peanut and peanut products in Burkina Faso showed that this is a serious health problem. As a matter of fact, consumption of aflatoxin-contaminated peanut products has been linked to the occurrence of primary liver cancer in the population of Burkina Faso (Traore, 1993).

A study showed the presence of aflatoxins B1, B2, G1 and G2 on the two local peanut varieties (Boanga and Wobgo), peanut paste, roasted peanuts and sugar nuts consumed in different regions of Burkina Faso. The average toxicity level was 250 ppb. A separate study on the two local peanut varieties - Boanga and Wobgo - indicated that improper storage conditions also induced production of aflatoxins. This was related to the changes in lipid and water content (the higher the lipid and water content the higher the aflatoxin level), two significant factors for mold growth and aflatoxin production during storage of peanuts. Moisture content, aflatoxins content, relative humidity and mean temperature for 18 months storage period were recorded and chemical analyses showed that protein and total sugar losses were of 8.2 % and 7.3 %, respectively, for the two varieties. Lipid loss was less significant, 3.2% for Boanga and 4.5% for the Wobgo variety. Total protein loss, lipid and sugar contents corresponded to an increase in aflatoxin levels, 414 ppb and 582 ppb, for Boanga and Wobgo varieties, respectively.

Research on detoxification strategies includes experiments on growth inhibitors using a strain of *Aspergillus* and extracts of *Allium sativam,* a commonly used item in the diet of the population. Scientists at the Universite de Ouagadougou were encouraged by finding that inhibition occurred when the mold was cultivated with 20% *Allium sativam* extracts at 30°C for 7 days.

IMPACT

Application of results on the use of *Allium sativum* as an inhibitor of aflatoxin growth on stored peanuts will have a tremendous impact on the health of the local population. The same objectives can be extended to other countries such as Ghana where the conditions under which peanuts and their products are sold in the markets predispose them to rancidity development and its associated nutritional and acceptability problems as well as microbiological and mycotoxicological implications.

The potential benefits of the use of *Allium sativum* as an inhibitor of aflatoxins are being further explored in terms of methods of utilization and application. The producers have been notified of the significance of properly handling their products and training is in process.

(4) New Products

The increased demand for healthier food products is a constant challenge for the U.S. food industry. One of the greatest assets of peanut is that almost everyone likes its flavor. In the United States, peanuts are mostly consumed as snacks or in the form of peanut butter. The high protein and fat content render this popular product specially suitable for combining with carbohydrate-based foods and the flavor is compatible with sweet and soft drinks. However, peanut butter has approximately 50% fat (75 % calories from fat). Thus, the need to develop an acceptable product with reduced fat content. However, a simple reduction of fat in existing foods does not lead to foods with the desired characteristics. This has been the major focus of the research conducted at Alabama A&M University on processing modification and product characterization as affected by changes in formulation.

Development of a reduced-fat peanut butter product faces the challenge of several unknown factors determining the final quality of the product, such as flavor and texture losses, nutritional quality and rheological behavior (spreadability and viscosity). The purpose of this research was to formulate a reduced-fat (about 60% reduction of fat calories) peanut butter with similar physico-chemical and sensory characteristics to the traditional peanut butter. Processing modifications were made (oil extraction and roasting methods) to accommodate the changes in formulation. Starch-based fat replacers produced a paste with same rheological behavior (shearthinning) as commercially available products. Sensory evaluation indicated that the reduced-fat product is acceptable to consumers in terms of flavor, texture and spreadability.

Research efforts have also been directed towards addressing the feasibility of extrusion cooking as a processing tool for development of alternative peanut-based food items. Formulation and process parameters were identified for the extrusion preparation of a sorghum peanut wafer (2:1 ratio). A wafer-type product was developed with acceptable texture and improved nutritional characteristics.

191

IMPACT

The Peanut CRSP project has greatly enhanced the research capability of scientists at Alabama A&M University. The projects has helped to expand the uses of a commodity of importance to the state of Alabama. Contributions to the scientific field in the areas of food technology, value-added processing, rheology and engineering are extremely valuable. Also, studies on extrusion show the potential benefits to the local economy of the countries in the SAT regions if extrusion cooking were to be implemented as a means to increase and improve utilization of peanuts in the area.

CONCLUSION

Research efforts have certainly lead to better utilization of peanuts in Burkina Faso. Improved methods of processing, packaging and storage and development of a variety of products are currently part of the post-harvest systems being employed in the country. Better health and nutrition as well as economic possibilities of local producers and processors are certain proofs of the benefits provided by the Peanut CRSP. The improvement and strengthening of the food scientists at the Universite de Ouagadougou are major benefits of the program. Above all, the most important aspect is the possibility of transferring appropriate and useable technology to other countries in the region such as Ghana, Mali, Niger or Senegal.

ACKNOWLEDGMENTS

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Quality Enhancement and Technology Transfer of Peanut Butter

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INTRODUCTION

These studies focused on quality enhancement of peanut butter in the US from a health perspective and the improvement of sensory, physical and health attributes of peanut butter in Belize with implications for other Peanut CRSP host countries.

In the U.S. there is a high per capita consumption of peanut butter because it is a highly desirable ingredient in sandwiches and snack foods. Hydrogenated vegetable oils are used as stabilizers to prevent oil separation in commercial brands of peanut butter. During the hydrogenation process, the unsaturated fatty acids in the vegetable oils are converted to their *trans* isomers. The growing concern about the correlation between human consumption of *trans* fatty acids and increases in total and low-density-lipoprotein serum cholesterol levels (Haumann, 1994). indicate the need for peanut butter stabilizers which contain no *trans* fatty acids. Unhydrogenated palm oil obtained from the mesocarp (flesh) of *Elaeis guineensis* was investigated as an alternative stabilizer for peanut butter because (I) it has physical properties similar to hydrogenated oils (Kheiri, 1985), (ii) it contains no *trans* fatty acids, (iii) it does not demonstrate adverse effects on health (Basiron, and Ibrahim, 1994;Wood, 1992) , and (iv) it would be readily available in many Peanut CRSP host countries e.g. West Africa.

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In the case of Belize, Central America, there was a ban on importation of peanut butter 10 years ago when peanut butter production using locally-grown peanuts was initiated. Since then there has been a decline in purchase and consumption of peanut butter by Belizean consumers. Quality enhancement of Belizean peanut butter was approached from a two-fold perspective. The three local processing companies were visited, processing operations were critiqued and appropriate advice and technical information were provided. Secondly, a consumer evaluation study was carried out to identify acceptable and unacceptable attributes of Belizean peanut butter (5).

Stabilizing Peanut Butter with Palm Oil

Peanut butter formulations containing either hydrogenated vegetable oil (1.5%) or unhydrogenated, deodorized, bleached palm oil (2.0, 2.5 or 3.0%) were prepared from roasted peanuts (Florunner variety) (Hinds, *et al.*, 1994). Hot peanut butter samples were deposited into jars and graduated 25 mL pipets and stored at 15, 25 or 35°C. Oil separation (percent), texture and color of all formulations were measured after 0, 1 and 2 wk storage. Oil separation (percent), was calculated by dividing the volume of oil that separated from the peanut butter by the original volume of peanut butter before oil separation. Firmness of the peanut butter samples was interpreted from the force required for a cylindrical probe to penetrate the peanut butter to a distance of 3.5 cm below the surface. Color attributes (L*, a*, b*) were measured and hue angles (arctangent b*/a*) were calculated. Oil separation (percent) and texture of the experimental products were compared with those of commercial brands of peanut butter. Response surface regression (Box and Draper, 1987) of the data from samples stored at 35°C was used to predict physical properties after > 1 year storage of the experimental peanut butters.

The results indicated that 2.0-2.5% unhydrogenated palm oil would prevent oil separation in peanut butter stored at 21-24°C for at least 1 year. Experimental products containing palm oil were not significantly different in color but were softer than those containing hydrogenated vegetable oil. The stabilizing property of palm oil could be applied to improve textural quality of peanut pastes and other semi-solid peanut products which are indigenous to Peanut CRSP host countries e.g. Africa.

Technology Transfer of Peanut Butter to Belize

In September 1994, the three Belizean peanut butter factories were visited, consumer evaluation of peanut butters was carried out and a training workshop on testing peanuts for aflatoxin was held (Hinds, 1994).

Peanut Butter manufacture in Belize

Quality of the raw materials and unsuitable formulations and processing operations all contributed to the poor quality attributes (viz. oil separation, lumpy texture, little or no roasted peanut flavor, noticeable off flavor e.g. caramel, oily, bitter) of the Belizean peanut butters.

Major improprieties observed at the Belizean peanut butter factories were:

(a) Raw materials:

- varieties of peanuts were not ascertained
- nuts were of mixed maturity stages - no grading was done
- moisture and fat contents and aflatoxin levels in seeds were not tested

(b) Formulations:

- sweeteners: one manufacturer used an aqueous solution of white cane sugar while another used a mixture of brown cane sugar and molasses
- stabilizers: one manufacturer used coconut oil (no fixed proportion) while another used a 1:3 ratio of partially hydrogenated vegetable oil to peanut paste in addition to 4% fully hydrogenated vegetable oil.

(c) Processing operations:

- peanuts were roasted in shells
- hearts were not removed from seeds
- factory 1: peanuts were ground with sugar, salt and hydrogenated vegetable oil to 71-74°C, the mixture was cooled overnight to 21°C and then corn oil was blended into the mixture before the jars were filled.
- factory 2: all ingredients were ground in a screw-propeller mill, the paste obtained was warmer than room temperature (27-32°C) but temperatures of paste and butter were not monitored, no heat was applied during grinding/mixing or when hydrogenated vegetable oil was added.

- factory 3: ground peanuts, brown cane sugar, salt, coconut oil and molasses were blended at < 43°C in a kettle, and the resulting mixture was passed through a finisher used for making chocolate candy bars.
- Jars were either filled manually with peanut butter at 32-38°C or at room temperature (27-32°C) or filled mechanically with butter at 21-27°C.
- Jars containing freshly-prepared peanut butter were not cooled but stored at 27-32°C until they were sold to retailers.

Consumer Evaluation of Peanut Butters

CARDI (Caribbean Agricultural Research and Development Institute, Belize) recruited consumers from the eastern, central and western regions of Belize. A total of 63 panelists (35 teens and 28 adults) evaluated eight coded peanut butters, three of which were manufactured in Belize, one was a CARICOM (Caribbean Common Market) brand which had been recently imported into Belize, and four were prepared at the University of Georgia, Griffin (UGA) from Belizean-grown peanuts. Acceptability, purchase intention and 10 attributes related to appearance, flavor and mouth feel of the eight peanut butters were evaluated by each panelist.

Responses (% of panelists) to acceptability and intention to purchase the peanut butter samples are presented in Table 1. All three Belizean brands of peanut butter tasted too oily and the brand which contained molasses was too sweet. 48-78% of the panelists indicated that they would not buy the Belizean manufactured products compared with 57-71% who were willing to buy peanut butters prepared at UGA from Belizean peanuts. Mean scores indicated that the Belizean products were 'disliked moderately' to 'disliked slightly' compared with 'liked slightly' to 'liked moderately' for samples prepared at UGA from Belizean-grown peanuts. The results indicated that Belizean-grown peanuts are suitable for peanut butter production but manufacturing practices need to be improved.

Table 1. Consumer Responses (%) to Acceptability and Intention to Purchase Peanut Butters

	Belizean Brands			CARICOM Product	UGA Product *
	1	2	3		
Like	38.1	25.4	15.9	20.6	77.8
Dislike	47.6	66.7	76.2	25.4	11.1
Would buy	23.8	11.1	9.5	44.4	71.4
Would not buy	47.6	63.5	77.8	31.7	4.8

* Made from Tennessee Red peanuts grown in Belize, 2% corn oil was used in formulation.

Assistance Provided to Belizean Peanut Butter Manufacturers

1. On each site visit, appropriate alternative formulations, equipment needed and processing operations to improve product quality were explained to the owner/manager of the factory. Samples of roasted, blanched peanuts were given to factory personnel for use as references. Brochures containing technical information including typical formulations and standard practices in the U.S. (Woodroof, 1983.) were also provided.
2. A detailed list of pertinent recommendations (arising from the factory visit and consumer evaluation study) to improve the quality of the products was mailed to each factory.

Aflatoxin Training Workshop

The 17 participants included farmers, extension officers, peanut butter manufacturers and laboratory personnel from CARDI and the Ministry of Agriculture. Discussions were held on the carcinogenic effects of aflatoxin, practices to reduce the incidence of mold contamination of peanuts and to sensitize participants to the importance of testing peanuts and peanut products for aflatoxin. Seventy five percent of the workshop was devoted to

hands-on training of the participants. Each trainee had the opportunity to prepare peanut samples and analytical testing solutions and to conduct a complete test using a chromatography mini-column (Target ™, Terratek Company, USA). Laboratory guides prepared at UGA were provided for the workshop and for subsequent needs of the participants.

Major Outcomes of Technology Transfer

1. Peanut butter manufacturers in Belize received technical information at site visits, follow-up brochures to improve processing operations and overall quality of peanut butter, and recommendations from consumer study to alter formulations. To date, two of the processors have implemented some changes to improve the quality of their products.
2. Information and training in Aflatoxin testing was provided to persons in various sectors of the Belizean peanut industry. Since then CARDI has initiated a system to screen farmers' peanuts for Aflatoxin using the Target Test.
3. The staff of CARDI (Belize) learnt how to conduct a Consumer Evaluation Study. This means that in future they would be able to monitor the quality of Belizean-manufactured peanut butter.

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199

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Improving The Nutritional Value of Foods Through The Use of Peanut

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INTRODUCTION

During the planning stages of the Peanut Collaborative Research Program (CRSP), established in Thailand, Philippines and other selected countries in late 1981, discussions revealed that appropriate storage and utilization of peanut were constraints that existed in the consumer delivery system. As a result a project entitled "Appropriate Technology for Storage/Utilization of Peanut" was initiated in July 1983 to investigate low cost methods of storage and their attendant consequences. The lead research team was affiliated with the Department of Food Science and Technology at the University of Georgia, Griffin. The host institution was Kasetsart University (Department of Product Development) and the linkage institution was the University of the Philippines at Los

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Banos (Institute of Food Science and Technology). In 1993, Visayas State College of Agriculture (Department of Agricultural Chemistry and Food Science) in Leyte, Philippines joined the project as a second linkage institution.
A major problem associated with inadequate storage conditions is the growth of molds (*Aspergillus flavus* and *Aspergillus parasiticus*) on peanuts and consequent accumulation of aflatoxins. Initial research efforts in the project were therefore heavily directed toward evaluating and developing handling, sorting, processing, packaging and storage procedures that would minimize the level of aflatoxins in peanuts and peanut products reaching the consumer in Thailand and Philippines.

Another major objective in the project in its early stages was to obtain baseline consumption data for the Thai and Filipino populations. Of particular interest was the need to learn the role peanut played in supplying nutrients in the diets of Thais and Filipinos. Information from these surveys, as well as from numerous subsequent surveys done to determine consumer peanut products, has enabled project researchers at all collaborating institutions to make significant advances in providing highly acceptable peanut-based or peanut-supplemented foods with greatly enhanced nutritional value.

The processing, packaging and distribution technologies developed during this investigation are available for use by national and international food processing and delivery systems. Examples of transfer of peanut utilization technologies in Huay-Bong-Nue village, Thailand and in Ormoc and Guadalupe, Philippines are presented elsewhere in these Proceedings. From the many accomplishments and impacts of our project over the years of its existence, we have been asked to review those aspects dealing with utilization of peanut to improve the nutritional status of foods. The space limitation for this summary means only a few examples will be discussed briefly. Emphasis is given to research carried out in Thailand and the Philippines. Detailed descriptions of research and development activities are available in annual reports of the Peanut CRSP and in M.S. theses, Pd.D. dissertations, scientific journal articles, abstracts, bulletins, brochures, newspaper articles and proceedings from several workshops organized by project team members and supported by the Peanut CRSP.

202

Product Development and Modification with the Goal of Improving Nutritional Status

Thailand

Flour from Thai-grown Peanuts

In Thailand, peanuts are mostly consumed boiled, roasted, fried, ground and in confections. Peanut flour can easily be made from peanut press cake that is a by-product from the peanut oil industry. Peanut cake currently is used as a supplement in the animal feed industry. However, a high level of quality control in the production of peanut flour from peanut cake must be maintained to minimize aflatoxin content and maintain protein nutritive value and acceptable sensory qualities when it is incorporated into a wide range of potential new products. For these reasons, studies were done to determine the suitability of Tainan-9 and SK-38 peanuts for making flour. Peanuts were hand sorted and defective seeds were removed. Peanuts were analyzed for aflatoxin content and only those in which no aflatoxin was detected were used to prepare flour. Flour processing involved blanching the peanuts, pressing the peanuts hydraulically and grinding the press cake using a centrifugal grinder. The flour had an off-white color and a fat content less than one-half of the original amount in the whole peanut. The protein content in flour was nearly 50% more than that in the whole seed. Although the efficiency of the mechanical process for preparing the flour was low, this study did prove that an acceptable product can be produced from Thai cultivars for use in developing new food products.

Thai Sausage Supplemented with Peanut Flour

The basic sausage formula used in these experiments is one generally used in northeastern Thailand. The product depends on lactic acid bacterial fermentation and is served as an appetizer with vegetables such as Chinese lettuce, Chinese parsley and sliced young ginger root either at restaurants or by vendors. Peanut flour was used to replace ground pork at levels of 10, 15, 20 and 25%. Both raw and roasted flour were evaluated. Since the product originated from northeastern Thailand, preferences of Thais in various parts of the country were different. Some considered the product to be unclean because natural casing was used and fermentation takes place. Some did not like the sausage because making it in the home was inconvenient. Questions concerning price, serving, odor, flavor, texture, preference and purchase intention were asked.

Results showed that consumers thought that Thai sausage containing peanut flour had a good odor (75%), regular flavor (50%) and good smooth texture (50%). The sensory qualities of Thai sausage containing 25% roasted peanut flour were quite acceptable. Thai sausage containing roasted peanut flour has great potential for the Thai consumer market.

Sommanut Cookie Supplemented with Peanut Flour

Experiments were done to evaluate the performance of partially defatted roasted peanut flour in sommanut, a Thai cookie. A typical formula consists of egg white, sugar, shredded coconut and salt. Egg white is beaten until fluffy and sugar is added during beating at high speed. Roasted peanut flour was used to replace shredded coconut in the basic recipe. No significant difference existed among treatments for odor, color, flavor and overall preference. The mean scores for these quality factors indicated that sommanut cookies containing roasted peanut flour are a highly acceptable product containing more protein than sommanut prepared using the traditional recipe.

Chicken Patties Extended with Flour

Important benefits of using vegetable proteins as meat extenders include cost reduction and increased product yields. Limited work has been done to evaluate the performance of peanut flour when added to comminuted meats. Beef consumption in Thailand is limited because of its low quality. However, chicken is a popular meat among Thai people. The objective of this study was to determine the quality attributes of ground chicken extended with defatted (DPF) and partially defatted (PDPF) peanut flours (Chompreeda *et al.*, 1994.). Peanut flour from each treatment was added to ground chicken meat and the other ingredients. Cooking losses and shrinkage of extended ground chicken patties were less than those of the pure chicken pattie control. Extending ground chicken with peanut flour increased the percentage of water retained by patties during cooking. Shear forces required to compress extended patties were less than those required for the control. The higher water-retention properties of extended ground chicken patties evidently contributed to their increased tenderness as indicated by lower compression values. Extended chicken patties stored in vacuum bags at -18°C did not undergo changes in sensory qualities for at least 12 weeks. Fifty-five percent of 109 consumers tested reported that they liked the extended patties while 36% neither liked

204

nor disliked the product. Comminuted chicken and other meats hold potential as vehicles to use peanut press cake from oil extraction operations for reducing the cost of meat products without substantially sacrificing nutritional quality.

Noodles Supplemented with Peanut Flour

Chinese-type noodles are an important staple food in Asia and growing in popularity worldwide. Yellow noodles, free of any darkening or discoloration, with sufficient firmness to give a clean bite without being tough, and some degree of springiness or elasticity is preferred. High-protein legume flours are easily incorporated as a partial replacement of wheat flour in noodles. This effort was to study the effects of supplementation of Chinese type noodles with defatted peanut flour on physical and sensory quality characteristics of cooked oven-dried and deep-fried noodles (Chompreeda *et al.*, 1988).

Results show that supplementation of Chinese type noodles with as much as 15% defatted peanut flour and 8% cowpea flour effectively increases the protein content to 21% without significantly sacrificing color or textural quality attributes (Chompreeda *et al.*, 1988). Data allowed the amount of cowpea and peanut flour necessary to produce acceptable quality characteristics while also providing a desired level of protein to be estimated. This prompted a study to learn the amino acid profile and nutritional quality [protein efficiency ratio (PER)] of noodles. The PER of supplemented noodles was 50% of the casein control. Based on their highly acceptable sensory and nutritional qualities, a supplemented noodle would be an excellent vehicle for enhancing the nutritional status of low income populations in Thailand and other southeast Asian countries.

Because of the very promising results from studies on peanut-supplemented noodles prepared in the laboratory, a study was done to expand production to an industrial scale. Supplemented Chinese-type noodles were produced in Thai Preserved Food factory in Bangkok. Defatted peanut flour (11.5%) was used to replace wheat flour in noodles without causing problems with processing equipment. The factory produced one batch of noodles that consisted of 6,000 aluminum foil packages. The protein content of peanut-supplemented noodles was 50% higher than that of the control. Consumer tests designed to evaluate peanut-supplemented noodles were conducted using three groups of

participants. One test was conducted at Kasetsart University using 200 participants. A second test was conducted at the Department of Food Science and Technology, University of Georgia using 114 participants. Noodles were prepared as in the first test, except that chicken seasoning was used instead of Tom Yum seasoning. A third test was done with 120 students (age 9-12 years) from a secondary school in the Nakorn-Patom area of Thailand. Chicken seasoning was also added to the noodles served to these consumers. Results showed that all groups of consumers accepted the peanut-supplemented noodles. The U.S. consumers liked this kind of noodle more than the Thai consumers did. This may be due to the soft texture of the noodle. Thai and U.S. consumers recognize the nutritive value of peanut-supplemented noodles as a reason for buying enhanced noodles in the future, if they were available.

Infant Food Containing Roasted Peanut Flour

The development of lowcost nutritious infant foods using partially roasted peanut flour produced by small industries was investigated. Formulation to meet the nutritional requirement for infants used linear programming. A mixture of partially roasted peanut flour, rice meal, sesame meal, egg, sugar, full-fat dried milk, mashed papaya and natural orange flavor was processed into a supplementary food for infants. A dough was formed, rolled into sheets and baked. The product was then ground, packaged and stored in aluminum foil bags at room temperature. Consumer panelists rated all sensory characteristics of infant food as acceptable. Raw material cost for the dried infant food was 32 Bht/kg. At this price, low and medium income families can afford to purchase the product, thereby improving the nutritional status of their children.

Supplementary Food for Pre-School Children

Development of a supplementary food for preschool children involved the use of linear programming to formulate a product with minimum cost and high nutritive value. The formulation contained rice flour, peanut flour, mung bean flour, sesame meal, milk, egg, papaya puree, sugar, water, orange flavoring, vitamin C, vitamin A and iodized salt. The process consisted of mixing ingredients, extruding, forming, cutting, steaming, pressing to form a thin sheet by using two rollers, then baking, cooling and sealing in aluminum foil pouches. Nutritional qualities of the product met the Thai FDA requirement. The cost of the supplementary food was 5.97% Bht/25 g. Results of

acceptability tests using 100 target consumers from each of five regions in Thailand, indicated that everyone accepted all aspects of quality.

Snacks for School-Age Children

Linear programming was used to develop four formulas for crisp snacks for school-age children, aiming at low ingredient cost and a product containing 25% of the RDA of nutrients for children of age 7-9 years. The sources of protein used in formulas were skim milk powder, egg yolk, whole peanut flour and defatted peanut flour. Preparation of snacks was very simple and is suitable for use in rural areas. Results show that the four formulas, especially one containing whole peanut flour, were accepted by panelists. The recipe with whole peanut flour received the highest score for overall acceptability. The protein, vitamin A, thiamine, niacin, calcium, phosphorous and iron contents in all formulas were higher than in the commercial snacks. According to the Index of Nutritional Quality (INQ) formulas containing skim milk powder, whole peanut flour and defatted peanut flour would be considered as nutritious snacks. The protein and iron met the ¼ RDA requirement; vitamin A content was lower than the specified requirement. However, this requirement could be met by adding vitamin A during preparation. Although the snack formula containing added egg yolk was not classified as nutritious by INQ, it contained more than the ¼ RDA of protein and iron. When the cost of production, availability of raw materials, method of preparation, acceptability and nutritive values were considered, recipes containing egg yolk and whole peanut flour were recommended for extension to the community. With improvements in texture and nutrient content, most formulas could be introduced on a commercial scale.

Extruded Snack Containing Peanut Flour and Pregelantinized Starch

Extruded snacks are produced mainly from cereals, tubers and legumes, either individually or in combination. Extruded snacks are usually produced as a snack base which is then seasoned before packaging. These snacks are generally very low in nutritive value, especially protein content, because starch is the main component. The purpose of this study was to improve nutritive quality of an extruded snack and to transfer this technology to the industry in anticipation that it will be commercialized.

Defatted peanut flour produced from Tainan-9 peanut at the Thai Department of Agriculture pilot oil extraction plant was used as a protein source for snack formulas. Pregelatinized tapioca starch was mixed with defatted peanut flour and baking powder to prepare the snack base. The effects of various amounts of baking powder and pregelatinized starch on extension ratio, puffing ratio, bulk density and compressive force of the snack base were investigated. Results suggested that the extension ratio and bulk density were not affected by baking powder and pregelatinized starch in the mixture. Both ingredients affected the puffing ratio and compression force of the snack base. The extension ratio and bulk density were not affected by the baking powder and pregelatinized starch in the mixture. Response surface methodology was employed to set the optimum formula. It was concluded that a snack base composed of 33% defatted peanut flour, 46% pregelatinized starch and 21% water should be used.

The study was conducted at a snack factory in Thailand using a single screw extruder. The ingredients in the snack base were formulated by modifying the original formula used by the factory. Defatted peanut flour was used in the formula To provide at least 10% protein. To study shelf-life of the extruded snacks, products were packaged in polypropylene and aluminum bags and stored at 25°C and room temperature (30°C) for six weeks. Sensory analysis of the stored snack revealed that panelists still accepted all products at the end of six weeks.

Tube Feeding Product Containing Peanut

A prototype tube feeding product consisting of whole egg powder, pumpkin, peanut protein, whole milk powder, maltodextrin and water was developed. Spray drying the mixture produced a good quality, light yellow powder with a good aroma. Additional studies were devoted to evaluating sources of protein (peanut and soybean) and vitamin A (pumpkin and carrot) in tube feeding formulas. Peanut protein isolate in combination with carrots gave the best quality tube feeding formula. The product exhibited no foaming characteristics, and had a yellow color and a mild sweet aroma. It was concluded that peanut protein isolate is suitable as a protein source, and carrot is a suitable vitamin A source in a tube feeding formula.

208

Peanut Butter Spread

The prospect of developing modified peanut butter products such as a spread containing peanut butter and tropical fruit preserves, jam, fruit butter or fruit paste was explored. Spreads containing pineapple, banana, papaya jam and fruit paste were evaluated. Difficulty was encountered in obtaining a homogenous mixture. Nonhomogeneous ingredients made it difficult to study the most acceptable viscosity of the various formulations. Spreadability of the products needs improvement. However, preliminary studies using a sensory panel indicated that a mixture of banana and papaya at the ratio of 1:3 (75% peanut butter) was acceptable.

Replacing fruit paste with drum-dried fruit powder was investigated. This study had as its goal the development of a peanut spread containing banana, papaya and durian powders mixed with peanut butter. Durian powder was introduced in the study because it is a popular natural fruit flavor among many Thais. Results showed that peanut spreads mixed at ratios of 1:1 (powder: peanut butter) and 1:2 were unacceptable because the products were dry and cracked, and fruit flavors were too strong to be compatible with peanut butter flavor. A ratio of 1:3 was moderately accepted, but a mixture of 20% fruit powder and 80% peanut butter was highly acceptable.

Peanut Butter Bar

While some Thais do not like peanut butter because of its texture, candy bars are highly acceptable among most Thais, and it was hypothesized that many people would accept such bars containing peanut butter. A Kaset Peanut Bar was therefore formulated which contained 72% fine ground roasted peanuts, 12% maltose syrup, 9.5% fine ground sugar, 3% roasted desiccated coconut, 2% fine ground roasted rice, 1% roasted sesame seed and 0.5% salt. A questionnaire consisting of 100 questions was prepared to obtain background information on the consumers, preference for the product, the price willing to pay for the product, the packaging expected and the frequency of eating. Two hundred and fifty-one questionnaires were randomly distributed to consumers of different backgrounds. Results showed that more than 57% of the consumers preferred this product at high to highest levels. About 74% of the consumers indicated interest in buying the product.

Peanut Tofu Spread

A non-traditional peanut spread was identified in survey work as having good potential for acceptance. This product was perceived as a nutritious, convenient food, and therefore was selected as a model system for development. Peanut tofu was used as a basic component in developing the spread since soybean tofu (a product similar) is well accepted and has been appropriate for development of spread-type products such as tofu dressing and mayonnaise. The objectives were to prepare "peanut milk" which retained maximum extracted protein content and minimum lipoxygenase activity, and to prepare peanut tofu by coagulating peanut milk with $CaSO_4$ or citric acid (Sukumsuvun *et al.*, 1992). Another objective was to optimize the formulation of spreads prepared from peanut tofu such that sensory qualities would be highly acceptable.

Tofu coagulated with $CaSO_4$ or citric acid were used as base ingredients for the successful development of chocolate and tangerine flavored spreads, respectively. This process resulted in minimum lipoxygenase activity and maximum protein extraction. Optimization of the amounts of ingredients (sugar, starch, colorants and flavoring agents) in spread formulations was achieved from data collected from sensory evaluation tests using non-Thai and Thai university students as panel members.

Chocolate Flavored Peanut Beverage

Milk-like beverages prepared from oilseeds have great potential as nutritional substitutes in areas where cows' milk is too expensive or indigestible. A study was undertaken to develop a chocolate flavored peanut beverage. The objectives were to optimize the sugar and chocolate ratio in the beverage and to investigate consumer acceptability of the product (Chompreeda *et al.*, 1989.). Defatted peanut flour was used to prepare peanut protein isolate by an aqueous extraction method.

Chocolate flavored peanut beverage formulas were subjected to consumer panel evaluation. Fifty-five untrained panel members were asked to evaluate color, aroma, flavor and overall appearance. These sensory characteristics were rated acceptable by 96% of the consumer panel members. Consumers liked or liked extremely well all characteristics of the beverage. Most of the consumers were willing to pay 4.5 bahts for 250 ml of chocolate flavored peanut beverage.

Peanut Tempeh

Tempeh is an Indonesian product prepared by mold fermentation of soybeans. The objectives of this study were to investigate fermentation processes for making tempeh from peanuts and to evaluate the acceptability of peanut tempeh as an ingredient in other products. Thai sausage was supplemented with 30% partially defatted peanut flour or 30% dried ground tempeh. Color and flavor were not significantly different. Texture and overall preference for extended Thai sausage containing peanut tempeh were significantly higher than that for sausage containing partially defatted peanut flour.

Flavoring (Seasoning) Sauce from Peanut Press Cake

Peanut press cake was studied as a base for preparing a flavoring sauce. An acid hydrolysis method was employed. The ratio of peanut press cake to acid, acid concentration and hydrolysis conditions were studied. Preliminary results showed that a ratio of 1:4 (peanut press cake to HCl acid) and digestion at 121°C for 3 h gave the best sauce. However, the chemical composition, particularly the total nitrogen content, amino acid nitrogen and sodium chloride content, did not meet the Thai standard for sauce. Therefore casein and mungbean protein isolates were added to increase total nitrogen content and amino acid nitrogen. The control consisted of sauce containing only peanut press cake. The mixture of mungbean protein isolate and peanut cake containing 70% protein resulted in a total nitrogen content which met the Thai standard.

Philippines

Development of a Film from Peanut

Peanut milk prepared using a 1:8 ratio (peanut: water) was used to produce yuba (peanut film). Glycerol at 1.0 and 2.5% levels was added and its effect on strength properties of films was determined. Full-fat (1:6, 1:7, 1:8 and 1:9 [peanut:water] ratios) and partially defatted (1:8 and 1:10) milk supplemented with 2.5% glycerol were also prepared, and the effect of the dilution on chemical and physical properties of films was determined. Increasing levels of glycerol caused an increase in breaking strength and a decrease in hardness of yuba. The amount of water used did not affect the chemical composition of films. However, tests for tensile strength revealed that formulations containing the least amount of water and made from full-fat or partially defatted peanut milk produced the strongest films. Partially defatted films, although containing a higher

amount of water-soluble constituents, were generally stronger than full-fat films. Scanning electron microscopy also revealed that partially defatted films have a more uniform and compact structure than full-fat films in which fat globules are liberally distributed.

Chemical analysis revealed that relative amounts of protein, fat and carbohydrate differ, depending upon when the film is withdrawn from the heated peanut/water/glycerol composite. The rate of drying may affect the amount of water in the films. Rapid drying yields films with higher solubles compared with films dried at a slower rate. Incorporation of glycerol into formulas results in a decrease in hardness of films. A study of the sensory qualities of films as affected by storage revealed that full-fat films develop "off" odors due to oxidation more rapidly than defatted films.

Development of Peanut Curd

Development of food products from peanuts offers potential opportunities for extending protein sources beyond currently accepted foods. Overall objectives were to increase the utilization of peanut as a source of nutrients for the consumer by developing new food products and to improve the quality of existing peanut products. Soft peanut curd was prepared from roasted and blanched peanuts. Various concentrations of firming agents ($CaC1_2$, $CaSO_4$, $MgC1_2$ and agar-agar) were added separately to peanut milk and resulting curds were evaluated for flavor, aftertaste, texture, aroma and acceptability.

Among the firming agents added to peanut milk, $CaSO_4$ was the most acceptable. No bitter taste was present when $CaSO_4$ was used as a firming agent. Addition of 0.3 and 0.4% agar-agar produced a palatable soft curd that was comparable to conventional soft curd made from soybeans. The addition of sugar improved the flavor of soft peanut curd by masking the strong raw peanut flavor considered to be unacceptable. Sweetness (14-16°Brix) improved the flavor of the curd. Roasting followed by steam blanching produced a flavor considered acceptable.

Fermented Peanut Milk

Studies were done to evaluate aqueous extracts of peanuts as substrates to produce fermented products similar to yogurt, buttermilk and other products based on animal

milk. Five lactic acid bacteria (*Lactobacillus acidophilus, L. bulgaricus, L. helveticus, Streptococcus diacetylactis* and *S. thermophilus*) were investigated for their fermentative capabilities. All test strains except *L. bulgaricus* produced acid in sufficient qualities to reduce the pH and cause coagulation of peanut milk. Approximately 0.11% titratable acidity was needed to cause coagulation. Coagulation occurred when the pH was reduced to about 5.0 and after 4-8 h of incubation. *L. bulgaricus* produced appreciable amounts of acid in 11% reconstituted skim milk and appreciably lowered the pH but caused only slight visible changes in peanut milk. The rate of decrease of pH was slow. *L. acidophilus, L. helveticus, S. diacetylactis* and *S. thermophilus* grew much faster than *L. bulgaricus*; pH was higher in peanut milk inoculated with *L. bulgaricus*. Fermented blanched, peanut beverages had a firm yogurt consistency, with syneresis occurring after eight h fermentations. The production of nutritious fermented peanut milk products with high acceptability seems feasible.

Pork- and Liver-Flavored Spreads

Spreads flavored with pork and liver were developed using the residue from peanut milk production as a base. Peanut milk residues were obtained from the extraction of peanut milk using a 1:6 peanut to water ratio. Steaming and grinding, alone or in combination, were applied to residues before using them as a base for preparing spreads. The desired qualities for a spread base are bland flavor and light color. Various formulations were made using pork and liver flavorings, alone and in combination. A predetermined level of spices (white pepper, mustard, paprika and nutmeg), MSG, salt, sugar, skim milk and food colors were also added. Hydrolyzed plant protein was pretested for addition to the formulations. These formulations were analyzed for proximate composition, a_w, pH, color, hardness and sensory evaluation. Protein content was significantly higher in the commercial sample of liver spread compared with residue-based spreads. Fat content was higher in residue-based spreads than in the liver spread but lower than in the potted meat product. Fiber and carbohydrate contents were higher in the residue-based spreads than in the commercial spreads, because they are from a plant source. Water activity values ranged from 0.94-0.95 and are similar to those of commercial products, while pH values are slightly higher (average 6.0) than that of traditional liver spread (5.8) and potted meat (5.6). General acceptability scores showed that spreads containing pork-liver flavor combinations had higher ratings than samples containing individual flavors.

Results suggest that peanut milk residue can be used as a base for meat spreads, although steaming and grinding of the samples are needed to enhance quality. Heat treatment is also recommended, since the spread has very high a_w and is in the low-acid food group.

Peanut Milk Concentrate

The development of protein-rich peanut milk concentrates has been investigated. The effect of heat and various concentrations of sodium bicarbonate on the reduction of off-flavor in peanut milk concentrate was determined. The effect of heat on the quality of peanut milk concentrate prepared in a traditional manner was determined using three different methods of processing. Sensory evaluation revealed that boiling peanuts after the soaking process significantly reduces the beany and earthy flavors in peanut milk concentrate. However, higher acceptability was observed when the hot water grinding method was employed compared with the concentrate prepared from peanuts which were only boiled. A combination of boiling and hot water grinding did not result in significant differences in end-product quality. Although sensory scores were relatively high for this product, much of the protein was denatured. The hot water grind method results in a significantly higher protein content compared with the other methods. It was concluded that the 75°C hot water grinding method gives a highly acceptable peanut concentrate with high protein content.

Peanut-Enriched Sweet Potato Snacks

The development and transfer of technologies using peanut in sweet potato snack products are described elsewhere in these Proceedings. It is important to note that, although this project was initiated by researchers at ViSCA in 1993, substantial progress has been made in developing village-based entreprizes to manufacture and market peanut-supplemented snacks traditionally containing low levels of protein (Palomar *et al.*, 1994). Achieving the goals of this new dimension of the project will result in demonstrated transfer of technology simultaneously with increased consumption of snacks with improved nutritional quality.

University of Georgia

Work on nutritional aspects of this project has largely been conducted in Thailand and the Philippines. While work at the University of Georgia to enhance the quality and

increase the consumption of peanuts and peanut products has had positive impact in terms of increased protein consumption, the major thrust of the research at the University of Georgia has not been devoted to characterizing the nutritional aspects of peanuts. Rather, fundamental and applied research on aflatoxin removal, functionally of peanut by-products, techniques for sensory evaluation and fermentation technologies have received primary attention. Results from these investigations as well as other studies done by Thai and Filipino researchers that are not nutrition related are described in annual reports, bulletins, newspaper articles, journal articles and abstracts. The reader is encouraged to seek out these reports for a more thorough account of research accomplishments achieved during the life of this project.

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We are extremely grateful to all technical, student and clerical staff who have made extraordinary contributions to achieving the objectives of this project. Appreciation is also extended to respective institutions who, out of commitment to international Food Science and Technology, have provided financial support in great excess of USAID requirements or expectations.

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Sensory Evaluation in Utilization of Peanuts in Value-added Products

A.V.A. Resurreccion[1]

Sensory Evaluation

Sensory quality. The definition of sensory quality is the acceptance of the sensory characteristics of a product by consumers who are regular users of the product category or who comprise the target market for the product. Dr. Roland Harper in 1981 developed a scheme that specifies the interrelationships between the affective value or hedonic value of a food and its sensory and physico-chemical attributes. In his scheme, physico-chemical variables are related to sensory variables in a psycho physical relationship between stimulus and sensations; and there are relationships between those sensations and hedonic variables. This relationship is called psycho hedonic because there are two types of psychological variables. It was noted that efforts to explain sensory acceptance on the basis of physico-chemical variables directly have not been very successful because the sensory variables are often ignored.

A strategic approach to utilization of peanuts in value-added products is shown in Fig. 1

It involves as the very first step, the identification of the product. Identification of the product is based on consumer food consumption patterns and food preferences. This is followed by identification of the critical attributes, usually by focus groups. Critical attributes in prototypes are quantified using affective tests, descriptive analysis and physico-chemical measurements. These tests provide the basis for establishing product

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specifications using consumer responses. The prototype product is modified according to specifications. The modified prototype is tested to determine consumer response. Models are verified, and final products are developed that have the attributes that are valued by consumers as important. This method is recommended for use in the development of value-added products. The final product is one that is ready for commercial adoption--it is not the final product. Manufacturing capabilities and adaptation to large scale production will result in appropriate modifications. If adopted, the strategic process will minimize the probability associated with the large percentage of product failure in the marketplace.

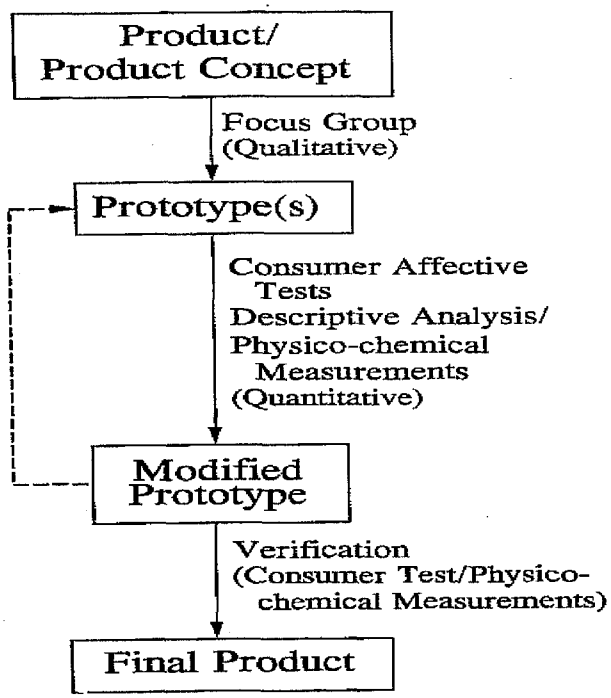

Fig. 1. A strategic approach to utilization of peanut in value-added products.

Consumer affective tests. Consumer affective tests are used to quantify quality. This type of sensory evaluation method involves acceptance and preference tests involving consumers. Acceptance tests measure acceptability or liking for a food. Preference tests

212

measure appeal of one product over another. "Attribute diagnostics" measure consumer responses to attributes which determine a product's preference or acceptance.

The nine-point hedonic scale has been used and validated in the scientific literature and has been used most frequently in consumer affective tests. In some cases as in testing with children or special target populations a nine point "smiley face" scale is appropriate.

Most of the consumer we conduct to determine consumer acceptance of value-added products are laboratory tests as opposed to central location or home placement tests. Conducting the tests in the sensory laboratory which provide highly controlled testing and sample preparation conditions. Samples are served to consumers using a sample pass-through to minimize contact between researchers and consumers. Consumers rate products in individual partitioned booths to minimize any interaction between panelists during a test.

Physico-chemical measurements. Instrumental and chemical measurements are used to quantify those product attributes that consumers like or dislike. Some of the physico-chemical measurements obtained are for color -- measured using the colorimeter (L, a, b); flavor -- using the gas chromatograph to quantify flavor volatiles; tastes -- analyzed by chemical analysis of tastants such as sodium chloride, and sucrose; texture -- using the Instron universal testing machine for measurements of textural parameters; and viscosity -- using the Brookfield viscometer.

Descriptive analysis. Quite often, it is not possible to quantify intensity of a critical sensory attribute through instrumental, physical or chemical measurements. In cases such as these, sensory descriptive analysis methods are recommended. Several descriptive analysis methods are cited in the literature. These include the flavor profile methods, quantitative descriptive analysis (QDA), the spectrum method or hybrids of these methods.

In general, descriptive analysis requires a panel leader trained in the descriptive analysis techniques. Subjects develop terminology, definitions, evaluation techniques and references. The method requires 10-12 highly trained panelists who have been calibrated

to rate intensities of the attributes to be evaluated. Panelists evaluate products in partitioned booths. A 150-mm unstructured line scale for each attribute is used to rate attribute intensities. Each scale is displayed on a computer video terminal and intensity ratings are entered by panelists using the cursor keys on a computer keyboard.

Quantification of sensory quality. Quantification of the sensory quality of the food involves plotting consumer hedonic ratings against physico-chemical measurements or the attribute ratings from the descriptive analysis. The plots may result in plots that show no relationship, linear or quadratic relationships. These curves (Fig. 2 and 3) help the researcher to determine specifications for the product. In Fig. 2, if the researcher sets quality ratings for overall acceptance at 6.5 (1=dislike extremely; 9=like extremely) which corresponds to "like slightly" and "like moderately," the attribute intensity rating must fall between 5.8 to 9.9 on a 15-mm line scale (58 to 99 on a 150-mm line scale). If the researcher sets specifications to correspond to a hedonic score of 6.0, product specifications are broader at 4.9 to 10.9 (49 to 109 on a 150-mm line scale). The specifications, for the attribute, that meet the predetermined quality rating for overall acceptance by consumers represent a broad range of attribute intensities.

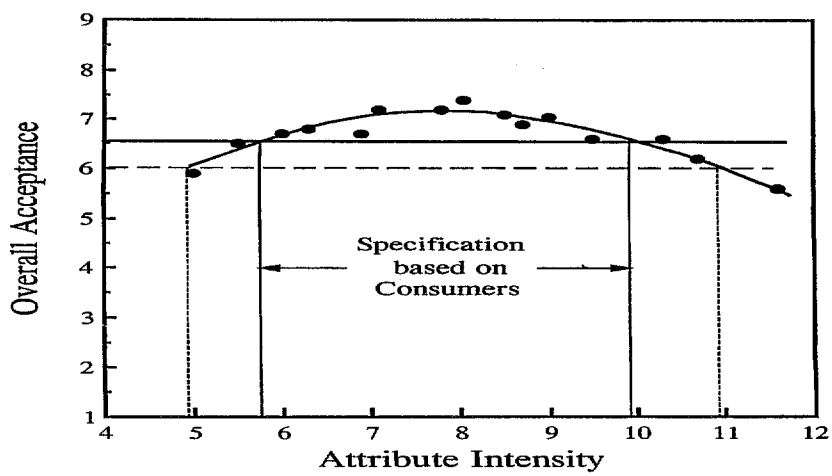

Fig. 2. Establishment of specifications based on consumer response. Overall acceptance was measured using a consumer panel that rated product on a 9-point hedonic scale (1=dislike extremely; 9=like extremely). Attribute intensity was determined from mean ratings by a descriptive panel using a 15-point (150-mm) line scale.

220

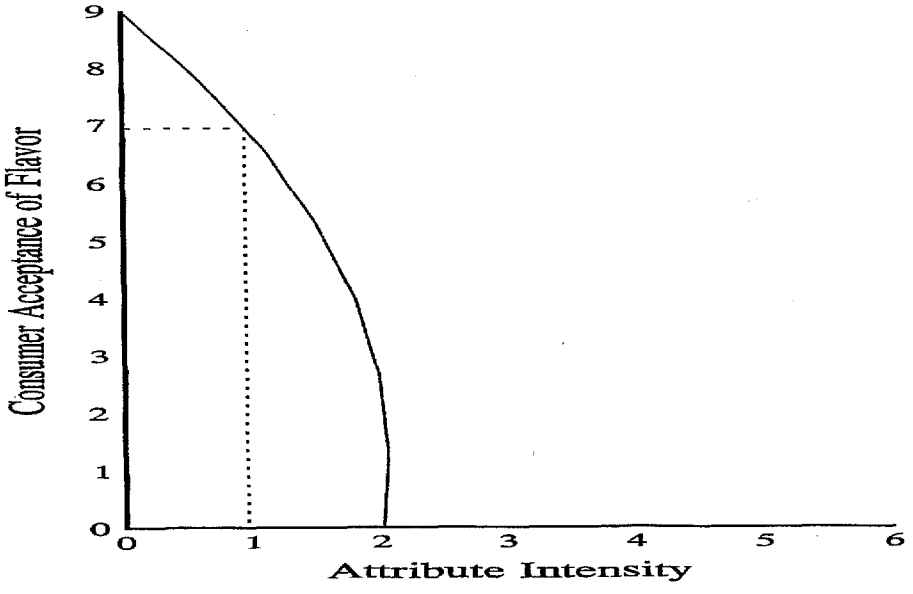

Fig. 3. Consumer acceptance of flavor and intensity ratings of an off-note. Flavor acceptance was measured using a consumer panel that rated flavor on a 9-point hedonic scale (1=dislike extremely; 9=like extremely). Flavor intensity was determined from mean ratings by a descriptive panel using a 15-point (150-mm) line scale.

Certain attributes have a very narrow range for acceptability. An off-note such as the oxidized flavor in peanut butter may have a strong influence across a very narrow range (Fig. 3). This example shows that when scores for oxidized flavor are higher than 1 on a 15-point scale consumer acceptance very rapidly decreases. Prediction equations allow for a simple computational task to determine the acceptance implication of perceptually different experimental samples. Regression models are used; the relationships may be linear or higher order.

Sensory Evaluation of Peanut Products

Sensory evaluation was used in our laboratory in the study of peanut products. These include peanut beverage (Galvez and Resurreccion, 1990; Rubico et al., 1988), coffee whitener from peanut (Malundo and Resurreccion, 1993 and 1994), peanut-based whipped topping (Abdullah et al., 1993), peanut paste and spreads (Santos and Resurreccion, 1989; Muego-Gnanasekharan and Resurreccion, 1992; Muego-Gnanasekharan et al., 1993), peanut supplemented oriental noodles (Chompreeda

221

et al., 1987, 1988), and muffins (Holt et al., 1992a) and tortillas (Holt et al., 1992b) from peanut flour.

Peanut beverage. Milk type beverage formulations can be made from peanuts. These have the potential for use as a substitute for cow's milk especially in developing countries where there is inadequate dairy production. An off-flavor, if present in the milk, is likely to limit consumer acceptance of this product. In studies conducted in our laboratory, we found that "peanut beverage from full fat peanuts were whiter and less chalky than beverages prepared from partially defatted kernels. " Rubico et al. (1988) found that increasing the processing temperature for peanut beverage resulted in significant increases in cooked flavor and odor and raw/beany odor; chalkiness was not different in samples; and increasing processing temperature resulted in darkening of the beverage (Table 1). By using regression analysis we found that processing time had a more significant effect than homogenization pressure on sensory attributes of peanut beverage processed at 100 and 121 °C. (Galvez and Resurreccion, 1990).

Peanut-based coffee whitener. Peanut extract was used to prepare coffee whiteners in dry and liquid forms (Malundo and Resurreccion, 1993 and 1994). Mixture response surface methodology was used to optimize the formulation of liquid whitener prepared using varying levels of peanut extract cottonseed oil, and water. Prediction models were used to generate contour plots. Overall acceptability was the limiting response for the optimum product. Use of under 50% peanut extract in the blend resulted in acceptable product. The maximum amount of oil in acceptable formulations was 1 % of the component blend. Increasing the proportions of peanut extract increased sensory ratings for roasted nutty and peanutty flavors. Increasing oil increased ratings for oily flavor and decreased astringency, and increased surface layer thickness and the tendency of the oil phase to separate from the product after processing.

The significant findings of this study were that aqueous peanut extract can be used in an acceptable liquid whitener at 20-40% of the formulation and hydrogenated oil may be eliminated from the formulation using 1.6% mono- and diglyceride emulsifiers to enhance whitening power.

Peanut-based whipped topping. We investigated the formulation of a peanut milkbased whipped topping from aqueous extract of peanut (Abdullah et al., 1993). In formulation and evaluation studies, we found that the physico-chemical characteristics of peanut-based whipped topping compared favorably with commercial dairy-whipped topping. In optimization studies, we found that acceptable formulations may be obtained by using 40% peanut milk, 17% corn syrup and 13-19% fat.

Peanut spreads. Peanut based products consumed as spreads on bread or crackers were developed and evaluated for sensory quality (Santos and Resurreccion, 1989; MuegoGnanasekharan and Resurreccion, 1992; Muego-Gnanasekharan et al., 1993). A cheese flavored spread was prepared from a paste from peanuts that were subjected to water extraction to remove some of the precursors of the roasted peanut flavor.

We studied the effect of temperature, time and number of water extractions on the physico-chemical and flavor characteristics of the peanuts and found that temperatures of 30 experimental samples. Regression models are used; the relationships may be linear or higher order.

Sensory Evaluation of Peanut Products

Sensory evaluation was used in our laboratory in the study of peanut products. These include peanut beverage (Galvez and Resurreccion, 1990; Rubico et al., 1988), coffee whitener from peanut (Malundo and Resurreccion, 1993 and 1994), peanut-based whipped topping (Abdullah et al., 1993), peanut paste and spreads (Santos and Resurreccion, 1989; Muego-Gnanasekharan and Resurreccion, 1992; Muego-Gnanasekharan et al., 1993), peanut supplemented oriental noodles (Chompreeda et al., 1987, 1988), and muffins (Holt et al., 1992a) and tortillas (Holt et al., 1992b) from peanut flour.

Peanut beverage. Milk type beverage formulations can be made from peanuts. These have the potential for use as a substitute for cow's milk especially in developing countries where there is inadequate dairy production. An off-flavor, if present in the milk, is likely to limit consumer acceptance of this product. In studies conducted in our laboratory, we found that "peanut beverage from full fat peanuts were whiter and less chalky than

beverages prepared from partially defatted kernels. " Rubico et al. (1988) found that increasing the processing temperature for peanut beverage resulted in significant increases in cooked flavor and odor and raw/beany odor; chalkiness was not different in samples; and increasing processing temperature resulted in darkening of the beverage (Table 1). By using regression analysis we found that processing time had a more significant effect than homogenization pressure on sensory attributes of peanut beverage processed at 100 and 121 °C. (Galvez and Resurreccion, 1990).

Peanut-based coffee whitener. Peanut extract was used to prepare coffee whiteners in dry and liquid forms (Malundo and Resurreccion, 1993 and 1994). Mixture response surface 90°C significantly affected peanut color and flavor. Increased extractions produced darker colored peanuts with less raw peanut flavor but more cooked peanut flavor. We concluded that water extraction at 90°C for 10 min would produce a light colored bland peanut.

In a second study, a narrower range of temperatures was used with a constant extraction time of 10 min. Extraction was done 2-4 times. We measured the effect of extraction conditions on color, hexanal which is responsible for the beany flavor and sensory attributes. The optimum water extraction conditions were 90°C, for 10 min each for 3 passes.

224

Table 1 - Mean Sensory evaluation ratings[a] for peanut beverage processed at different temperature and time[b]

	Temperature (°C)		
Sensory attributes	85	100	121
Flavor			
Raw	67.0	60.0	52.4
Cooked	54.7b	62.2a	64. la
Beany			
Aftertaste	64.9a	69.3a	63.4a
Odor			
Raw	59.0ab	50. lb	58.6a
Cooked	47.7b	50.2ab	58.6a
Viscosity	60.9b	66.2ab	72.8a
Chalkiness	41.3	45.4	45.1
Color	55.5b	60.5b	71.3a

a Scales used were 150 mm line scales anchored with description at both ends. Descriptors for each of the attributes were 'weak' and 'strong' for raw flavor and cooked flavor; 'thin' (like water) to 'thick' (like buttermilk) for viscosity; 'imperceptible' to 'highly perceptible' for chalkiness; 'very beany' to 'not beany' for aftertaste and 'light' to 'dark' for color.

b Values in the same row for temperature and time followed by the same letter are notsignificantly different ($P \leq 0.05$).

Next we determined changes when peanut was stored at 30, 40, and 50°C (Muego-Gnanasekharan and Resurreccion, 1992). Sampling was every 2 weeks for the first month, monthly for the next five months, and after one year. Strong oxidized flavors

225

developed in pastes stored at 189 days at 40 and 50°C. Pastes that did not have objectionable flavors were evaluated after 189 and 366 days of storage. Graininess increased slightly. Chroma reached a maximum at 161 days. Hue decreased with time indicating progressive browning. When oxidized flavor is used as an indicator of storage deterioration, peanut paste has a predicted shelf-life of 152, 98, and 96 days at 30, 40 and 50°C respectively.

Peanut supplemented noodles. We partially defatted peanuts, ground it to a flour and used the flour in the preparation of oriental style noodles (Chompreeda et al., 1987). Consumers prefer yellow noodles free from discoloration or darkening, with sufficient firmness without being tough with some degree of springiness or elasticity.

Noodles were prepared from wheat flour which served as control (C) and mixtures which were prepared by replacing 10, 20 and 30% of the wheat flour with peanut flour (Table 2). Lightness of the control was greater than that from blended flours. As the level of peanut flour increased, the noodles became darker. The force and energy to cut the noodles decreased as peanut flour increased. Flavor intensity, firmness, yellow color and lightness of the noodles decreased with increasing levels of peanut flour used in the blend.

Composite flours. Defatted peanut flour was used in composite flours which were used to optimize muffins (Holt et al., 1992a) and tortillas (Holt et al., 1992b). Mixture response surface methodology was used to determine mixtures that would result in muffins and tortillas with sensory properties similar to control. Blends depend on relative proportions not on the total formulations and combinations of components must equal 100%.

Muffins are a popular food, therefore we did not use a consumer panel but used a control consisting of muffins from 100% wheat flour. Sensory analysis involved a descriptive panel consisting of 10 experienced panelists and was conducted in two parts, to evaluate: (1) visual appearance, and (2) mouth feel, taste and flavor. Prediction models were developed for those sensory attributes which had a coefficient of determination (R

1926

square) greater than 0.70. These were tunneling, grainy flavor, beany flavor, sheen, internal color lightness, and cell size.

Table 2 - Effect of peanut supplementation on color lightness, texture and sensory ratings of cook fresh noodles prepared from wheat-peanut blended flours

	Peanut flour (%)			
Measurement	0	10	20	30
Hunter color values				
Color lightness, L	60.18ba	58.34b	56.58c	56.16c
Instron texture measures				
Maximum cutting force (N)	0.37a	0.31b	0.21c	0.14d
Cutting Energy (J x 10-3)	2.70a	2.33b	1.47c	0.80d
Sensory attributes				
Flavor intensity	82.10a	78.06ab	74.69bc	68.04c
Texture-firmness	74.96a	68.10b	45.83c	22.92d
Color-yellow	84.15a	66.06a	42.04c	26.85d
Color-lightness	77.04a	57.13b	44.04c	26.85d

a Value in each row not having a common letter are significantly different at P ≤0.05.
b Unstructured category line scales; (Flavor intensity, 0 = strong, raw peanut flavor, 100 = bland; Texture, 0 = softy and mushy, 100 = firm and elastic; Color yellow, 0 = pale yellow, 100 = bright yellow; Color-lightness, 0 = dark, 100 = light).

Contour plots for each attribute were prepared using the predication equations developed and areas were marked which correspond to those formulations which would result in muffins with attribute ratings similar to those made from 100% wheat flour. The plots were superimposed and the area of overlap was outlined. The area of overlap shows the flour mixtures that would result in muffins that are similar to control, except for the beany flavor. If the beany flavor is removed, the range of mixtures that would produce muffins similar to the control is much narrower. Prediction models were verified.

We found that if wheat flour replacement is less than 50%, nonwheat flour may be present at the following levels: cowpea, O to 43%; peanut, 0 to 44%; no cassava and no sorghum. If wheat flour replacement is 50% or greater, nonwheat flours may be present at the following levels: cowpea, O to 43%; peanut, 0 to 44%; cassava, 49 to 76%, except for mixtures containing: O to 70% cowpea, 21 to 31 % peanut, and 70 to 72% cassava.

We used similar methodology to determine mixtures that would result in tortillas with sensory properties similar to that of tortillas from 100% wheat flour (Holt et al., 1992b). Contour plots for the attributes sensory color lightness, yellow color, gray color, instrumental color lightness, chrome, hue, beany flavor, sweet aromatic, doughy flavor, baked wheat flavor, and bitter taste were generated. Areas of the plot for each attribute, that represent formulations that would result in an attribute intensity similar to control, were shaded. The contour plots were overlain resulting in a region of overlap of the shaded areas. The area of overlap corresponds to mixtures which would produce tortillas with sensory properties similar to a 100% wheat control. Optimizing based on 11 attributes - color lightness, yellowness, grayness, beany, sweet aromatic, and doughy flavors, bitter taste, and instrumental color values of lightness, chrome and hue - indicated that successful substitution of wheat flour with 0 to 24% cowpea flour, 0 to 46% peanut flour, and combinations of cowpea and peanut flours within the above limits, would result in tortillas with quality characteristics similar to 100% wheat.

Conclusion

In conclusion, sensory evaluation is critical in research on the utilization of peanuts in value-added products. It is important in defining product attributes that are valued by consumers of the product and in the development and optimization of these products.

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The Incidence of Aflatoxin in Stored Groundnut in Ghana and The Effects of Some Plant Extracts on Growth of *Aspergillus parasiticus* and on Aflatoxin Synthesis

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INTRODUCTION

In Ghana, Groundnut (*Arachis hypogaea* L.) is an important food and oil crop. Much of the total national production of 113,000 metric tons (Anon., 1991) is in the Upper West, Upper East and Northern Regions of the country. These areas are within the Guinea and Sudan Savannas with an annual rainfall of about 1000 mm. Some amount of groundnut production takes place in the transitional belt around Takyiman, Kintampo and Atebubu (all in the Brong Ahafo Region) and Ejura in the Ashanti Region. The crop is also grown in the Volta, Western, Eastern, and Central Regions of the country, although production in these areas is relatively minor.

A major problem facing groundnut production in Ghana is decay and subsequent aflatoxin contamination of the seeds. Aflatoxins are carcinogenic compounds produced by *Aspergillus flavus* Link ex Fries and A. *parasiticus Speare*. Groundnut contaminated by aflatoxins is unsuitable for human and animal consumption because the aflatoxins can cause serious health problems (Enomoto and Saito, 1972; Cheng, 1992).

Even though considerable concern has been expressed in Ghana about the groundnut aflatoxin problem, studies highlighting the national importance of the problem are lacking, and the few studies attempting to address the problem have been limited in scope

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(Beardwood, 1964; Mintah and Hunter, 1989). Nor are we aware of any study in Ghana focussing on the inhibition of the aflatoxigenic fungi and control of aflatoxin synthesis.

The present research is an attempt to establish the level of contamination of stored groundnut in Ghana by fungi and aflatoxins. Results of our work on the effects of certain plant extracts on growth of *A. parasiticus* and on aflatoxin synthesis are also briefly presented.

Materials and Methods

Groundnut samples stored for 6-8 months were collected from markets in each of the ten regions of Ghana. Samples from a market were bulked together, sorted out into undamaged and damaged seeds, and the percentage of damaged seeds estimated. Fungi associated with the seeds were assayed on half strength potato-dextrose agar and identified using appropriate texts. Aflatoxins were extracted from the seeds following the method of Pons (1979). They were identified and quantified by reversed phase liquid chromatography with post column iodine derivatization (Shepherd and Gilbert, 1984). Eighteen plant extracts were tested for anti-Aspergillus and anti-aflatoxigenic action. Extracts were prepared as steam distillates, hot water infusions, and pure oils. The assay was accomplished on two aflatoxin inducing media, viz. Yeast Extract Sucrose (YES) medium and ½ strength Potato Dextrose Broth (PDB). Four milliliters of media in screw-capped vials were amended with 0.2 ml of each plant extract, inoculated with a Norsolorinic Acid (NOR) mutant of *A. parasiticus* (Keller et al. 1994) and incubated for eight days. NOR is a visible orange colored intermediate in the aflatoxin synthesis pathway and its absence from a vial shows absence of aflatoxins.

Results and Discussion

Damage in groundnut samples collected from all ten regions in Ghana ranged from 1.5 to 9.25% (Average 3.8%). Although we had expected a higher level of damage in seeds from the more humid parts of the country, we could not detect such a trend. Of the two aflatoxigenic fungi, *A. flavus* was more frequent, being observed in 31.7% of damaged seeds and from 12.8% of undamaged seeds. *Aspergillus parasiticus* was not as commonly encountered and was absent from 37 of the 42 groundnut samples assayed.

A. *niger van Thieghem* was recorded in high frequencies on both healthy (29%) and damaged (39%) seeds. Metabolites from this fungus have occasionally been shown to be toxic, so it may be useful to analyze the isolates of *A. niger* from groundnut for mycotoxins in the future.

Other fungi encountered on both damaged and unhealthy seeds, although in extremely low frequencies, were *A. candidus* Link, *A. tamarii* Kita, *A. ochraceous* Wilhelm, *Penicillium* spp, a *Trichoderma* sp, *Rhizopus stolonifer*, and a *Mucor* species. A few unidentifiable fungal species were also encountered. Some of these fungi have been reported as residents of stored peanuts (Joffe and Borut, 1966) and can produce toxins other than aflatoxins.

Aflatoxin was detected in all the damaged seed samples (Table 1). Most of these samples were characterized by aflatoxin levels greater than the WHO recommended limit of 30 ppb. Aflatoxins were not detected in some of the undamaged seed samples, and even when present in such seeds the levels were generally very low (Table 1). Thus, the groundnut aflatoxin problem in Ghana may be partly solved by sorting out damaged seeds from undamaged ones - which should not be difficult to do since the damage to groundnut in storage is low.

Steam distillates from *Xylopia aethiopica* (Dunal) Rich, *Monodera myrstica* (Gaerth), *Cinnamomum verum* Presl. and hot water infusion from *Piper nigrum* L. completely inhibited NOR formation in PDB. However, these extracts were ineffective in the YES medium. In preliminary experiments, however, we have noted that at concentrations of >0.5 ml /4 ml YES medium, distillates from *Ocimum gratissimum* L., *Cymbopogon citratus* (D.C.) Stapf. and *Xylopia aethiopica* completely prevented growth of *A. parasiticus*. This agrees with a previous report of anti-fungal activity by extracts from these three Ghanaian traditional medicinal plants (Awuah, 1989). Extracts from these plants and also those from *C. verum* and *Syzygium aromaticum*, which also completely inhibited fungal growth in the present study, should be considered for use in treating groundnut seeds to control the aflatoxin producing fungi.

232

Table 1. Aflatoxin levels in damaged and undamaged peanut seeds in Ghana.

	Total Aflatoxin Levels (ppb)1	
City/Town	Damaged seeds	Undamaged seeds
Accra (Greater Accra)	75.6	ND
Ashiaman (Greater Accra)	12.2	ND
Mankessim (Central)	17.7	0.2
Cape Coast (Central)	860.6	1.4
Koforidua (Eastern)	5.7	0.1
Takoradi (Western)	13144.3	ND
Kumasi (Ashanti)	105.0	0.4
Ho (Volta)	22168.0	ND
Sunyani (Brong-Ahafo)	54.2	ND
Takyiman (Brong-Ahafo)	5530.1	ND
Tamale (Northern)	71.4	0.5
Wa (Upper West)	14.5	ND
Navrongo (Upper East)	3505.2	154.2
Bolgatanga (Upper East)	301.8	12.2

1 ND = None detected.

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Genetics of Aflatoxin Biosynthesis in Aspergillus Fungi

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SUMMARY

Aspergillus spp. constitute a major portion of the mycotoxin producing fungi that contaminate US and world food supplies. Several species, including A. *flavus*, A. *nidulans* and A. *parasiticus* produce one or both of the toxic and carcinogenic metabolites aflatoxin (AF) and sterigmatocystin (ST). AF and ST are products of the same biosynthetic pathway (Figure 1) and these compounds are found contaminating diverse foods including peanuts, corn, tree nuts, cheese, milk and meat. A compilation of epidemiological studies, feeding studies, biochemical and chemical studies have established that both compounds cause mammalian hepatocarcinomas and are classified as carcinogens. Consequently, strict national and international standards of allowable amounts of AF (more commonly analyzed than ST levels) in food supplies have been imposed to protect public health. These standards have traditionally been met by destroying contaminated food products or by decontamination using ammoniation or aluminosilicate sorbtion. Compliance to these regulations causes the loss of millions of dollars in produce in the USA each year; trade sanctions and health effects likely triple these losses. In third world nations that do not have the ways, means or luxury to destroy contaminated foods, a high incidence of human liver cancers is correlated in certain geographic areas with the ingestion of AFs. In fact, it has been shown that AF induced liver cancer is linked to a specific mutation in the tumor suppresser gene p53. The longterm goal of our research is to provide alternative methods for meeting the stringent standards imposed on food products by identifying novel means for controlling fungal AF and ST production. We hope to achieve this goal through understanding how ST/AF production is regulated in fungi. We are isolating and characterizing genes identified in both *Aspergillus* and host plants which are required for ST/AF production. An

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235

understanding of the molecular genetic processes controlling the expression of these genes will allow us to elucidate measures to suppress ST/AF biosynthesis in nature.

Aspergillus Genes

Because ST and AF are final end products of the same lengthy biosynthetic pathway, we are using the genetically accessible ST producing fungus *Aspergillus nidulans* as an experimental model to unravel the molecular genetics of AF production. In collaboration with Dr. Thomas Adams' laboratory (Dept. of Biology, Texas A&M University), we have isolated and began to characterize many of the genes required for ST/AF production in A. *nidulans*. We have identified a ~ 60 kb gene cluster containing 25 genes proposed to encode bot-h enzymatic activities and regulatory proteins necessary for ST and AF biosynthesis (Figure 2). This 60 kb cluster appears to be conserved as a 'package' in A. *flavus*, A. *parasiticus* and A. *nidulans*. We demonstrated that the A. *flavus* AF regulatory gene, *aflR*, can activate expression of A. *nidulans* ST genes indicating a conservation of regulatory mechanisms in these clusters. We have also identified the A. *nidulans aflR* homologue in the ST cluster. This has helped to focus our question from what regulates AF/ST biosynthesis to what regulates *aflR* expression. We now plan to examine the molecular factors controlling expression of *aflR* and of other genes required for ST production in order to elucidate measures to suppress ST/AF biosynthesis in nature.

Environmental Factors

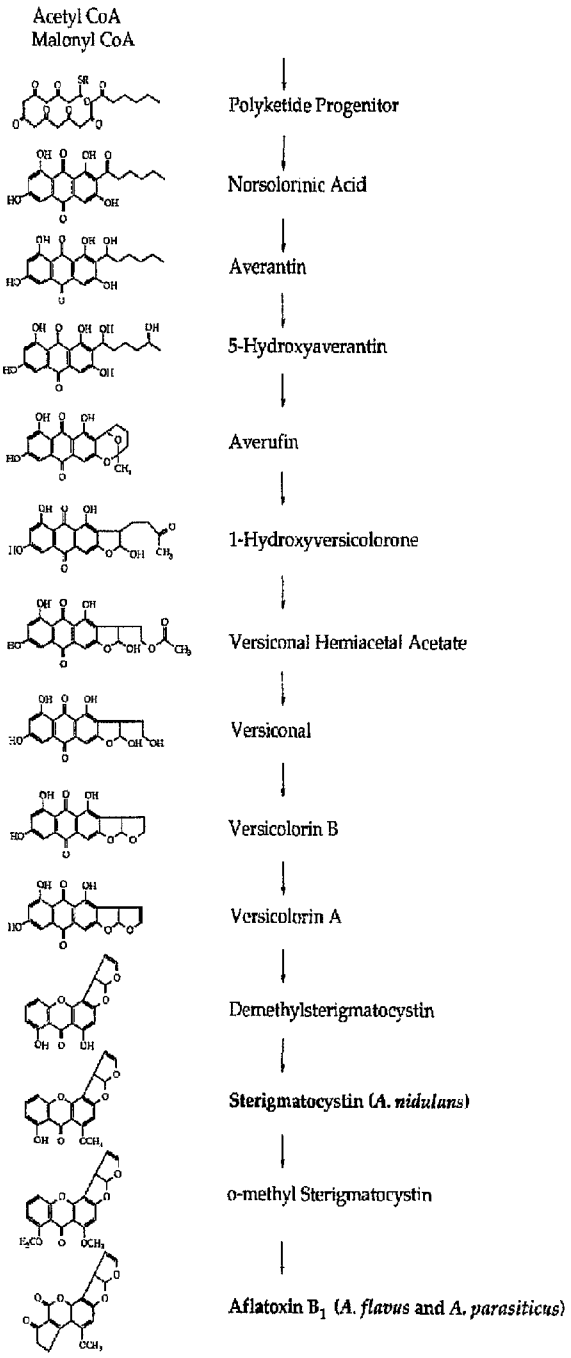
We are also interested in identifying environmental factors which may be involved in either the induction or inhibition of ST/AF biosynthesis. For example, in vitro tests have determined that pH regulates ST/AF production such that acidic environments favor high production and alkali low production. This response is likely to be regulated by the A. *nidulans pac*C gene which regulates expression of alkali and acid expressed genes. We are currently cloning the *pac*C homolog in A. *parasiticus* (AF producer). One strategy could be to find a way to permanently keep the PacC protein in the alkali-gene inducing form.

Plant Genes

The intent of this approach is to address the problem of ST/AF contamination by (I) genetic engineering or breeding of ST/AF inhibiting compounds into susceptible crops and/or (ii) genetic engineering or breeding of ST/AF inducing compounds out of susceptible crops. Because Aspergillus spp. preferentially colonize and produce the greatest amounts of ST/AF on oil seed crops, we have focused our attention on metabolites from these tissues.

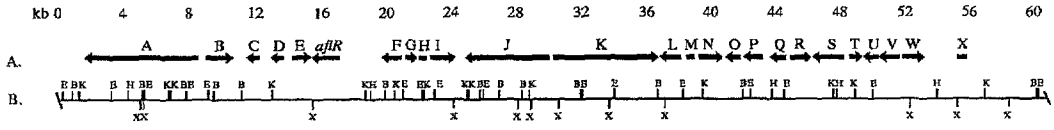
Recent progress in our lab has indicated that lipid metabolites from both AF susceptible crops (e.g. peanut) and AF resistant crops (e.g. soybean) may play a major but opposing role in the ability of *Aspergillus* spp. to colonize and produce ST/AF in seeds. We have identified an endogenous 'antiST/AF' lipid metabolism gene from soybean, a crop known to be resistant to AF contamination. The activity of this gene decreases *Aspergillus* grow-th and inhibits ST/AF production. These results indicate that soybean gene(s) and/or their product(s) are putative regulators of AF/ST biosynthesis. We are currently trying to transform peanuts with this soybean gene (and, in the future, other 'anti-ST/AF' metabolites identified by our research) and will assess the ability of the transformed plants to resist *Aspergillus* infection and subsequent AF contamination. Complementary studies are focused on identifying and eliminating ST/AF inducing compounds from peanuts.

Figure 1. Aflatoxin and Sterigmatocystin Biosynthetic Pathway in *Aspergillus* spp.



238

Figure 2. The Sterigmatocystin Gene Cluster of *Aspergillus nidulans*



A. 25 co-regulated genes comprise the Sterigmatocystin Gene cluster.

stcA = polyketide synthase
stcB = P450 monooxygenase
stcC = oxidase
stcD = unknown
stcE = dehydrogenase/reductase
aflR = zinc cluster transcription factor
stcF = P450 monooxygenase
stcG = dehydroggenase
stcH = unknown
stcI = esterase
stcJ = fatty acid synthase α
stcK = fatty acid syntase β
stcL = P450 monooxygenase
stcM = unknown
stcN = dehydrogenase/reductase
stcO = *A. parasiticus* cluster gene
stcP = *O*-methyltransferase
stcQ = *A. parasiticus* cluster gene
stcR = unknown
stcS = P450 monoxygenase
stcT = elongation factor gamma
stcU = ketoreductase
stcV = dehydrogenase/redutase
stcW = monooxygenase
stcX = unknown

B. Restriction map of the ~ 60 KB of the Sterigmatocystin Gene Cluster.
E = EcoRI restriction site; B = BamHI restriction site; K = KpnI restriction site; H = HindIII restriction site

Management of Arthropod Pests of Peanuts in North Carolina

Rick L. Brandenburg[1]

INTRODUCTION

The effective management of arthropod pests on peanut in North Carolina has continued to be a challenge in light of increasing demand for reduced pesticide residues, lowering production costs, reduced risk, and the occurrence of new pest problems. The pest management strategies developed for peanut in the 1970s and 80s were heavily dependent upon preventive pesticide use. Four major pests attack peanut on a more or less annual basis. These include: thrips, corn earworms, southern corn rootworm, and spider mites. Several other pests including wireworms, cutworms, fall armyworms, and lesser cornstalk borers attack on a much less frequent, but none less damaging basis.

Current Integrated Pest Management (IPM) strategies for the four major pests include the use of preventive insecticides. Thrips are generally managed with at-plant, in-furrow systemic insecticides and southern corn rootworms with a preventive application of a granular formulation of insecticide at-pegging time. Despite the "non-IPM" nature of these applications, farmers perceive rescue treatments for these pests as risky. Despite repeated educational programs and documentation of the economic benefits of rescue treatments based on economic threshold for thrips, farmers almost exclusively chose at-plant treatments.

One pest, the corn earworm, is managed based upon a validated economic threshold and remedial treatments as needed. However, the use of conventional pesticides to manage this pest in an IPM context often induces a secondary pest, the twospotted spider mite. In effect, the high value nature of peanuts and the potential devastating losses from insects provided past incentives toward low risk management systems that marginally fit into the definition of IPM.

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During the 1990s however, with the additional challenge of tomato spotted wilt virus vectored by thrips, and the uncertain future of the Peanut CRSP program, increasing foreign competition, and manufacturers demands for no pesticide residues in peanuts, research emphasis has shifted. Research to incorporate cultural and biological control into peanut production has been underway for more than eight years. Techniques of forecasting pest outbreaks to reduce the risk associated with rescue treatments have shown promise and offer hope for reducing prophylactic treatments. Studies focusing on these preventive treatments have also revealed options to minimize their potential adverse environmental affects. Other research has provided significant insight into the mechanisms responsible for inducing secondary pest outbreaks and basic biological studies have helped us better understand the ecology of the tobacco thrips which vectors the tomato spotted wilt virus.

The following pages provide a brief overview of the outcome and significance of these studies. They include: research on thrips' biology and ecology, improving pesticide usage and timing, the use of cultural practices to reduce pest populations, pest prediction and forecasting, and developing an understanding of factors causing secondary pest outbreaks. Where measurable, the impact of these studies is documented and their "fit" into future pest management programs for peanuts is discussed.

Thrips' Biology and Ecology and Tomato Spotted Wilt Virus

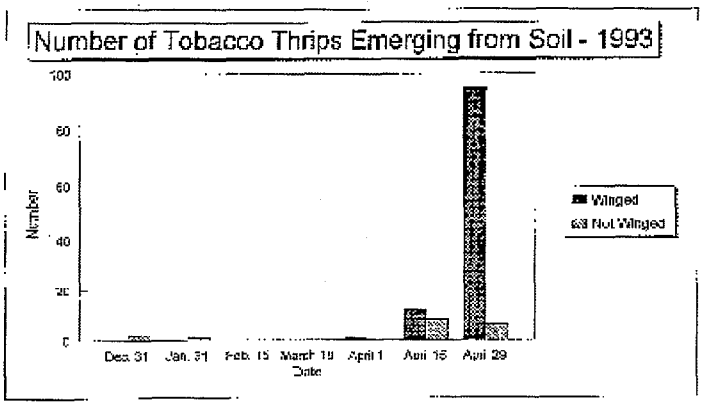
The tobacco thrips, *Frankliniella fusca,* a long-time pest of Virginia-type peanuts has become increasingly important due to the recent introduction of tomato spotted wilt virus (TSWV) into North Carolina. Thrips transmit this destructive virus and while numerous studies on these two pests have been underway in Texas, Georgia, and Alabama, the nature of peanut production, climate, and pest ecology are significantly different among these states. The availability of relatively cheap and effective pesticides during the 1970s and 80s precluded much research on this pest. As a result our understanding of thrips' overwintering, migration, and in field biology is somewhat limited. To remedy this situation, studies were initiated in 1990 to further investigate these aspects of thrips' ecology.

Research on thrips overwintering has revealed a significant portion of the resident thrips population overwinters in the soil, in and around fields that were in peanuts the previous growing season. Emergence traps and exclusion cages have revealed that thrips do overwinter in the soil, however, they emerge approximately one month prior to peanut planting (Figure 1). Since peanut seedlings are infested with thrips immediately upon soil cracking, this defies conventional wisdom that the thrips emerged at the same time peanuts were germinating. However, cages placed over peanut rows at planting virtually eliminated thrips infestation on plants within those cages indicating few, if any thrips remain in the soil at planting (Table 1).

Table 1. Total and mean no. of thrips found on plants and sticky cards/cage interiors, and damage ratings for plants inside of, and outside of emergence cages.

	No. of Thrips				Trips damage	
	Plants		Sticky cards/damage			
Location	Total	Mean[1]	Total	Mean	Total	Mean
Inside	9	0.3B	0	0B	2	0.2B
Outside	576	19A	69	2A	54	2A

[1]. Vertical means, per three tetrafoliate leaves or stick card are separated bt F test (P>0.0001).



242

Figure 1. The number of tobacco thrips (*Frankliniella fusca*) emerging from the soil from fields planted to peanut the previous year as measured by emergence traps. Bertie County, North Carolina. 1993-94.

Additional studies have shown that those thrips that emerge from the soil prior to planting, feed on feral vegetation, small grains and seedling corn. Sticky traps reveal that following peanut planting significant aerial dispersal of thrips begins. Up to 20 percent of these thrips are species known to vector TSWV (Table 2). Since these thrips entering the peanut field are at least one generation removed from the overwintering population, the acquisition of the virus may well take place on many of the feral plant species bordering fields that serve as hosts for both the thrips and TSWV (Barbour and Brandenburg 1994).

Table 2. Total number and percent of total for thrips species collected from sticky carsd in fields with emergence and exclusion cages in 1991.

Thrips species	n[a]	%
Frankiniella fusca[*]	1572	17.3
F. tritici	1957	21.5
F. occidentalis[*]	21	0.2
Trips tabaci[*]	78	0.9
Neohydatothrips variabilis	4102	45.1
Others	571	6.3
Unidentifiable	800	8.7
Total	9102	100.0

[a]Total number of cards = 384; [*], known vectors of tomato spotted wilt virus.

Most thrips captured on sticky traps are caught on traps placed close to the crop canopy rather than those elevated 2 meters high. This would indicate a localized rather than a wide area dispersal. Most dispersal occurs during the middle of the day. The compass direction capturing the most thrips always corresponded to the predominant wind direction indicating that while dispersal may be an active function of thrips behavior, passive dispersal on wind currents plays a significant role in field infestations (Figure 2).

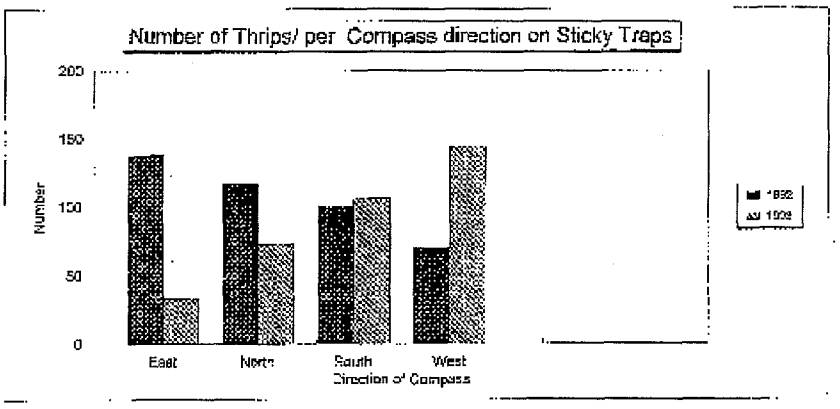


Figure 2. Cumulative thrips catches on sticky traps placed on peanut field perimeters. Bertie County, North Carolina. 1992 and 1993.

The practical application of this information aids in assembling a clearer picture of thrips' ecology and when and where the virus is acquired. Unlike south Georgia and Alabama, where volunteer peanuts (often infected with the virus) are found during the winter months, volunteer peanuts are only seen in the late spring about the time peanut planting begins in North Carolina. It is most likely that feral hosts are playing an important role as a source of inoculum for the thrips. The overwintering generation is not the source of early season infection in peanuts since it emerges prior to planting. Rather a generation occurs before planting where the immatures acquire the virus and then disperse into peanut fields as adults to infect plants. Future management considerations may include selective management of field border vegetation to reduce viruliferous hosts. Future research includes the isolation of those hosts and thrips outside of peanuts most likely to introduce the virus into the peanut field.

Improving Pesticide Usage and Timing

Management of the southern corn rootworm, *Diabrotica undecimpunctata*, has also relied quite heavily upon the use of preventive application of granular formulations of insecticides. This is the result of complicating factors including: the subterranean nature of the pest, our inability to predict the occurrence of this pest, and the lack of cultural and/or biological controls for rootworms in peanuts. As a result the use of an at-pegging band application of a granular formulation of a soil insecticide has become accepted practice for researchers, extensionists, as well as farmers for control of this pest.

Since our current understanding of rootworms and limited technology to control them forces us to accept a preventive pesticide approach, research has been aimed at improving the use of these products. One approach with multiple benefits, including increased effectiveness, reduced impact on beneficials, and less crop damage from application has been thoroughly researched.

Our studies have focused on changing application time from mid-July to mid-June. While this may sound like an even more preventive approach, the timing of mid-July does not provide any additional information that might allow for making decisions to avoid treatment (Brandenburg and Herbert 1991). However, early application has a decreased effect on beneficial arthropods later in the season when they are important for the natural control of spider mites (*Tetranychus urticae*) and corn earworms (*Helicoverpa zea*) (Barbour and Brandenburg, Submitted). The mid-June application provides additional time for beneficial arthropod populations to resurge prior to the threat of spider mites and corn earworms during August as compared to the mid-July application (Table 3).

The results from this earlier application also demonstrate equivalent control to the standard application date (Table 4). A major advantage to this earlier application date is the lack of vine damage from tractor tires by applying the product before vines meet in the row middles. Since these products are applied with four row equipment as contrasted to 12 row equipment for leafspot sprays, significant vine damage can occur. Porter and Powell (1978) reported significant vine damage from pesticide application equipment used mid and late season. Using their data and extrapolating for the benefit

245

of an early season application, we can demonstrate a 49 lb/acre yield savings on the 80,000 acres that are treated annually in North Carolina. That equates to an annual crop loss reduction exceeding 1.3 million dollars. Almost 100% of those farmers that apply rootworm treatments now use the early application approach. The study of Porter and Powell (1978) also indicated a reduction in Sclerotinia from less vine damage. Dr. Jack Bailey, plant pathologist at NCSU, indicates that about 30% of the 80,000 acres treated for rootworms in North Carolina are subject to severe Sclerotinia outbreaks. Based upon the previous study the early application of rootworm insecticides and subsequent reduction in vine damage could reduce crop losses from Sclerotinia in North Carolina by 1.75 million dollars.

Table 3. Mean number (±SEM) of arthropods captured on peanuts treated at flowering and at pegging with chlorphyrifos in 1990.

	Predaceous Arthropods[1]					
Time of Application	Hemipterans		Spiders		Others	
Flowering	11.1	±2.23	8.75	±1.01	0.19	±0.10
Pegging	4.8	±1.47	6.0	±1.30	0.19	±0.10
P<F	**0.0234**		**0.1167**		**1.000**	

[1]Numbers of arthropods per 8 row meters: n = 16 for Hemiptera and others, n = 8 for spiders. Values represent pooled means from plots in four fields.

Additional studies have focused on predicting rootworm outbreaks in peanuts to avoid the unnecessary application of prophylactic insecticides. The objective was to evaluate the use of attractant pheromone traps for southern corn rootworm males to identify those fields that are at risk from attack. This information could then be used to make a decision on the need to treat that particular field and thus provide us with technology that would help us avoid the preventive approach scenario.

Table 4. Southern corn rootworm control in peanuts as influenced by insecticide treatment timing, North Carolina, 1989.

Treatment	Rate/ha, kg(AI)	Timing	Bertie County				Halifax County			
			% Damaged pods (±SEM)		Yield kg/12.2m (±SEM)[a]		% Damaged pods(±SEM)		Yield kg/12.2m (±SEM)	
Chlorpyrifos 4EC	4.44	Preplant incorporated	8.25	±7.46 a	5.23	±0.61 b	0.00	±0.00 a	3.70	±0.10 a
Chlorpyrifos 15G	2.22	At planting	10.25	±3.91 a	5.18	±1.11 b	0.00	±0.00 a	3.51	±0.46 a
Chlorpyrifos 15G	2.22	At flowering	1.75	±0.43 a	5.58	±0.51 b	0.25	±0.43 a	4.77	±1.00 b
Fonofos 10G	2.22	At flowering	15.50	±8.50 a	4.88	±0.61 b	4.75	±4.02 a	4.05	±0.37 ab
Chlorpyrifos 15G	2.22	At pegging	8.50	±7.83 a	5.59	±0.35 b	0.25	±0.43 a	3.94	±0.41 ab
Untreated	-	-	50.00	±23.03 b	3.7	±0.45 a	33.35	±13.08 b	3.98	±0.30 ab

Means followed by the same letter are not significantly different (P = 0.05;DMRT). Mean separation vertical. Bertie County ANOVA (pod: F = 5.06; yield: F = 5.65; df = 8,15). Halifax County ANOVA (pod: F = 10.53; yield: F = 8.15; df = 8,15).

[a] Moisture at harvest was 16% at Bertie County and 15% at Halifax County. Yields are based on weight of peanuts with a moisture content of 8%.

Studies over a five year period monitoring traps and rootworm populations in over 100 fields revealed a relationship between the occurrence of rootworm adults in June and the subsequent larval outbreak in August (Figure 3). However, the correlation was too weak to make confident decisions on eliminating treatments for very many fields (only about

16%) (Brandenburg et al. 1992) (Figure 4). While the cost of treatment is relatively high ($25/acre) the cost of not treating and suffering rootworm damage is many times that figure.

However, work in North Carolina and Virginia on improved attractants (that attract both male and female beetles) as well as a characterization of soil drainage in fields show potential for allowing us to increase the percentage of fields that we can confidently make treat/no-treat decisions about (Ang *et al.*, 1994). Once refined, this will allow North Carolina peanut farmers to avoid preventive application on a significant acreage with a cost savings close to one million dollars.

Additional studies on the use of biological control for southern corn rootworm has shown only limited success. The use of entomogenous nematodes has been demonstrated to significantly reduce the percent of damaged pods in the field. However, since such nematodes are prone to desiccation in the first few days after release, this means of pest management is best suited to irrigated peanuts, which are a very small percent of the acreage in North Carolina.

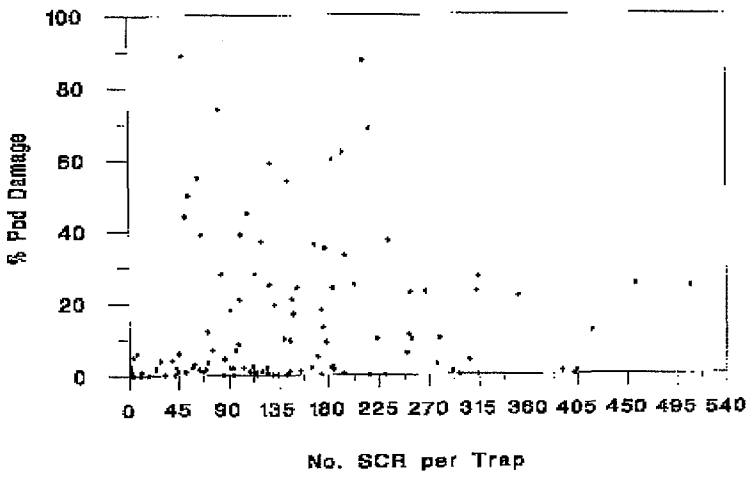


Figure 3. Five year data for southern corn rootworm (*Diabrotica undecimpunctata*) adult males. Per cent pod damage plotted against number of adults in 107 North Carolina and

Virginia peanut fields from 1986-90. Each symbol represents the average number of adults per field in a single week.

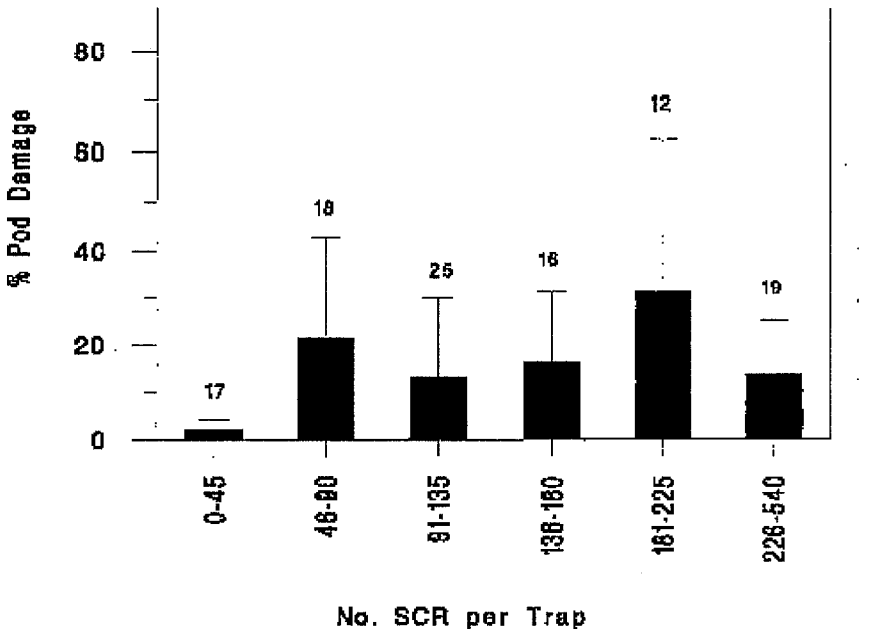


Figure 4. Per cent peanut pod damage plotted against number of rootworm beetles for years 1986-1990, grouped into classes of 45 or more beetles per trap.

The Use of Reduced Tillage Production for Minimizing Insect Pests

Reduced tillage has been investigated for many years as a means of reducing soil loss and production costs in North Carolina peanuts. Our studies have revealed a significant and consistent effect of conservation or minimum tillage peanut production on several pest species of insects (Brandenburg *et al.*, In prep.). The mechanism(s) for this reduction is not understood, but the effect is often observed season long. Even late season pests such as corn earworm and southern corn rootworm may be effected. The effect on southern corn rootworm may be through increased abundance of predaceous soil mites that feed on rootworm eggs in the no-till plots (Brust 1990). The most pronounced effect is on early season pests such as thrips (Table 5). The effect is often of such magnitude as to preclude the need for insecticides. Based upon studies of mulches and cover crops for pests in other crops it is likely that the mechanism at work here is that the thrips are confused during early season migration and host location. This effect may be of even greater significance

in reducing the incidence of TSWV, since other control strategies have been unsuccessful. Reduced host location early in the season could have a significant effect on cumulative virus impact. Continuing studies are investigating the long-term impact of no-till production and rotations on weeds and pests such as cutworms which have increased in some no-till systems for other crops.

Effect of Atmospheric Pollutants on Insect and Mite Pest Status

Atmospheric pollutants are a serious problem in many peanut-producing areas of the world including the United States, Southeast Asia, and India. Numerous studies have documented that various pollutants can increase insect and mite abundance through either direct or indirect effects. Tropospheric ozone is a common pollutant along the southern Atlantic Coast. It is the result various combustion pollutants drifting South and the increasing solar intensity found in the North Carolina peanut production region. The presence of these pollutants interrupts the normal process by which ozone is reincorporated back as desirable atmospheric gases. The results are ozone levels that may exceed 80ppb during peak occurrences in the summer months.

Table 5. Tillage effect on Thrips" populations and Injury on Peanuts, Chowan County, North Carolina - 1991.

	% thrips damaged leaflets		No. of thrips/5 unopened leaflets
Treatment	23 May	5 June	5 June
MBP + disc	66 a	92 cd	38.0 b
MBP + disc + rip	75 a	97 d	37.75 b
Disc	80 a	93 cd	38.25 b
NT + FC	62 a	34 a	12.25 a
NT + rip	66 a	50 b	12.50 a
NT + BH + RT	70 a	78 c	10.25 a

Means followed by the same letter are not significantly different. DMRT (P= 0.05) - Mean separation vertical. MBP = moldboard plow, NT = no-till, rip = shank tillage, FC = fluted coulter on planter, BH = bush-hog mower, RT = roto-till seed bed.

Since ozone has been documented to increase insect populations on a variety of host plants, we initiated a study to determine if the presence of ozone could be responsible for the consistent spider mite problems experienced in the North Carolina production areas (Heagle et al. 1994). This study utilized closed chambers at the USDA Air Quality Laboratory at NCSU. Preliminary findings indicate a rather significant effect on total mite populations within three weeks of exposure to elevated ozone levels (Figure 5). Further studies have documented that this effect is mediated through the host plant and that some cultivars are more susceptible than others. While the mechanism itself is yet unclear, the immediate effect is that egg-laying is initiated sooner in the adult female and initially at a higher rate. The cumulative effect of this accelerated egg laying is that the effective generation time is shortened and populations grow more rapidly under such conditions (Hummel *et al.*, In prep.).

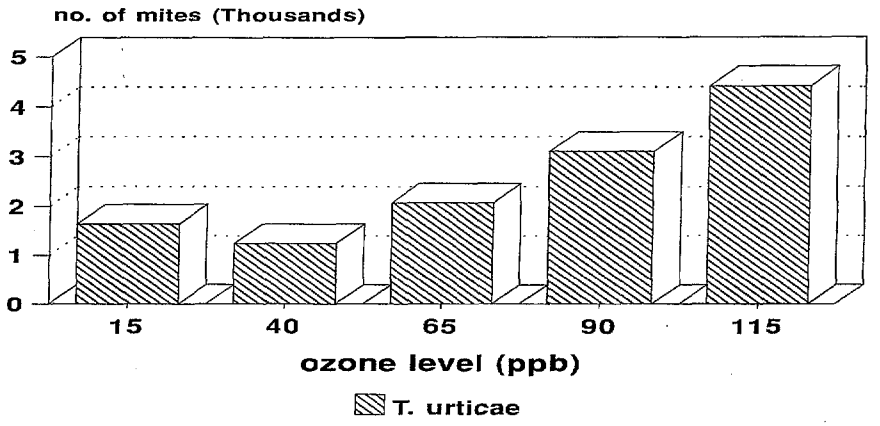


FIGURE 5. Spider mite (*Tetranychus urticae*) populations on peanut under different ozone concentrations three weeks after initial exposure. Wake County, North Carolina. 1992.

While there is much more to study concerning this interaction, it appears that the effect of this common pollutant is significant. These results also indicate the need to screen peanut cultivars for susceptibility to ozone with the goal of selecting those cultivars that are least likely to induce mite outbreaks through the effect of elevated ozone levels.

Forecasting Arthropod Pests of Peanuts

An enhanced knowledge about pest biology is critical in developing the most effective management strategies. Recent developments in our ability to forecast or predict insect growth and development as well as pest outbreaks provides extensionists and growers alike with insight into crop loss potential from arthropod pests. Advanced warning of pest occurrence helps make scouting and the application of management strategies a more timely and efficient operation.

More recently, scientists have relied upon intuitive modeling to aid in pest management programs. Intuitive modeling looks for relationships between certain environmental events and then attempts to develop "if, then" statements based upon these relationships. Such modelling can usually be accomplished in a relatively short amount of time, yet still provides pest managers with insight into potential pest outbreaks. In North Carolina we have recently validated the lesser cornstalk borer (*Elasmopalpus lignosellus*) model developed by Mack *et al.*(1993). This model simply records the number of days that are

252

very hot and dry minus the days that are cooler and wet. The result is a relative risk scale for the occurrence of this insect. This model also functions as a strong indicator of the likelihood of aflatoxin.

An additional model is currently being validated in North Carolina. A model for the occurrence of the twospotted spider mite is designed to predict those conditions that encourage the early infestation of peanuts. Spider mites typically infest peanuts in August in North Carolina. During some years outbreaks may occur in July which results in serious crop loss due to growers being caught off-guard by the early incidence. This model predicts those years in which the spider mite development is accelerated and the naturally occurring pathogen, *Neozygites floridanum*, (Smitley and Kennedy 1988) is suppressed. The result is an early warning to growers to begin a timely scouting program to detect such early infestations. This model also helps prevent unnecessary scouting during those years when early infestations are not likely.

Space precludes a complete discussion of additional projects that include the evaluation of pesticide use patterns and their impact on natural enemies, developing a new host plant resistance program, the use of biorational products for pest control, refinement of a reduced input, no pesticide residue production program, crop loss assessment studies, and other research programs directed at developing more sustainable peanut production schemes.

Acknowledgments

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Impacts and Scientific Advances Through Collaborative Research on Peanut in Nigeria

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Peanut CRSP Symposium[4]

INTRODUCTION

Peanut (Arachis hypogaea L.) is an important food crop in West Africa especially in Nigeria. It constitutes a principal source of protein and dietary oil for both subsistence farmers and urban dwellers. It also provides a significant source of cash income through sale of seed, peanut cake, dietary oil, and haulms.

Traditional commercial peanut producing areas encompass the Sahel (12 - 13 degrees N), Sudan (10 - 13 degrees N) and the Northern half of the Northern Guinea Savannah (8 - 11 degrees N) vegetation zones with rainy season lasting 75 - 150 days with a range of 500 - 1400 mm. In Nigeria, an estimated 0.8 - 1.2 million hectares of land are planted to groundnut annually but pod and forage yields have been restricted by diseases, drought and poor management practices such as late planting, lack of fertilizers and chemicals, unavailability of improved seed and labor problems during critical stages of production (seed preparation, weeding, and harvesting). Pod yields therefore range from 800-3,000 kg/ha.

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[4] 29 - 31 March 1995, Washington, D. C.

Between 1956 and 1967, peanut products, including cake and oil, accounted for some 70% of total Nigerian export earnings, making it the country's most valuable single export crop. The drought years of the early 1970's, the unprecedented epidemic of groundnut rosette in 1975, and the increasing prevalence of rust disease combined with infection by leafspot diseases that occur every year resulted in the considerable decline of peanut production after 1967 (Alabi et al. 1990). The focus of research since then has been on crop improvement with emphasis on breeding for resistance to diseases and drought.

The breeding program which started in 1928 puts emphasis on development of genotypes with following attributes:

* high yield with good agronomic characteristics;
* different season lengths for the various ecological zones;
* drought tolerance for the Sahelian and Sudanian zones;
* high nutritional quality; and
* pest and disease resistance.

Groundnut rosette is the most important peanut virus disease in Africa. In Nigeria, it is endemic, with an annual incidence of up to 5% although individual fields within an area may have much more than a 5% level. Apart from the pandemic year (1975), when virtually the entire crop was lost, regional epidemics in 1983, 1985, and 1988 had a major influence on farmers decisions to concentrate on cereal crops and cowpea production. Because farmers realize the importance and nutritional values of peanut they have continued to produce the crop the best way they can with the hope that the mandated Institute for Agricultural Research (IAR) will find solutions to dependable peanut production.

Breeding Activities 1928 - 1986

Breeding work in the first four decades focused on introduction and selection as well as hybridization and evaluation of the material for productivity, disease resistance, and adaptability. The emphasis during the next 2 decades was concentrated on disease resistance and drought tolerance. The genetic material/ base population was therefore widened by introducing material from other countries in West Africa, America, and Asia.

This resulted in the release of rosette resistant varieties such as M25.68, and M554.76, as well as introductions such as RMP 12, RMP 91 and 69-101 to the farmers. Among the exotic lines, 55-437 (Ex Dakar) was found to be drought-tolerant but susceptible to rosette. All these recommended varieties were suitable for the Northern and Southern Guinean zones where the rainy season lasts for 150 days with a total annual rainfall of 1000-1600 mm. The traditional commercial peanut producing areas still need short-season, rosette-resistant varieties. Combined efforts by the IAR, Peanut CRSP, and ICRISAT have been made to transfer rosette resistance to short-season varieties.

Breeding Activities 1986-1995

Inheritance of resistance, mechanisms of resistance to rosette, and epidemiology became the major focuses since 1985 because it was apparent that all available resistant varieties were long-duration and little information was available on the disease.

A disease resistance study was conducted by the IAR, Zaria, in collaboration with the University of Georgia, USAID Peanut CRSP and the Institute for Viruskrankheiten de Pflanzen, Braunschweight, Germany. Crosses were made between resistant and susceptible selections on short-, medium-, and long-duration varieties. Selections followed in the early segregating generations. The screening procedure used was that described by Bock and Nigam (1988). Results of this work have been reported by Olorunju et al. (1990, 1991, 1995).

Breeding for Resistance to Rosette in Short-season Varieties

Available genetic resistance in cultivated groundnut has been demonstrated in a limited range of germplasm. Most of these are the late maturing Virginia types (52-11, 52-14, 48-14) that have been used in Senegal, Malawi and Nigeria to come up with resistant varieties such as RMP 12, RMP 91, RG 1 and SAMNUT-16 (M554.76).

The only reported source of resistance in short season sequentially branching genotypes has been the KH series eg KH 149 A from IRHO, Burkina Faso (Harkness, 1977), and KH 241 D (Hildebrand and Nigam, 1991). KH 149 A was used extensively in the initial hybridization programme and resultant varieties showed some resistance but were agronomically unacceptable (Boye-Goni et al., 1992).

Among the crosses made in 1986, four of the parents were short-season agronomically acceptable susceptible varieties (RRB, 55-437, JL 24 and ICGS 56 (E)). Recovery of resistant plants from these crosses was very low ranging from 6-26% in the field and 4-7% in the green house experiments. On average, recovery was 6 and 14% in the green hose and field, respectively, confirming the report of Harkness (1977) and Hildebrand and Nigam (1991).

Resistant lines that matured within 110 days were selected and advanced through a modified bulk breeding method. Selected lines later entered into replicated yield trials where yield and its components and other agronomic characteristics were also monitored. Table 1 shows the performance of these lines. The resistant best yielders will be tested in the Nationally Coordinated Groundnut Research Project (NCGRP) starting in 1995.

Currently, the breeding nursery has materials ranging from F1s to advanced breeding lines being tested for rosette resistance, early maturity and yield. Some of these segregating and advanced lines are shown in Tables 2 and 3.

Table 1. Performance of Short-season varieties in an advanced groundnut variety trial at Samaru, Nigeria 1992-1994.

Serial No.	Entry	Pedigree	Maturity Days	Pod Yield ton/ha	Shelling %	100 Seed Mass (g)	Seed Color b
1.	ICGS 45		110	1.51a	62	36.9	T
2.	ICGV 88709	SP1 x RMP 91	110	1.23	69	27.2	T
3.	ICGV 88710	Egret x RMP 91	110	1.55	67	36.1	T
4.	ICGV 88711	Mani Pinta x RMP 91	110	1.79	65	38.7	Vg
5.	48-115B		90	1.11	63	31.0	T
6.	M359-79	RMP12x(4750.70x3520.71)	110	1.84	58	39.2	T
7.	176-85a		110	1.64	71	26.9	T
8.	1691-79		110	1.83	57	29.8	T
9.	M669.8		110	1.36	62	36.6	R
10.	M563.78		110	2.14	58	40.0	T
11.	UGA 2	RMP12xICGS-56(E)	110	1.73	65	31.3	Vg
12.	UGA 3	RMP12 x 55-437	110	2.04	67	37.8	Vg
13.	UGA 4	RMP12 x M1204.78I	110	2.24	67	35.9	Vg
14.	UGA 5	RMP 12 x JL24	110	1.80	57	38.9	Vg
15.	UGA 7	RMP 12 x RRB	110	1.69	73	30.6	Vg
16.	UGA 8	RG 1 x ICGS 56 (E)	110	1.49	65	40.1	T
17.	UGA 9	RG 1 x 55-437	110	2.05	54	41.3	T
18.	UGA 10	RG 1 x ML204.78I	110	1.91	67	38.6	T
19.	UGA 11	RG 1 x JL 24	110	1.29	66	30.0	T
20.	UGA 13	RG 1 x RRB	110	1.92	69	32.9	T

a = Yield averaged over three years. b: T = Tan, Vg = Variegated, R = Red

259

Table 2. Reaction of 184 entries of F4 segregating populations to infection by Groundnut Rosette virus at Samaru, Nigeria, 1994.

Serial No.	# of Entry A	# of Entry B	Genotype	# of Rosetted Plants: Group A		Total # of Plants Group B	
1.	7	10	ICGM 751/754 x 55-437	25:490	[5.1]	309:689	[44.8]
2.	14	11	ICGM 751/754 x ICGV 86055	418:920	[45.4]	503:780	[69.9]
3.	15	24	ICGM 751/754 x ICGV 86061	327:1019	[36.5]	1523:1820	[83.7]
4.	4	13	ICGM 751/754 x ICGV 86105	11:260	[4.2]	718:839	[84.4]
5.	15	53	ICGM 751/765 x ICGV 87922	179:994	[18.0]	2888:3595	[80.3]
6.	5	3	ICGM 751/754 x Chico	127:327	[38.8]	85:192	[44.3]
				Group C			
7.			ICGM 751/754 x JL 24	51:72	[70.1]		
8.			ICGM 751/754 x ICGV-SM 85057	43:59	[72.9]		
9.			ICGM 751/754 x ICGV-SM 83031	42:64	[65.9]		
10.			ICGM 751/754 x ICGV-SM 86053	64:79	[81.0]		
11.			ICGM 751/754 x Valencia R 2	49:65	[75.4]		
12.			ICGM 751/754 x ICGV 86105	49:81	[60.5]		
13.			ICGM 751/754 x ICGV 86061	54:63	[85.7]		
14.			ICGM 751/754 x ICGV 86055	58:69	[84.1]		
15.			ICGM 751/754 x Chico	56:66	[84.8]		
16.			ICGM 751/754 x ICGV 87922	65:77	[84.4]		
	Controls						
17.			UGA 3 (Resistant)	0:229	[0.0]		
18.			48-115B (Susceptible)	85:85	[100.0]		

[ ] Percentage of Rosetted plants. Group A = Single plant selections from Rosette Disease Nursery (RDN)

Group B = Selections based on yield and not rosette resist.

Group C = Entries advanced from F2 through Single Seed. Descent method and screened in RDN in F3.

Table 3. Performance of 25 Early Maturing varieties in the Fourth International Early Groundnut varietal trial - 89 (IV IEGVT - 1989) at Samaru, Nigeria, 1993 - 1994.

Serial No.	Entry	Pedigree	Maturity Days	Pod Yield ton/ha	Shelling %	100 Seed mass (g)	Seed Color b
1.	RRB	KH149A x 2424.74	100	1.43	70	41.8	R
2.	ICGV 86015	ICGS 44 x TG 2 E	110	1.60	69	45.8	T
3.	ICGV 86054	JH 335 x Chico	90	1.44	67	45.6	T
4.	ICGV 86055	72-R x Chico	90	1.47	65	40.2	T
5.	ICGV 86124	JL 24x (Dh3-20xRobut33-1)	100	1.29	63	40.0	T
6.	ICGV 86125	JL 24x (Dh3-20xRobut33-1)	100	1.50	58	30.1	T
7.	ICGV 86143	ICGS44x(Robut37-xNCAc2821)	100	1.57	59	34.7	T
8.	ICGV 86145	JL 24 x(Robut31-1xNCAc2821)	90	2.24	61	39.7	T
9.	ICGV 86149	TG 1 E x ICG (FDRS) 7	90	1.66	61	33.0	T
10.	ICGV 86162	(Shulamith x Chico) x PI337409	90	2.07	64	38.5	T
11.	ICGV 87003	JL 24 x (Dh 3-20xRobut 33-1)	90	1.88	65	41.4	T
12.	ICGV 87005	JL 24 x (SM5xNC Ac 17500)	90	1.91	69	38.4	T
13.	ICGV 87018	JL 24 x (M13 x Gangapuri)	90	1.5	64	34.7	T
14.	ICGV 87034	JL 24 x (Robut 33-1x NC Ac2821)	90	1.38	62	36.9	T
15.	ICGV 87050	Chico x TG 1E	90	1.78	72	47.5	T
16.	ICGV 87051	Chico x TG 1E	90	0.74	53	26.3	T
17.	ICGV 87052	Chico x JL 24	90	1.53	60	43.9	T
18.	ICGV 87054	91176 x TG 2E	90	1.71	70	35.1	T
19.	ICGV 87055	91176 x JL 24	100	1.27	61	39.1	T
20.	ICGV 87059	91176 x (Florigiant xNCAc 1107der)	90	1.65	68	39.2	T
21.	ICGV 87061	TG 2E x ICG (FDRS) 7	100	1.85	66	35.6	T
22.	ICGV 87063	JL 24 x ICG 5728	100	2.22	61	40.0	T
23.	ICGV 87069	JL 24 x (FlorigiantxNCAc1107der)	90	1.95	68	38.0	T
24.	ICGV 87073	JL 89 x TG 2E	90	0.99	60	33.5	T
25.	Chico		90	0.87	56	30.0	T

a = Yield averaged over two years. b: T = Tan, R = Red

261

ACCOMPLISHMENTS

The Institute for Agricultural Research, Samaru, in collaboration with the USAID Peanut CRSP, has developed a number of rosette resistant varieties: SAMNUT-10 (RMP 12), SAMNUT-11 (RMP 91), SAMNUT-16 (M554.76), SAMNUT-20 (M412.80I) and SAMNUT-21 (MDR-8-19). The first three are currently in circulation and in great demand by farmers whereas the latter two are recent releases (1994). Table 4 shows other varieties developed by I. A. R. And in great demand despite their susceptibility to rosette.

Table 4. IAR Groundnut Recommended Varieties and Characteristics

Variety	Maturity Days	Average Pod Yield kg/ha	Shelling %	Ecological Zone	Remarks
SAMNUT10 RMP 12	130 - 150	2800 - 3500	75	NGS & SGS	Rosette Resistant
SAMNUT 11 RMP 91	130 - 150	2800 - 3500	75	NGS & SGS	Rosette Resistant
SAMNUT 16 M554.76	120 - 130	2800 - 3500	74	NGS & SGS	Rosette Resistant
SAMNUT 20 M412.80I	120 - 130	2800 - 3500	73	NGS & SGS	Rosette Resistant
SAMNUT 21 MDR-8-19	130-140	2800-3500	74	NGS & SGS	MULTIP LE *
SAMNUT 19 K720.78	100 - 110	2000 - 2800	70	SUDAN & NGS	Rosette Tolerant
SAMNUT 18 RRB	100 - 110	2000 - 2800	72	SUDAN & PART NGS	Drought Tolerant
SAMNUT 17 48-115B	90 - 100	2000 - 2800	70	"	Drought Tolerant
SAMNUT 14 55-437 Ex-Dakar	90 - 100	2000 - 2800	72	SUDAN SAHEL & PART NGS	Drought Tolerant

NGS - Northern Guinea Savannah.

SGS - Southern Guinea Savannah.

* - Rosette, Rust and Leafspot Resistant.

Five early-maturing (110 days) rosette resistant varieties (UGA 3,4,9,10,13) have been identified form testing in the NCGRP this year. After two years of testing in the Sahel and Sudan savannah zones these genotypes will be released to the farmers.

The I.A.R. in collaboration with some Federal Government parastatals and the USAID Peanut CRSP produces seed for the farmers (foundation seed and recently breeder's seed). Since 1991, 11 ha of the institute's land is used annually for seed multiplication (mostly foundation seed). In 1994, six hectares of land were planted with six varieties of breeder's seed for the National Seed Service. This seed will be given to contract growers who will produce foundation seed. An average of about 20 tons of foundation seed is produced by I.A.R. each year and given to National Seed Service for sale and distribution to farmers either directly or through the Agricultural Development Projects. This has greatly improved availability of improved seed with resistance which is supplied to farmers.

Groundnut production has increased after the unprecedented decline resulting from the drought and rosette years in the mid 1970s to mid 1980s. According to Schilling and Misari (1992) and Schilling and Demanche (1994) production has increased from 550,000 tons (1982-1986) to 1,214,000 tons (1992) (Fig.1). The production is still below the national demand for peanut.

GROUNDNUT PRODUCTION TREND IN NIGERIA
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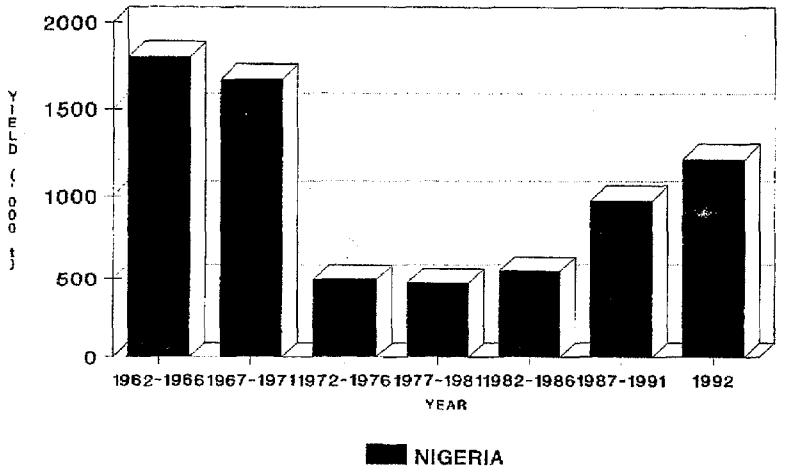

Source: Schilling and Demanche (1994)

263

Farmers have increased their hectarage because of the high profits they realize from the crop especially with the availability of rosette resistant varieties. Market prices have remained high because the demand is high for this crop.

The use of resistant varieties has had a great impact on the environment: using resistant lines, together with timely planting and right spacing, reduces the use of insecticide sprays for aphid control, thereby providing a less polluted environment and also reducing the exposure of unskilled labor to dangerous chemicals.

Small scale industries have been revived by the increase in peanut production. When production declined in the late 1970s and early 1980s, due to rosette disease, peanut processing industries closed down and the Federal Government banned the exportation of peanut. The small scale industries are now functioning because production has improved, due in part, to the use of new varieties by the farmers. The change in peanut processing capacity from 1982-1992 has been dramatic especially at the local level and at the level of small scale industries. Oil mills in some of the northern states have been revived after several years of idleness.

Nutrition consciousness is high among the nationals and thus peanut is added in soups, vegetables and other dishes; some secondary school children add roasted peanut to their "garri" snacks to enhance the nutritive value of the meal. Due to this consciousness, small portions of land are planted with peanut around homes and small farms. Percentage of peanut and peanut products consumption is as follows: Boiled peanut (10-15%), roasted peanut (20-30%), and Peanut oil (60-80%). Snacks such as "Kuli-kuli" are usually made from by-products of oil extraction. Haulms are also a by-product of the crop. The per ha value of haulms compares favorably with that of the grain, especially for improved, foliar-disease resistant varieties which retain most of their foliage at harvest.

By using resistant varieties, the previously low morale of farmers has been boosted for several reasons; the increase in production associated with reduction of crop losses due to diseases, beneficial inclusion of the peanut crop in a rotation system without losing yield, and the gain from its ability to fix nitrogen. New technology is readily adopted by the

264

producers as most of them are enlightened through the monthly technology review meetings of the Training and Visit system of our agricultural extension system.

Staff of the Institute have received some form of training (PhD degree, on-the-job training, study visits, workshops, conferences, etc.). These include Drs. P. E. Olorunju, S. M. Misari, and O. Ansa. Technical staff who received in-house training are Ibrahim Wayo, Saidu Sule, William Olarewaju and Alex Jibunor. Mr. Lassane Belem from Burkina Faso also received some training in rosette screening techniques and aphid manipulation at Samaru from Drs. P. E. Olorunju and S. M. Misari. Other benefits from the program include strengthening international, collaborative projects in breeding, pathology and entomology.

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Control Program of Peanut Virus Diseases in Asia

Sopone Wongkaew[1]

Among twenty six viruses infecting peanut as listed by Sreenivasulu et al (1991), Peanut bud necrosis virus (PBNV), peanut stripe virus (PStV), peanut clump virus (PCV), peanut stunt virus (PStV) and cucumber mosaic virus (CMV) are ranked the most important in the Asia-Pacific region. Although not officially declared in many countries, it is believed that both PBNV and PStV are widespread throughout Asia. The bud necrosis incidence was reported to be as high as 90% in some of the fields in Thailand (Wongkaew, 1994). Such high incidences were also reported in India. Since infected plants usually bear no pods if affected early, the amount of yield loss could be as much as the disease incidence its elf Apart from peanut, PBNV can also severely affected other cash crops such as tomato, cucumbers, sweet pepper and eggplants which are high valued. Therefore its epidemic can be detrimental to all growers not only to peanut farmers. This assumption could apply to peanut stripe virus as well. Some PStV isolates can reduce peanut yield as much as 79% if infected early. In China, yield losses of 43-44% have been reported (Xu et al. 1994). This virus can also severely affect other legumes such as bean, cowpeas and soybeans which are main cash crops of many Asian countries.

Since control measures of any diseases are pathogen specific, correct diagnosis and identification of the causal agent is a prerequisites for the measures to be effective. This rule is applied to virus diseases as well. The control measure should also be practical and cost effective in the particular cropping system. Followings are some of the current control measures that have been prescribed and adopted by farmers.

[1] Khon Kaen University, Thailand

Peanut Bud Necrosis Virus

PBNV the causal virus is thrip transmitted therefore an understanding of the vector is the key for effective control. Thripspalmi is reported to be a major vector of the disease in India. It is believed that this species could be the main vector elsewhere but may not be the only one. In Thailand, T palmi is rarely found on peanut (Wongkaew, 1994) where Scirtothrips dorsalis is the predominant species. Preliminary results indicated that this species could also transmit the Thai isolates although at a very low frequency.

At present, recommendation for BND management depends on the integration of cultural practices, host-plant resistance, insecticide application and biological control. Some of these methods can reduce the losses caused by BND but yet are suited to marginal farmers. Since the disease is not seedborne, legislation of quarantine regulation of seed movement is not necessary.

Cultural practices

Five methods in cultural practices appear to be effective in BND management adjustment of sowing date, using high plant density, intercropping peanut with fast growing non host crops, eradication of alternate hosts and using plastic mulching. In India it is advised to sow peanut early to avoid the thrip migratory flights so that the plants are sufficiently developed to withstand the infection by PBNV. Such effect has also been observed in Thailand. Peanut sown earlier in December or later in February appear to have lower BND incidence than those sown in mid January. Avoid planting peanut in dry season is as well a good alternative. In Thailand BND seems to be prevalent only during the dry season.

Using high plant density is also effective in reducing losses from BND. This can due mainly to the compensation effect of the surviving plants. But dense plant canopy is known to reduce movement of thrips hence spreading of the disease. Canopy closure in the shortest time is less attractive to the vectors. Farmers are advised to sow good quality seed that has been treated to avoid stand thinning by pests and diseases. It was found that the incidence of BND in crops that were sown at low densities was proportionately higher than in those sown at high densities.

Intercropping peanut with a fast growing cereal, such as corn, millet or sorghum can reduce the incidence of BND. In Thailand apart from corn, peanut is PBNV intercropped with sugarcane which is also effective in reducing BND incidence.

Both crop plants and weeds can act as a primary source of PBNV. In India, Glycine max, Lycopersion esculentum, Pisum sativum, Solanum melongena, S. tuherosum, Vicia faba, Vigna mungo, V. radiata and V. unguiculata were identified as alternate hosts of the virus. In Thailand the virus was found affecting tomato, eggplant, many species of cucumbers and capsicum peppers (Wongkaew, 1994). Intercropping these plants with peanut should be avoided. Among many weed species which could act as a virus reservoir, Acanthospermum hispidum, Ageratum conyzoides, Calotropis gigantica, Cassia tora, C. obtusifolia, Desmodium triflorum, Lagascea mollis and Xanthium strumarium have been checked to harbour the virus in India. In Thailand, the virus was found in Catharanthus roseus, Cleome viscosa, Physalis minima, Spilanthes paniculata and Synedrella nodiflora Elimination of these weeds to reduce BND incidence may be cost effective for other cash crops or for large scale peanut production. But for small scale farmers who grow peanut as a second crop the action may not be practical or cost effective.

Using silver-colored plastic mulching has been observed to reduce incidence of many virus diseases including that caused by PBNV in tomato, capsicum and cucurbits in Thailand. In China, a similar result was reported when applied to peanut although the occurrence of BND was not mentioned (Xu et al, 1994). Since plastic sheet is costly and can have an adverse effect on the environment, its use should be considered carefully. In China it has been used primarily to increase the soil temperature to improve seed germination. Its effect on virus diseases in this case, is secondary.

Host-plant resistance

Attempts have been made in screening for peanut lines resistant to BND Despite intensive efforts over many years by ICRISAT, none of the Arachis hypogaea genotypes tested has proved to be PBNV resistant. However, lines with a high level of field resistance as well as a good agronomic characteristics have been identified. Among them are ICGVs 91056, 90013, 90009, 86598, 91183, 91228, 86325 and 91229 (ICRISAT, 1994). Some of these lines such as ICGV 86388 performs well across India. This line also has lower BND

incidence when tested in Thailand. Its lower infection rate when inoculated with the virus indicates its possible resistance to PBNV infection. It is expected that within a few years there should be a released cultivar that has both high yield and durable BND resistance.

Insecticide application

Use of insecticides in granular form such as aldecarb G or carbofuran G at the sowing time or a high and frequent doses of dimethoate spray can decrease BND incidence. The marginal increase in seed yield however, may not cover the cost of insecticide application. Therefore this practice should be reserved for the areas where BND is a severe problem or to high-valued crops only.

Biological control

At present this area of disease management has received more attention since it leaves no harmful effects to the environment. Because of its soft body and slow-moving in nature, thrips larvae are easily preyed by many predators. Among them are anthocorid bugs, mirids, wasps, ladybird beetles, syrphids, spiders and predatory thrips. The larvae can be parasitized by Eulophidae wasps and the eggs by Trichogrammatidae and Mymaridae. If biological control is to be applied, extreme precaution should be taken in using insecticides because it could nullify effect of the former.

PStV was first discovered in experimental plots in the USA in 1982 (Demski et al. 1984). It has received more attention after knowing that it could transmit through peanut seed at a very high frequency up to 37% (Demski and Lovell, 1985). The virus is endemic in most of the Asian countries and could have its origin there. In Thailand, evidence was obtained to show that PStV has been occurring since 1972 but was misidentified as peanut mottle virus (PMV) (Wongkaew and Dollet, 1990). Apart from being seed-borne the virus is transmitted by many aphid species in a nonpersistent manner. Although a number of disease control measures have been recommended for the virus, using virus-free seed appears to be the most effective. Because of their common natures in dissemination, the strategies used for PStV can be applied to PMV, PStV and CMV as well.

266

Using virus-free seed

Although PStV is detected in many weed species in peanut fields its source of primary inoculum appears to be mainly from infected peanut seed. The transmission rate of 2-5% is sufficient to lead to an epidemic of 100% incidence at harvest because of the subsequent dissemination by aphids. There fore production and distribution of virus-free seed should be the method of choice in controlling the disease. In areas where farmers keep their own seed stocks, which is a common practice in most Asian countries, they should be advised to collect seed only from healthy-looking plants. Preparing a separated seed plot is also a good alternative, where intensive care is given to eliminate all infected plants. In some countries where government sectors play a key role in seed production and distribution, consideration should be taken in finding locations, cropping systems or seasons that are disease-free to produce seed stock. International exchanging of germplasm should take extreme precaution especially from countries where PStV is prevalent. It may be necessary to restrict the export of seed from infested areas. Plant quarantine units should develop expertise and facilities to detect PStV in seeds. At present, there is a nondestructive ELISA protocol that can be used for testing peanut seed.

Eradication of alternate hosts and infected plants

Because PStV has a considerable wide host range especially among legume species this strategy may not be effective in controlling the disease. In Asia, many legume hosts of this virus are used as cattle feed therefore its elimination is undesirable for farmers. It is advised to use this method only when the epidemic occur in areas where PStV has just been introduced. An effort done by the Indian Government to eradicate all PStV infected peanut is a good example and appear to be effective. This method should also be applied in seed stock production scheme.

Host-plant resistance

Like any other diseases, cultivation of resistant cultivars should be the most effective method in PStV management, but resistance to PStV has not yet been found in cultivated peanut. The screening of approximately 10000 accessions from ICRISAT's germplasm bank, in Indonesia yielded only PStV tolerant lines (Saleh et al. 1989). However, resistance to PStV has been identified in some wild Arachis species (Prasada Rao et al. 1991), therefore attempts should be made to transfer this resistance to A. hypogaea.

Another approach is to develop peanut cultivars with very low or no seed transmission. This approach has proved to be successful in controlling PMV. This strategy would reduce both sources of primary inoculum and subsequent spread by aphid vectors. Promising genotypes have been identified in China (Xu et al. 1994) and in Thailand. In China 7 genotypes have been screened out from over 1300 entries tested. These genotypes showed less than 1% PStV seed transmission each in three consecutive tests.

Vector control

Insecticides could be applied to decrease the aphid population but may not be effective in reducing virus dissemination. Insecticides usually do not kill aphid fast enough to prevent virus spread in the field. Nonpersistent viruses are transmitted readily at the testing probe which takes only few seconds when aphids are searching for food. Therefore pesticide spray is not recommended for PStV control.

In China, application of transparent or silver-colored plastic film mulch was found effective in reducing virus disease incidence. But because of its high cost, this method may not be applicable for routine production. This practice however may have its merit in seed production. Light reflection from plastic film is known to repel aphids and many other insects.

Peanut Clump Virus

Peanut clump is considered one of the most economical diseases in India and West Africa. Although the causal viruses share common physicochemical properties, the one that occurs in India is not serologically related to that causing disease in Africa. The viruses are therefore called Indian peanut clump virus (IPCV) and African peanut clump virus (APCV) respectively. Both viruses are seed borne and can be transmitted by the plasmodiophoromycete fungus Polymyxa graminis. Using crop rotation and virus-free seed appear to be the most effective control measures for the disease.

Crop rotation

Peanut clump is prevalent only in the areas where peanut is rotated with sorghum or corn and in sandy soil. In Thailand, where peanut is rotated with rice, the disease has never been detected. Because the fungus vector needs monocotyledonous plants to multiply in

high number, interruption of the normal cycle between peanut and graminae with other dicotyledons will reduce the disease incidence. Disappearance of clump from areas where peanut is planted continuously after the epidemic, is a common phenomenon observed in many fields. Peanut roots naturally infected with APCV are not effective as source of infection, whereas roots of sorghum are. More research may be needed to understand the ecology of P. graminis and the epidemiology of the disease.

Using virus-free seed

Because the virus is seed-borne, using virus-free seed should reduce the chance of disease outbreak in the non-infested areas. Unlike other seed-transmitted viruses, results of ELISA tests on dry seed are not always correlated with that of the growing out tests. Therefore, there is a risk to lose some seed that give positive reaction to PCV-antiserum but yet are not infected by the virus.

Future Control Strategy

If farmers could be supplied with agronomically good cultivars that are resistant to all the major viruses, problems from virus diseases would be solved. Unfortunately, none of the cultivated peanut tested showed resistance to the viruses. Although good level of tolerance or field resistance have been indicated in some genotypes, the traits are less desirable than resistance to virus infection. Tolerant lines can act as a virus reservoir for spreading to other crops or to less tolerant cultivars. Field resistance can break down easily if it works on vector non-preference characteristics.

In recent years significant progress has been made towards using viral genes for transformation of plants to induce resistance to virus infection. In peanut, virus coat protein (CP) gene appears to be the most often used in producing transgenic plants Kumar et al. 1994; Cassidy et al. 1994). Although, transformation of peanut explants has been successful in many laboratories, regeneration of the transformed tissues into transgenic plants is still far-fetched especially in cultivated peanuts. At present successful regenerations have been obtained from protoplasts of A. paraguariensis, leaf tissue of A. paraguariensis and A. villosulicarpa Kumar et al. 1994) which are wild species. In cultivated genotypes there have been reports of successful attempts when cotyledon and plumular tissues were used as explants. These tissues although are less difficult to

regenerate, uniformed transformation may not be obtained hence make it less desirable for production of transgenic plants.

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271

Assessments of Crop Loss from Insect Pests

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INTRODUCTION

Peanut productions in Thailand has never met the domestic requirement although peanut is grown in most parts of the country. The major production areas are in the North, Northeast and the Central regions. The peanut growing area is over 100,000 hectares each year for the past decade. It is varied to some extent from year to year. In 1992, the total peanut yield obtained was only 136,853 tons but consumption was about three times more than this (465,909 tons). The average yield of peanut is still considerably low as compared to other developed countries. Several factors cause peanut yield reduction, and insect is one of the major constraints in production. About twenty species have been recorded as causing damage to peanut in the field (Manochai, et al., 1990; Turnjit, 1991). Some insect pests cause constant damage, whereas others are only occasionally important, Many of the insects damage to peanut are widely distributed but others are regionally specific and more restricted. The subterranean ant (*Dorylus* orientalis Westwood) , for examples, is known to be the most destructive to peanut pods and present only in Thailand and India (Roonwal, 1975). Insect pest infestations depend on many factors, the more important being the availability of food, growth stage of plant, growing season, and weather conditions. In dry season, sucking insect pests such as thrips, leafhoppers and aphids can increase very rapidly. They may be disappear at the end of a growing season and only to re-establish when adults migrate into the area again. These tiny pests, for example, thrips, *Frankliniella* spp., *Scirtothrips dorsalis* Hood and aphids, *Aphis craccivora* Koch not only

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damage directly to peanut but also clearly transmit virus diseases resulting m more yield reduction.

In contrast, peanut leaf damage caused by foliage inhibiting pests such as the cotton bollworm, *Heliothis armigera* era (Hubner) , or the common cutworm, *Spodoptera litura* F. may not result in any significant yield loss if the pods are fully formed. A relatively light infestation by under ground pest such as subterranean ants, termites and white grubs may not in itself reduce the yield significantly, but it should be remembered that any damage to the pods is likely to lead to fungal contamination. Research on soil insects damage peanut pods indicated that the higher percentage of pods damaged by insect the greater the infection of *Aspergillus flavas* had been detected both on peanut pods and seeds.

Numerous research projects on peanut have been conducted to gather information related to peanut yield loss caused by major insect pests. This information, (e.g. the action threshold of the insect pest's damage on peanut) is very useful to the growers for making an appropriate pest control decision. In fact, it is essential to reduce reliance on costly chemical control.

Major insect pests of peanut

Depending on the part of the plant insects attack, it is convenient to distinguish between insects which damage part of plant above or below the ground level. Major insect pests of peanut can be categorized into three groups as follows:

1. soil insect pests: subterranean ants, termites and white grubs.
2. sucking insect pests: thrips, leafhoppers and aphids.
3. defoliators: cotton bollworm, common cutworm and leafminer.

At present, subterranean ant is the most important insect pest of peanut growing area. Since the insect attacks pegs and pods it is very difficult either to measure or predict the population density. Normally, the infestation varies from location to location as well as in different growing seasons. Preventive control by using chemical insecticides is being practiced and recommended for protecting peanut yield though it is unnecessary in an area without the insect infestation.

Some granular insecticides, namely carbofuran (Furadan 3% 0), Quinalphos (Ekalux 5% G), thiofanox (Fanex 10% 0) and disulfoton (Solvirex 10% G), each of which applied at the rate of 1.25 Kg a.i. per hectare, have been reported to control this insect (Sepsawasdi, et al., 1987). These chemical insecticides can be applied by two methods, either treated one time at 36 days after planting or split doses applied twice at 36 days for the first time and at 64 days later. As compared with non-treated all of those insecticides were not statistically different but the peanut applied with Quinalphos gave higher yield than others. The method of application resulted in significantly different results with the split dose application. The highest yield obtained was in the peanut treated with disulfoton (Table 1). Furthermore, in 1993, a comparative research on the best timing of insecticide application against subterranean ant between chlorpyrifos (Lorsban 40% EC) and carbofuran (Furadan 3% 0) indicated that the lowest damaged pod density was found in the peanut treated two times at 60 and 80 days after planting (DAE) with chlorpyrifos at the rate of 2.5 Kg a.i. per hectare. The highest yield, however, was obtained from the peanut treated onty one time at 60 DAE. (Table 2).

Table 1. Effectiveness of some insecticides against subterranean ant on peanut yield (Kg/ha),

1986-1987.

Insecticides	Methods of application		Mean
	Al	A2	
1. carbofuran (Furadan 3%G)	791.7 ab	939.8 ab	865.7
2. quinalphos Ekalux 5%G)	993.1 a.	956.2 ab	974.8
3, thiofanox (Fanex 10% G)	928.0 ab	931.3 ab	929.8
4. disulfoton (Solvirex 1O%G)	733.8 b	1,006.3 a	870.1
Mean	881.8 b	958.4 a	

Al = one application at 36 DAE.

A2 = two applications at 36 and 64 DAB by split dose of Al into half.

Table 2. Efficacy test of different insecticide applications to control subterranean ant in a farmer field, Yasothon Province, July-October, 1993.

Treatment	Rate. (Kg/ha)	% Damaged pod 80 DAE	Harvested	Yield (Kg/ha)
1. Before planting into bed	18.75	17.0	17.3	2,218.8
2. Two applications ; Treatment 1 at 60 DAE	9.38	-	20.5	2,256.3
3. One application at 60 DAE	18.75	10.4	20.3	2,612.5
4. Two application: 60&80 DAE	9.38	-	26.9	2,093.8
5. Broadcast at 60 DAE	18.75	18.8	16.6	1,693.8
6. Broadcast at 80 DAE	18.75	-	22.4	1,750.0
7.Spray with chlorpyrifos 40% EC at 60 DAE	2.5	7.9	17.5	2,725.0
8.Spray with chiorpyrifos 40% EC at 60 & 8O DAE	2.5	-	9.0	2,112.5
9.At planting into bed with neem seed powder	31.25	17.2	27.2	2,031.3
10. Untreated	.-	22.2	22.9	1,906.3

Note: Treatment 1-6 applied with carbofuran 3 % G. and treatment 3&4 applied around the root area of peanut plant.

Cultivation methods was investigated in a farmer's field to verify their effect on subterranean ant infestation. By one plowing at the pegging stage the farmer could gain more yield of peanut than without plowing. The number of damaged pods in the without plowing of peanut field was less but its weight was more (Table 3).

Table 3. Effect of cultivation methods against subterranean ant in a farmer field, Amphur Phrao, Chiang Mal Province, May-August, 1993.

Treatment Conventional methods (At pegging stage)	No.of Pod	No.of Damaged Pod	Damaged Pod wt.(g).	Pod Wt. (g/30 plts)
1. with plowing	3,724	500	454	6,382
2. without plowing	3,508	489	533	6,194

Under the Peanut CRSP, peanut seeds which had potential resistant to major insects were provided by Dr. R. L. Brandenburg. For example, NC6 is being used in a comparative study on screening for peanut variety resistant to soil insects conducted at the Rayong Field Crop Research Center during the dry season this year (1995).

Crop loss assessment on major peanut pests

The problem of unfilled pods was significantly due to the infestation of leafhopper, defoliators (cutworm and leafminer), thrips and aphids. The vulnerable growth stages were found to be R5, R4, R3, and R1, respectively. Moreover, thrips, leafhoppers and the defoliators were the main cause of yield reduction, approximately by 0.66, 0.97 and 2.8% per percent of infested leaves, respectively (Sepswasdi, et at., 1990).

Effects of simulated defoliation on yield of peanut was conducted by Sepswasdi, et al. (1986) revealed that simulated defoliation would certainly affect yield and seed weight, the more the defoliation increased the more the yield and seed weight decrease accordingly. However, defoliations made either at low percentage or at vegetative stages slightly affected on yields and seed weights but more seriously as the percentages and stages increased concurrently. For instance, defoliation at 25% would result in reduction in yield of about 8% and gradually increase up to 30% when the defoliation was made at 100%.

276

In the same way, yields reduction of about 10 and 20% were observed when the defoliation were made at 20 and 80 days of ages, respectively.

Using the cultivar Khon Kaen 60-1, one defoliation at 62 days after planting reduced yield significantly when defoliation approached 100% . Yield reduction was obviously greater with two defoliations at 48 and 62 days after planting. Yield reduction was noticeable when defoliation reached 50% and more seriously at 75% and 100% (Table 4). Slightly different results were obtained for Khon Kaen 60-2, the boiling peanut type. One defoliation at 42 days after planting caused a yield reduction even when defoliation was as low as 25%. Greater yield reduction was observed when defoliation was done twice at 42 and 56 days after planting Table 5).

Table 4. Pod yield of peanut cultivar Khon Kaen 60-1 defoliated once and twice at different levels, Khon Kaen Field Crops Research Center, January-April, 1987.

Defoliation (%)	Pod yield (Kg/ha)	
	Defoliation 1 time*	Defoliation 2 times*
0	2,313 a	2,239 a
25	2,003 a	2,199 a
50	2,074 a	2,144 ab
75	2,156 a	1,717 b
100	1,271 b	514 c

*Defoliation 1 time was made at 62 days, and 2 times at 48 & 62 days after planting. Means in the same column followed by the same letter are not significantly different at P < O.O5 by DMRT.

Table 5. Pod yield of peanut cultivar Khon Kaen 60-2 defoliated once and twice at different levels, Mahasarakham ,December 1988-April 1989.

Defoliation (%)	Pod yield (Kg/ha)	
	Defoliation 1 time*	Defoliation 2 times*
0	2,842 a	2,985a
25	2,227 a	2,270 b
50	2,193 b	2,316 b
75	2,108 b	2,175 b
100	1,962 b	1,371 c

*Defoliation 1 time was made at 62 days, and 2 times at 48 and 62 days after planting. Means in the same column followed by the same letter are not significantly different at $P < 0.05$ by DMRT.

Evaluation of peanut germplasm for resistance to an insect complex . Two hundred and nine plant introductions and breeding lines(cultivars) from North Carolina State University had been evaluated for resistance to thrips, leafhopper, and peanut yellow spot virus (PYSV) under natural field infestation. The result of the F7-test can be reported . The lowest thrips density were found on NC6 cultivar but hopperburn and the incidence of PYSV were less on GP-NC 343. Nine entries exhibited higher yield than Tainan 9.

The immigration of some insect vectors into peanuts was investigated by using sticky traps and revealed that the number of insect vectors found on the traps was rather low throughout the growing season. Approximately, 2.5, 2.5 and 5.0 were observed per a square inch for thrips, aphids and leafhoppers, respectively. However, peak of PYSV incidence was in the early October whereas the peanut mottle virus (PMV) and hopperburn were found in late October.

Relationship of thrips density and the peanut yellow spot virus and their effects on yields of selected peanut cultivars (KK 60-3, KK 60-1 and Tainan 9) are still questionable to many factors. In 1991, the research indicated that thrips density did not relate to the

278

incidence of PYSV. The number of leafhoppers did not correspond with its damaged hopperburn. The damaged leaflets evaluated at 60 days after planting were obviously less on the KK 60-3 than that of Tainan 9 and KK 60-1. In addition, the early application without repeating treatments resulted in peanuts that were more attractive to the defoliator insects. One time treatment and untreated peanuts probably succumbed to defoliator insects, such as the *Heliothis*, less than two or three times treated peanuts. However, yields were significantly different for the peanut cultivars and the different levels of insecticide treatments. Nevertheless, the previous research, in 1990, confirmed the number of thrips and the PYSV incidence had positive correlation. In other word, the higher the number of thrips the more the infected of PYSY were on peanut and vice versa. The lowest number of thrips was found on peanut treated twice (at wk 2&4 treatments) and one time (at wk 3). The untreated (check) as well as the only one time treatment (at wk 2) peanuts suppceed the highest density of thrips population. Furthermore, peanut treated twice (at wk 3&5 treatments) showed the lowest incidence of PYSV. The time of insecticide application affected on thrips population and the PYSV. There were not significantly different for number of thrips, incidence of PYSY and hopperburn on the two peanut cultivars. Nevertheless, the higher incidence of PMV, a virus disease transmitted by aphids, had been found on Tainan 9 thsau that of KK 60-1 cultivar.

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Evolution and Variability in the *Arachis* Species

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INTRODUCTION

The genus *Arachis* L. consists of 69 described species and perhaps another 12 that will be described in the near future. The described species have been assigned to nine taxonomic sections based on the most important morphological characters, including: pegs, fruits, rhizomatous and stoloniferous stems, root systems, hypocotyl, and leaflet numbers. The greatest number of species belongs to the *Arachis* section, including the primary cultigen, *Arachis hypogaea* L. This species, known as peanut, or groundnut is a warm season legume that behaves as an annual under cultivation and is grown in most tropical, subtropical, and temperate regions of the world as a food crop to be eaten raw, roasted, boiled, or as a paste called peanut butter. Many other uses are made of the peanut, including the use of the vines for animal feed. World leaders in peanut production for 1993, in descending order of total production include: China, India, Africa, United States, Argentina, Brazil and Mexico. Only recently has China become an exporter of peanut products, and India and Africa have not exported any quantity of their crop for several years, managing only to contribute to domestic needs. In recent years accessions of *A. glabrata* Benth. and *A. pintoi* Krapov. and W.C. Gregory have become popular as forage plants in tropical climates.

Evolution of *Arachis*

The genus *Arachis* (2n=2x=20 and 4x=40) originated in South America, in southwestern Brazil or northeast Paraguay (Gregory *et al.*, 1973; Gregory *et al.*, 1980). This theory is based in the fact that this region is where the species are found which are considered most primitive (i.e., sections *Trierectoides*, *Erectoides*, and *Extranervosae*). Also, geological history plays a part in this theory. This region (referred to by Gregory *et al.*, 1980 as the

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291

Planaltine ellipse) is recognized as the Southern part of the "old Brazilian Shield" lifted by a series of mid-Tertiary uplifts as the continent continued its westward drift from ancient Africa. Because of the geocarpic fruit, the evolution of the *Arachis* genus is assumed to be closely related to downward movement of soil and water, as proposed by Gregory *et.al.*, 1973, and Gregory *et.al.*, (1980). Thus, the peneplain origin theory becomes an important part of the genus' history as the peneplain was dissected by the moving waters and along with it the genus *Arachis* was dissected into separate river valley systems. Much has been written about the separation of the various sections into different river systems, mostly based on the statement by Gregory *et.al.*, 1980. However, more emphasis may have been placed on this statement than should have been, or Gregory *et.al.,* 1980 intended (W.C. Gregory, personal communication). Gregory *et.al.*, 1980 became aware soon after the statement was written that many of the materials were not confined strictly to specific river valleys, and they recognized that the task of collection was far from complete. The extent that collection was incomplete, the extensive distribution overlaps of sections, and the occurrence of some sections in several river valley systems has been a surprise to most *Arachis* germplasm collectors.

There are several distinguishing characteristics of the *Arachis* species that can be identified as evolutionary end-results of environmental factors. The tuberous, tuberiform, and/or fleshy roots of the more ancient species obviously evolved because of the extremely harsh alternating seasons, wet vs. dry, simply as a mechanism to survive the intense drought. However, the soil, or maybe lack thereof, also contributed to the need for special survival means. This is evident in the sect. *Extranervosae* where the small tubers of some species are connected by thin sections of root, which would fit into the small cracks and crevices in the schist rock outcrop where *A. prostrata* Benth., *A. Macedoi* Krapov. & W.C. Gregory, *A. lutescens* Krapov. & Rigoni, *A. Pietrarellii* Krapov. & W.C. Gregory, and other species are found. Also, a likely contributing factor to evolution of the tuberous root systems was the occurrence of frequent fires in this region. Although man has accentuated this phenomenon by his annual dry-season "burn" philosophy, fires appear to have been a natural part of the ecosystem evolution well before the appearance of man. Lightening from a clear blue sky is common in this region during the dry season and many fires are started in this manner. The tuberous and fleshy roots would have aided in the survival of the species under such conditions. As evolution progressed the fleshy roots

were replaced by other mechanisms of survival more suited to the various new environs where more advanced materials appeared. For example, the fleshy, thickened hypocotyl of the sections *Arachis* and *Procumbentes* developed in deep, fertile soils of the Pantanal, Chaco, and the eastern Cordillera de los Andes. This feature is very evident in the perennial types of sect. *Arachis* and the *Procumbentes*, but also is easily recognized in many of the annual *Arachis* section materials of the western regions. The character is almost missing in the "annual" *Arachis* section species found in the Araguaia, Tocantins, and Parana North (Goias).

The most distinguishing character of the *Arachis* genus is the subterranean fruit placed underground by the peg. Although the peg of *Arachis* is not unique in plant taxa, there are very few structures in the plant kingdom that are similar. Evolution of the underground fruit and associated peg probably parallels the development of the tuberiform roots: simply a survival mechanism for the harsh environment of a wet/dry season ecosystem. However, the very long pegs of several groups are as much evolvement of a distribution mechanism as survival, actually the two can hardly be separated. The bi-articulated character of the wild *Arachis* fruit probably relates more to survival than to distribution. Two seeds placed near each other in the soil are more likely to be eaten by the same insect or armadillo, whereas two seeds placed 6 to 10 cm apart, and one being deeper in the soil gives a much higher chance of survival. This added depth also provides a better chance of surviving a vegetation fire during the dry season. It has also been found that the heat generated by a swift burning vegetation fire breaks the dormancy on seeds of various species of wild *Arachis*. The deeper-placed apical seed would be more likely not to have its dormancy altered, thus extending the survival range of time for a given seed generation.

Evolution of the cultivated peanut has been totally shaped by man. Classification of the species is presented in Table 3. It is very unlikely that the cultivated peanut evolved outside the 'field' of a hunter/gatherer turned cultivator. There has never been any indication that any known form of the cultivated peanut can survive without the essential element of man's intervention. Archeological evidence (as yet unpublished) referred to by Banks (1993) lends strong support for this idea, as does similar evidence from locations in northwest Argentina and southern Bolivia (A. Krapovickas, personal communication 1992). Cross-compatibility data indicate that *A. batizocoi* Krapov. & W.C. Gregory

probably played a significant role in the process (Gregory and Gregory, 1979, and Simpson, 1991 and unpublished). However, recently Kochert *et.al.*, (1991) stated that molecular data showed that *A. ipaensis* Krapov. & W.C. Gregory rather than *A. batizocoi* contributed the "B genome" chromosomes to *A. hypogaea*. Fernandez and Krapovickas (1994) with chromosome morphology analyses have interpreted their data to suggest that *A. ipaensis* and *A. duranensis* Krapov. & W.C. Gregory were the progenitors of the cultivated species. From a crossability standpoint, to generate introgression hybrids with good fertility, *A. batizocoi* is superior to *A. ipaensis*. Also, when interspecific hybrids are produced between *A. ipaensis* and other diploid sect. *Arachis* species, some fertility is encountered in the F_1's; which is not the case with *A. batizocoi*. This latter situation would be more likely to produce a spontaneous autotetraploid with high fertility.

Variability of *Arachis*

The discussion above on evolution gives some idea of the variability within the species of *Arachis*. The genus has been divided into nine taxonomic sections by Krapovickas and Gregory (1994). The major distinguishing character(s) of each section are listed in Table 1.

264

Table 1. Taxonomic sections of *Arachis* and their distinguishing characters.

Section	Distinguishing Character(s)
Trierectoides	Erect plants, trifoleolate leaves, tuberous hypocotyl and secondary roots, long pegs, perennial
Erectoides	Erect plants, tuberous/fleshy secondary roots, long horizontal pegs, perennial
Extranervosae	Tuberous and tuberiform roots of various types, thick-glossy-pubescent leaflets, pegs often with roots, perennial
Triseminatae	Axonomorphic roots, three segmented fruit, perennial
Caulorrhizae	Root primordia at nodes, hollow but fleshy stoloniferous stems, taproot axonomorphic, perennial
Heteranthae	Axonomorphic roots, annual or biannual, pubescent plant parts, long horizontal pegs
Procumbentes	Long fleshy horizontal pegs, fleshy secondary roots developing at right angles to axonomorphic taproots, perennial
Rhizomatosae	Rhizomatous, central root system axonomorphic, rooting at nodes of rhizomes, perennial, diploid and tetraploid
Arachis	Axonomorphic root system, annual and perennial, pegs at 45° angle, diploid and tetraploid

These nine sections encompass 69 described species (Table 2) and at least a dozen more undescribed species. The largest number of species (27) has evolved in section Arachis, to which the cultigen belongs (Table 3).

Table 2. Arachis Species Identities.

Section	Genus	Species	Authority (Also subspecies, variety, or secondary auth.)
Trierectoides	Arachis	guaranitica	Chodat & Hassl.
	Arachis	tuberosa	Bong. ex Benth.
Erectoides	Arachis	Martii	Handro
	Arachis	brevipetiolata	Krapov. & W.C. Gregory
	Arachis	Oteroi	Krapov. & W.C. Gregory
	Arachis	Hatschbachii	Krapov. & W.C. Gregory
	Arachis	cryptopotamica	Krapov. & W.C. Gregory
	Arachis	major	Krapov. & W.C. Gregory
	Arachis	Benthamii	Handro
	Arachis	douradiana	Krapov. & W.C. Gregory
	Arachis	gracilis	Krapov. & W.C. Gregory
	Arachis	Hermannii	Krapov. & W.C. Gregory
	Arachis	Archeri	Krapov. & W.C. Gregory
	Arachis	stenophylla	Krapov. & W.C. Gregory
	Arachis	paraguariensis	ssp.paraguariensis Chodat & Hassl.
	Arachis	paraguariensis	ssp.capibarensis Krapov. & W.C. Gregory
Extranervosae	Arachis	setinervosa	Krapov. & W.C. Gregory
	Arachis	Macedoi	Krapov. & W.C. Gregory
	Arachis	marginata	Gardner
	Arachis	prostrata	Benth.
	Arachis	lutescens	Krapov. & Rigoni
	Arachis	retusa	Krapov., W.C. Gregory & Valls
	Arachis	Burchellii	Krapov. & W.C. Gregory
	Arachis	Pietrarellii	Krapov. & W.C. Gregory
	Arachis	villosulicarpa	Hoehne

Section	Genus	Species	Authority
Triseminatae	Arachis	triseminata	Krapov. & W.C. Gregory
Heteranthae	Arachis	Giacomettii	Krapov., W.C. Gregory, Valls & C.E. Simpson
	Arachis	sylvestris	(A.Chev.)A.Chev.
	Arachis	pusilla	Benth.
	Arachis	Dardani	Krapov. & W.C. Gregory
Caulorrhizae	Arachis	repens	Handro
	Arachis	Pintoi	Krapov. & W.C. Gregory
Procumbentes	Arachis	lignosa	(Chodat & Hassl.) Krapov. & W.C. Gregory
	Arachis	Kretschmeri	Krapov. & W.C. Gregory
	Arachis	Rigonii	Krapov. & W.C. Gregory
	Arachis	chiquitana	Krapov., W.C. Gregory & C.E. Simpson
	Arachis	matiensis	Krapov., W.C. Gregory & C.E. Simpson
	Arachis	appressipila	Krapov. & W.C. Gregory
	Arachis	Vallsii	Krapov. & W.C. Gregory
	Arachis	subcoriacea	Krapov. & W.C. Gregory
Prorhizomatosae	Arachis	Burkartii	Handro
Rhizomatosae	Arachis	pseudovillosa	(Chodat & Hassl.) Krapov. & W.C. Gregory
	Arachis	glabrata	var. glabrata Benth.
	Arachis	glabrata	var. Hagenbeckii
			Benth. (Harms ex. Kuntze) F.J.Herm.
Arachis	Arachis	glandulifera	Stalker
	Arachis	cruziana	Krapov., W.C. Gregory & C.E. Simpson
	Arachis	monticola	Krapov. & Rigoni
	Arachis	magna	Krapov., W.C. Gregory & C.E. Simpson
	Arachis	ipaensis	Krapov. & W.C. Gregory
	Arachis	valida	Krapov. & W.C. Gregory
	Arachis	Williamsii	Krapov. & W.C. Gregory

Section	Genus	Species	Authority
	Arachis	Batizocoi	Krapov. & W.C. Gregory
	Arachis	duranensis	Krapov. & W.C. Gregory
	Arachis	Hoehnei	Krapov. & W.C. Gregory
	Arachis	stenosperma	Krapov. & W.C. Gregory
	Arachis	praecox	Krapov., W.C. Gregory & Valls
	Arachis	palustris	Krapov., W.C. Gregory & Valls
	Arachis	benensis	Krapov., W.C. Gregory & C.E. Simpson
	Arachis	trinitensis	Krapov. & W.C. Gregory
	Arachis	decora	Krapov., W.C. Gregory & Valls
	Arachis	Herzogii	Krapov., W.C. Gregory & C.E. Simpson
	Arachis	microsperma	Krapov., W.C. Gregory & Valls
	Arachis	villosa	Benth.
	Arachis	helodes	Martius ex. Krapov. & Rigoni
	Arachis	correntina	(Burkart) Krapov. & W.C. Gregory
	Arachis	Simpsonii	Krapov. & W.C. Gregory
	Arachis	Cardenasii	Krapov. & W.C. Gregory
	Arachis	Kempff-Mercadoi	Krapov., W.C. Gregory & C.E. Simpson
	Arachis	Diogoi	Hoehne
	Arachis	Kuhlmannii	Krapov. & W.C. Gregory
	Arachis	hypogaea	L.

Basically the section Arachis consists of the most recently evolved species of the genus, at least on the western fringe of the distribution. Smartt, et. al., (1978a and 1978b) and Smartt (1990) have proposed that the section Arachis consists of the A_1, A_2, and B genomes and that there are at least five other genomes in the genus (Am., T, C, Ex, E). Because of new names in official descriptions of materials and collection of new materials since Smartt's publications, the picture needs to be updated. Stalker (1991) has proposed the D genome for the section Arachis species A. glandulifera Stalker, and new collections of materials unknown before 1983, from the northeastern part of the distribution have

proven to be sect. Arachis. The section probably contains the following genomes and subgenomes:

A_1 Annual types

- A_1 Southwestern (Argentina, Bolivia, Paraguay)
- $A_{1'}$ Northeastern (Brazil-north & east of 15°S, 55°W)

A_2 Perennial types

B A. batizocoi and morphologically similar types that lack the "A" chromosome pair.

D A. glandulifera

Other genomes in the genus by Smartt's classification but updated to the new classification system by Krapovickas and Gregory (1994) are:

1. H: Heteranthae (Ambinervosae of Smartt 1990)
2. T: Triseminatae (Triseminale of Smartt 1990)
3. C: Caulorrhizae
4. Ex: Extranervosae
5. E: Erectoides.

Table 3. Taxonomy of Arachis hypogaea L.

subspecies	variety	US market type	Primary distribution
hypogaea	hypogaea	Virginia runner	Central and South Bolivia and Northwest Argentina
	hirsuta		Peru and Mexico
fastigiata	fastigiata	valencia	Peru, Brazil and Paraguay
	peruviana		Peru
	aequatoriana		Ecuador
	vulgaris	Spanish	Paraguay, Uruguay and Brazil
Publication authority: A. Krapovickas and W.C. Gregory (1994).			

289

The variability in genome, chromosome number, chromosome morphology and pairing, plant morphology, etc. is all interesting and useful, but the variability that interests the peanut breeder most is differences in pest and disease susceptibility and chemical makeup. The literature lists not less than 18 different pest and diseases (Table 4) for which the Arachis species have shown resistance or tolerance.

Table 4. List of peanut pests and diseases to which Arachis species are resistant or tolerant.

Early leafspot	Late leafspot	Rust
Web blotch		
Rosette virus	Tomato spotted wilt virus	Stunt virus
Mottle virus		
Cylindrocladium black rot	Sclerotinia blight	Rootknot nematode
Northern rootknot nematode		
Leafhoppers	Spider mite	Thrips
Army worm	Lesser cornstalk borer	Corn earworm
Other traits		
High triptophan	Above 60% oil	High linoleic acid content
Early maturity		

A review of the characters listed in Table 4, with literature citations is presented by Singh and Simpson (1994) and Stalker and Simpson (1995).

Several of these characters are being introgressed into the cultivated peanut currently (Simpson 1991) and many more will be used in the future for improvement of the cultigen.

290

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291

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Unlocking The Peanut Genome

H. T. Stalker[1], M.K. Beute[2], T.G. Isleib[1], and G. Kocherr[3]

INTRODUCTION

Peanut is a polyploid crop with two genomes derived from similar ancestral species. Throughout the 1960's and into the 1980's, dismally little was known about the genetics of *A. hypogaea* or its closely related species. Because improving selection efficiency is a primary goal of all plant breeding programs, and because 10 or more years are required to create a new cultivar, in-depth knowledge of the genetic make-up of peanut is highly desirable.

Plant breeders once thought that only a nonsignificant amount of variation existed in the cultivated species, but this is no longer believed to be true. The relative amount of polymorphism in the cultigen at the DNA level, however, is low as compared to many other crops. In large part because of efforts made at the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) and by plant breeders in the USA since the late 1970s, a major portion of the cultivated collection (with more than 12,000 accessions) has been evaluated for a number of disease and insect resistance traits. Efforts are being made to utilize *Arachis* genetic resources, but large-scale efforts are still needed to incorporate resistances into improved varieties. To date, only a few cultivars have been specifically released which confer either disease or insect resistance. Breeding efforts have

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been hindered by the polygenic nature of many desired traits and because only low to moderate levels of resistances have been identified for many of the most important pests in the cultivated germplasm collection. Further, restrictions placed upon breeding lines before they are approved for cultivar release in the U.S. is great; for example, lines must meet stringent criteria for pod and seed size, shape, color, and texture; oil percentage; shelf life; the ratio of seed weight to pod weight; how tightly attached the seed coat is to the seed, etc.

Many desired traits have not been found in the cultivated peanut collection and breeders have been forced to looked outside the *A. hypogaea* genetic pool for genes. Many *Arachis* species have been evaluated for numerous traits, and very high levels of resistance to the most destructive disease (for review see Stalker and Simpson, 1995) and insect (for review see Lynch and Mack, 1995) pests of peanuts have been identified. Attempts are now being made to incorporate *Arachis* species germplasm into the cultivated peanut genome.

When the Peanut CRSP program was initiated during the early 1980's, only 23 of the 69 currently described species had been described in the genus *Arachis* Further, only the cultivar NC 6 had been released with insect resistance and none specifically for disease resistance. High levels of resistance to several pathogens were already known in wild species, but few replicated tests had been conducted to specifically compare these accessions with resistant cultivated lines. Progress has been made during recent years to evaluate germplasm, but gene incorporation to the cultivated peanut has been difficult.

Because wild peanuts are significantly more difficult to work with than *A. hypogaea,* much basic research has been needed to yield meaningful progress in the use of *Arachis* species germplasm. Sterility problems and numerous agronomically undesirable traits also associated with wild species have prohibited direct exploitation for crop improvement. In order to utilize the genetic resources, several types of investigations have been conducted and will be discussed as follows:

(1) overcoming incompatibility barriers in the genus,
(2) gnomic characterization of *Arachis,* and
(3) selecting agronomic traits in interspecific hybrid derivatives.

294

OVERCOMING INTERSPECIFIC HYBRID BARRIERS IN *ARACHIS*

Utilizing wild species in most crop species is difficult, and especially troublesome in allopolyploids such as the cultivated peanut because of gnomic differentiation and ploidy differences among species. Most peanut species are diploids with $2n=2x=20$, whereas *A. hypogaea* is a tetraploid with 2n = 4x = 40. Hybrids between *A. hypogaea* and its direct tetraploid progenitor, *A. monticola, cola,* are fully fertile; however, few desired traits of importance are known in this species which do not already exist in the cultivated peanut. Other species in section *Arachis* are diploids and hybridization with *A. hypogaea* results in sterile triploid progenies. Hybrids can be treated with a chemical mutagen called coichicine to double the chromosome number of triploids to the hexaploid (2n=6x=60) level and fertility is restored, on average, in 40% of the progenies. Hexaploids can then be self pollinated or backcrossed to the cultivated species to obtain 40-chromosome interspecific hybrid derivatives (Fig. 1). Based on observations of hundreds of interspecific hybrid progenies, gene transfer from wild to the cultivated species appears to be random; and selection for desirable traits is difficult because of the low fertility levels prior to recovery of tetraploid progenies. A very large number of tetraploid hybrid derivatives have been obtained without apparent gene transfer. On the other hand, this cytological pathway has significantly increased variation available for crop improvement for at least

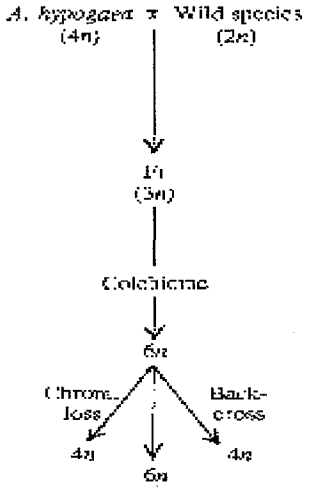

Figure 1. Hexaploid cytological pathway to tetraploid interspecific hybrids.

295

one interspecific cross, which will be described below.

An alternative cytological route is to hybridize species at the same chromosome level (Fig. 2). Although the chromosome number of *A. hypogaea* cannot be lowered to the diploid level via anther culture or other techniques, it is relatively easy to raise the diploid chromosome number to the tetraploid level. Autotetraploids and amphidiploids have been obtained for many species in section *Arachis* (Singh *et al.,* 1991). Varying levels of sterility also are present in hybrids derived from the tetraploid cytological pathway, and gnomic incompatibilities have slowed utilization of hybrid progenies. Many crosses, such as NC 6 x 4x *(A. stenosperma* x *A. diogoi)* were disappointing since desirable traits (such as leafspot resistance) were not expressed at high levels as expected when fertility was restored. In several progenies, however, selections have been made for agronomically important traits in hybrid derivatives (Singh *et al.,* 1991; Simpson *et al.,* 1993).

Cross-compatibility barriers restrict free gene exchange to the cultivated species from many species of the genus. A large number of pollinations is almost always required to produce hybrids even between relatively compatible species. Differences have been observed in hybridization success among cultivars used as parents and between reciprocal hybrids when the same cultivar and diploid species are used (Table 1). Interspecific crosses usually are more successful when *A. hypogaea* is the female parent, but there are a few exceptions. Although hybrids with *A. hypogaea* as the female parent have both genomes together in one organism, it is unknown whether disease or insect resistances are influenced by cytoplasmic genes in other species.

Table 1. Interspecific hybrids between *Arachis hypogaea* and species of section *Arachis*

	Pollin-ations	Different hybrids	Total plants	Success rate
	---------- no.	----------		%
cv. NC 4 x 23 *Arachis* accessions	2458	14	74	3.0
cv. Argentine x 21 Arachis accessions	2326	18	123	5.3
15 *Arachis* accessions x cv. NC 4	2610	5	28	1.1
14 *Arachis* accessions x cv. Argentine	2357	9	50	2.1

Taxa outside section *Arachis* are incompatible with the cultivated peanut, and fertile interspecific hybrids have not been produced. Studies have been undertaken to understand the timing and mechanisms of hybrid breakdown among species of the genus and to develop techniques to circumvent abortion.

Lu *et al.* (1990) found that the stigmatic surface and associated feathery trichomes in several annual species allowed greater numbers of pollen grains to germinate than for perennial species. However, under artificial conditions, such as those existing in a greenhouse where large amounts of pollen may be placed upon the style, fertilization is usually not considered a major obstacle to obtaining hybrids among *Arachis* species.

A major impediment to interspecific hybridization is embryo abortion, in large part because a complex system of reproductive development has evolved (Fig. 3). The embryo begins to grow a short time after fertilization, stops as the peg elongates, and then starts again after the peg enters the soil. Peanut is one of the few species which produces flowers on stems above ground, but propagates fruits and seeds underground. Embryo abortion can occur within a few days after fertilization (at a time when the embryo only has a few cells), or after growing and differentiation some weeks later (Pattee and Stalker, 1992).

297

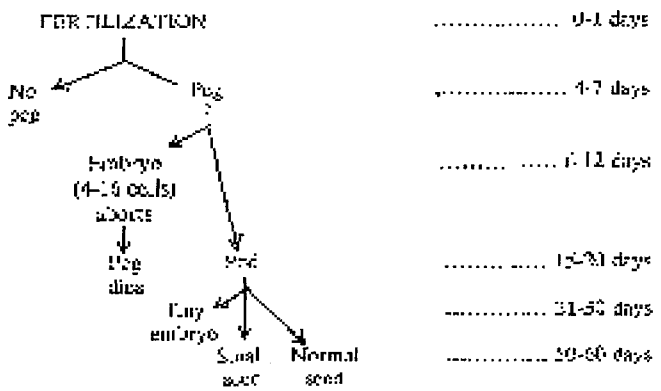

Figure 3. Reproductive development of peanut and possible aborting sequences.

To rescue aborting hybrids, *in vivo* and *in vitro* techniques have been developed to promote growth of young reproductive tissue growth until a time when embryos would survive without growth regulator supplements or artificial medium. For example, the growth hormone GA_3 will induce peg elongation when applied to reproductive nodes or leaves. Many experiments testing nutrients and sugars, hormones, pH, and environmental conditions were conducted in efforts to recover differentiated embryos which were at a heart or cotyledonary stage (about 3 weeks after fertilization in a normally developing system on the plant) (Fig. 3).

Embryo rescue techniques have become routine during recent years, and several unique interspecific hybrids have been obtained (Sastri *et al.*, 1981; Stalker and Eweda, 1989).

Because many embryos abort before the peg enters the soil, and these proembryos will not grow and differentiate, experiments have been conducted to recover hybrids from 1 to 10-day-old tissues. First, diploid *Arachis* species and *A. hypogaea* have been used to develop a model system whereby 1- to 16-celled proembryos would develop into mature plants *in vitro*. Culture of peg tips with the ovules and meristem has been most successful. A key ingredient appears to be size of culture tube, with larger flasks being better than

smaller ones. Pegs will elongate and produce pods when grown in the dark, and mature seeds can be obtained at a relatively high frequency (>40%) in test systems (Fig. 4). Recently, several hybrid combinations which have not been possible through normal sexual methods, for example, *A. hypogaea* x *A. giandulifera* have been obtained by this method. Studies are being expanded to include more distantly related species. The program to understand embryo development and the subsequent recovery of interspecific hybrids has been productive, and techniques have greatly expanded the potential for utilizing many species in the genus.

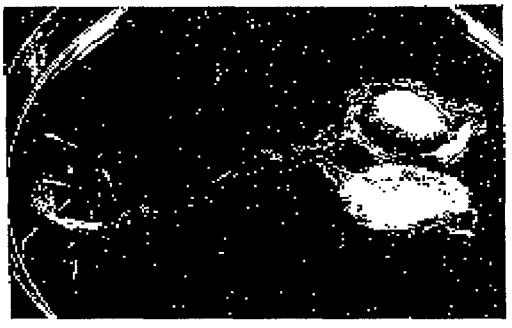

Figure 4. Seed recovered after in vitro culture of [illegible] *A. hypogaea* peg tips.

MOLECULAR CHARACTERIZATION OF THE PEANUT GENOME

Analyses of the genome of the cultivated peanut using isozymes, DNA restriction fragment length polymorphisms (RFLPs), and randomly amplified polymorphic DNA (RAPDs) have revealed that relatively little genetic variation can be detected in the genome of

A. hypogaea However, large amounts of molecular variation can be detected among wild species of the genus (Stalker *et al.*, 1994; Halward *et al.*, 1991, 1992). A RFLP molecular map has been made using two diploid *Arachis* species (Halward *et al.*, 1993), and RAPD markers have been used to create a second map using the same species hybrid (Stalker, unpublished data). Information is now being incorporated into a single map to be used for evolutionary studies, analyses of germplasm introgression from *Arachis* species to *A. hypogaea,* and identification of molecular markers associated with agronomic traits.

Many theories have been presented about the evolution of the cultivated peanut and other species in the genus *Arachis* Molecular marker studies indicate that *A. hypogaea* probably

evolved only once, and that introgression of diploid species germplasm to the cultivated species has rarely, if ever, occurred in their native habitats in South America (Kochert and Stalker, 1995). Studies of species relationships indicate that the probable diploid progenitors of the cultivated peanut are *A. duranensis* and *A. ipaensis* (Kochert and Stalker, 1995). These investigations will aid plant breeders by helping to identify species with greater homologies to the cultivated peanut and thus, correspondingly greater opportunities for gene transfer to *A. hypogaea*

Although many interspecific hybrids have been made between *A. hypogaea* and diploid species of section *Arachis,* the tetraploid derivatives are usually morphologically similar to the cultivated parent and have few of the desired traits such as disease resistance. Molecular markers have been utilized in studies to increase the efficiency of selecting progenies with gene introgression from wild species to *A. hypogaea* First, interspecific hybrids between the cultivated peanut and three diploids have been created, fertility restored at the hexaploid level and both self-pollinated to advance generations and the backcrossed with *A. hypogaea* to lower the ploidy from 60 to 40 chromosomes. DNA segments have been followed throughout different hybrid generations to identify introgression sites in the cultivated genome and when the maximum likelihood of gene transfers take place. Investigations thus far indicate that wild species DNA can be eliminated early in the hybridization cycle. Because we believe that introgression occurs infrequently following hybridization, these studies will greatly aid plant breeders in designing interspecific hybridization programs so they can make backcrosses at the generation with the highest probability of obtaining gene transfers. Of equal importance will be to elimination of large blocks of wild species genes that quality and yield.

One interspecific hybrid population derived by the hexaploid cytological route contains a large number of linkage groups with *A. cardenasii* genes (Garcia *et al.,* 1995). Genetic material from this diploid species has introgressed into both genomes of the cultivated peanut; this is opposed to earlier theories which stated that a particular wild species could only be used to incorporate genes into one-half of the *A. hypogaea* genome. A large number of RFLP and RAPD markers have been mapped in this population, several of which may have associations with disease and insect resistances.

300

Linkages between genes conditioning traits of interest and molecular markers also have been identified. Especially important are traits difficult to select in progenies, traits controlled by complex genetic systems, or traits measured by a destructive assay prior to seed. An example of the last case is the assay for nematode resistance which requires observations of young plant roots and subsequent extractions of eggs from roots, resulting in plant death. Screening of 450 RAPD primers revealed a tight linkage between both galling and egg production for one of the most devastating nematodes, *Meloidogyne arenaria* (Garcia *et al.,* 1995). Both genes are located in linkage group 1 in the RFLP map developed by Halward *et al.* (1991). The results are the first reported linkage of a molecular marker with a resistance gene in peanut, and results should allow faster development of improved hybrids. Crosses are being produced to link molecular markers with other agronomically useful traits of peanut.

Selecting Agronomic Traits in Interspecific Hybrid Derivatives.

Plants analyzed during the late 1970s from an *A. hypogaea* x *A. cardenasii* interspecific hybrid population were at the tetraploid chromosome level. From a highly variable population of hybrid derivatives were selected lines with high yields, large seeds, and useful levels of disease and insect resistances. First, lines were selected for resistance to early leafspot (caused by *Cercospora arachidicola* Ilori) and, as compared to the most resistant germplasm found in the cultivated peanut, several hybrids have low rates of sporulation, little defoliation and few lesions. Although the lines are not immune to the leafspots, they represent an important source of disease resistance for cultivar improvement. Four of selections were released as highly resistant to *C. arachidicola* and moderately resistant to *Cercosporidium personatum* [(Berk. & M.A. Curtis) Deighton] in 1993 (Stalker and Beute, 1993) (Tables 2 and 3). Crosses have been made between several of these leafspot selections and resistant *A. hypogaea* genotypes and the F_1s backcrossed to large-seeded cultivars to increase seed size and yield. High levels of resistance to *C. arachidicola* have been maintained while being accompanied by large seed size (Table 4), but yields have thus far remained depressed. Moderate levels of late leafspot resistances are present also in several of these lines.

Table 2. *Cercospora arachidicola* resistance in four *A. hypogaea* x *A. cardenasii* derived lines.

Genotype	*C. arachidicola* sporulated	
	No.	%
Hybrids		
NC-GP WS 1	19.8d	52.3cd
NC-GP WS 2	5.0 a-d	8.3 a
NC-GP WS 3	3.0 ab	14.5 abc
NC-GP WS 4	0.5 a	4.9 a
Parents		
A. cardenasii (GKP 10017)	0.3 a	2.4 a
P1261942	14.5 cd	28.5 bcd
Checks		
PI 109839	14.8 cd	56.7 cd
Florigiant	18.3 d	73.7 d

Numbers followed by a different letter are significantly different at $P < 0.05$.

302

Table 3. Field ratings of four *A. hypogaea* x *A. cardenasii* hybrids released for resistance to *C. arachidicola.*

	C. arachidicola[a]			*C. personatum*[b]
Genotype	Lesions	Defoliation	Rating	Lesion
	No.	%	1-9	No.
Hybrids				
NC-GP WS 1	5.0 ab	3lbc	3.5 b	0.1 a
NC-GP WS 2	5.7 abc	24 ab	3.3 b	1.0 a
NC-GP WS 3	2.7 a	17 a	2.5 a	0.3 a
NC-GPWS4	4.2 ab	25 abc	3.4 b	0.8 a
Checks				
P1109839	8.6 c	32bc	3.9 b	--
Kanyoma	11.9 d	33bc	3.5 b	--
Florigiant	19.9 e	55 d	6.2 c	4.4 b
NC 3033	--	--	--	7.5 c

[a]11-year average.

[b]2-year average.

303

Table 4. *Cercospora arachidicola* ratings in unsprayed plots in North Carolina, seed weight and yield of advanced generation interspecific hybrids which were backcrossed to *A. hypogaea*

Genotype	Mean rating	Wt 100 sd	Unsprayed yield
		g	kg/ha
Hybrids			
NC 6 x (PI 270806 x NC-GP WS-4)-46	2.8	71.2	2130
NC 6 x (PI 270806 x NC-GP WS-4)-52	3.0	48.4	1606
NC 6 x (NC 3O33 x NC-GP WS-1)-11	3.5	39.5	2124
NC 6 x (NC 3033 x NC-GP WS-1)-16	3.5	98.4	2381
NC 6 x (NC 3033 x NC-GP WS-1)-13	3.8	98.8	1304
NC 6 x (PI 270806 x NC GP WS-4)-50	4.0	91.0	2037
NC 5 x (PI 270806 x NC-GP WS-4)-20	5.3	92.8	1891
NC S x (NC 3033 x NC-GP WS-4)-40	5.3	119.2	1658
Resistant checks			
NC-GP WS 3	6.3	64.8	1934
PI 109839	4.3	30.8	2094
Susceptible checks			
NC 6	7.8	99.2	941
NC 7	9.0	105.1	379
LSD (0.05)	2.4	--	339

304

Additional lines from the cross *A. hypogaea* x *A. cardenasii* were selected for late leafspot and rust resistances by J. P. Moss at ICRISAT and are being used in the peanut breeding program in India. Insect resistance has also been identified in hybrid derivatives, for example, to corn earworm, leafhopper, and southern corn rootworm (Table 5). The mechanism of resistance for corn earworm appears to be antibiosis (R. Lynch, pers. commun., 1995). Several interspecific hybrid lines are highly resistant to the peanut root knot nematode, *Meloidogyne arenaria.* These lines have been derived either from the same *A. hypogaea* x *A. cardenasii* population (Stalker *et al.,* 1995) or from other interspecific hybrid combinations (Simpson *et al.,* 1993). Selections from both investigations have a tenfold decrease in galling and reproduction rates as compared to the most resistant cultivated germplasm (Fig. 5), Inheritance studies indicated that the resistance probably is conditioned by two (or more) dominant genes, so a backcross program to transfer the gene(s) is expected to be successful.

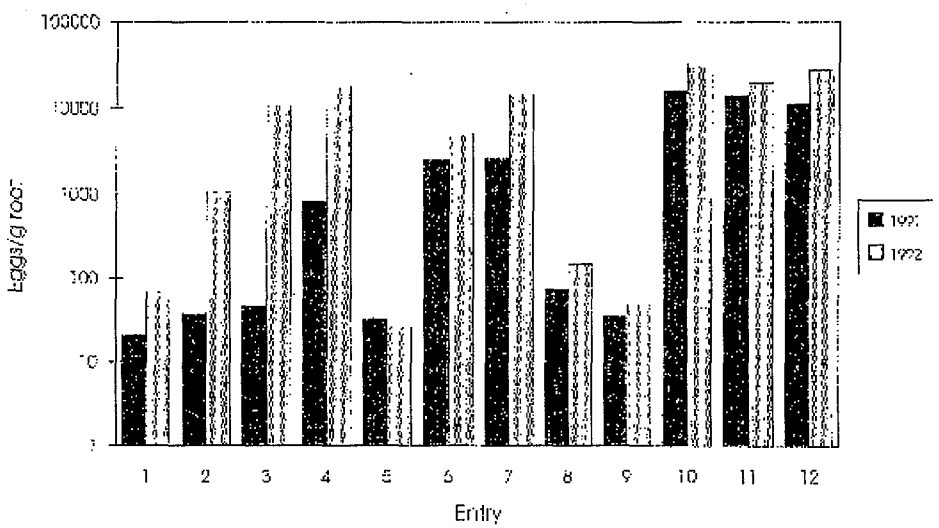

Figure 5. Reproduction of *Meloidogyne arenaria* in field microplots where entries 1-5 = tetraploid interspecific hybrids, 6-7 = resistant *A. hypogaea* plant introductions, 8-9 = resistant diploid *Arachis* species, and 10-12 = *A. hypogaea* checks.

SUMMARY

Utilizing *Arachis* species has been a long and difficult process, in large part because of sterility associated with interspecific hybrids. Further, even after fertile 40-chromosome populations have been obtained with known genes of interest, a relatively long period of

305

time has been necessary to stabilize resistances in uniform breeding materials and then to conduct crossing programs to improve yield and seed size and to eliminate detrimental traits, This ongoing process is now beginning to show results as genetic material with improved agronomic potential.

Table 5. Resistance to southern corn rootworm (SCRW), leafhoppers (LII), and corn earworm (CEW) in *A. hypogaea* x *A. cardenasii* hybrid derivatives based on 3-year average.

Genotype	SCRW	LII	CEW
	----------% damage ----------		
Hybrids			
1-02	7.4*	8.5	8.4
1-16	6.7*	8.3	4.6*
1-19	9.2	4.8	10.5
2-08	5.0*	11.1	6.1
2-25	5.9*	11.5	5.5*
2-30	4.4*	10.2	6.4
2-39	5.7*	5.7	7.4
Checks			
NC 6	21.2	5.0	11.4
GPNC343	32.1	6.8	15.0
Florigiant	43.5	13.1	11.9
Hybrid parents			
P1261942	21.7	40.4	19.4
A. cardenasii (GKP 10017)	--	0.0	11.0

*Significantly different from NC 6 at $P < 0.05$.

306

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306

Transformation of Peanut (Arachis hypogaea L.) for Virus Resistance

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INTRODUCTION

Peanut (Arachis hypogaea L.) is one of the most important protein-rich oilseed crops in the world. It is widely cultivated on six continents throughout the tropical, subtropical and warmer temperate areas. The maintenance of crop production and quality, crucial in efforts to meet the ever increasing demand for peanuts for human consumption, is dependant on the continual development of elite peanut cultivars with improved agronomic characteristics. The introduction and improvement of desirable traits, especially the ability to resist diseases and pest infestations, in new and existing peanut cultivars remains one of the greatest challenges facing peanut breeders today.

Recent rapid advancements in plant transformation technology now enable the in vitro genetic manipulation of plant cells and provide a unique tool to facilitate the introduction of desirable traits into crop plants. Over the past three years, our research efforts have been focused on the development of in vitro peanut regeneration and transformation systems, and the introduction of virus coat protein genes into peanut to induce resistance against virus diseases. To date, major progress has been made in all aspects of this program. In this report we summarize our results on the: 1.) successful regeneration of

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peanut plants from isolated protoplasts; 2.) transformation of peanut protoplasts using electroporation, and 3.) production of fertile transgenic peanut plants using an Agrobacterium-mediated transformation system.

Regeneration of plants from protoplasts of peanut (Arachis spp.)

Protoplasts provide an ideal experimental system for studies of genetic transformation, protoplast fusion, organelle transfer and somatic mutation. However, progress in the development of efficient protoplast regeneration schemes for Arachis has been slow. Earlier reports demonstrated that callus could be regenerated from peanut protoplasts isolated from various peanut explant tissues, including immature and mature leaves, cotyledons, and root tips of A. hypogaea (Oelck et al. 1982, Rugman and Cocking 1985).

In order to facilitate the development of an efficient transformation system for peanut, a study on protoplast regeneration in Arachis was initiated by utilizing a cultivated peanut-related wild species (A. paraguariensis) as a model. Using a nurse cell culture technique, we optimized conditions for callus induction from protoplasts of A. paraguariensis (Li et al. 1993). Protoplasts isolated from suspension cultures were imbedded in agarose medium containing 1 mg/1 each of NAA and BA using a plating density of 2x104 protoplasts/mi plating medium. After cocultivation with nurse cells for 14 days, up to 10% of protoplasts formed callus colonies. All protoplast-derived callus colonies of this species responded well to our defined plant regeneration conditions, and plantlets were routinely obtained. As many as 10 shoots were obtained from each callus colony after transfer to shoot regeneration medium containing MS medium, 0.5 mg/l NAA and 1 mg/l BA. Plantlets with normal leaf morphology were rooted on porous rootcubes saturated with MS medium containing
1 mg/l NAA.

The protoplast regeneration studies conducted using A. paraguariensis provided a valuable insight into the principal factors affecting regeneration of protoplasts of other Arachis spp. pp. and facilitated the extension of this technology to the cultivated peanut. High (up to 19%) levels of protoplast colony formation were reproducibly obtained from protoplasts isolated from immature cotyledons of a variety of US peanut cultivars and breeding lines using a nurse culture approach (Table 1). Our initial efforts to define a shoot induction

medium containing 2,4-D, BA, kinetin, zeatin, ABA and GA3 resulted in a low frequency (about 2%) recovery of plantlets from protoplast-derived callus colonies of several US cultivars. Protoplast-derived plants, grown to maturity in the greenhouse, were fertile and set viable seeds. Details of the protocols for protoplast isolation, culture and regeneration have been published (Li et al. 1994).

Recent modifications to our protoplast regeneration protocol, including the use of thidiazuron to enhance regeneration, have resulted in a dramatic increase in plant regeneration frequencies. Frequencies of 74.3 % and 81.2% of protoplast colonies of cvs. EC-5 and Florunner, respectively, differentiated and subsequently gave rise to shoots within a period of three months (unpublished data).

Table 1. Regeneration response of protoplasts isolated from 13 cultivated peanut (A. hypogaea L.) genotypes.

Genotype	Protolast plating efficiency (%)	Plant regeneration response[3]
GAT-2449	18.9[4]	+++
GAT-2461	12.3	-
GAT-2636	11.2	3
GAT-2736	13.8	-
GAT-2742	6.0	-
Georgia Red	5.6	0
Pronto	12.8	0
EC-5	17.2	+++
Florunner	19.3	+++
Florigiant	ND[5]	0
Georgia Runner	ND	+
NC-5	ND	-
NC-7	ND	-

[3]Visual indications of embryogenesis observed (+), somatic embryos and shoot primordia produced (++), plantlets with normal leaves and roots obtained (+++), not responsive (-).

[4] Data represent means of at least two experiments. Data on plating efficiency was not collected.

[5]Data on plating efficiency was not collected.

Protoplast-mediated transformation in peanut using electroporation

The successful regeneration of plants from peanut protoplasts permitted the development of a protoplast-mediated transformation system. There are several advantages to utilizing protoplasts in transformation studies. Protoplast-mediated transformation provides a rapid and efficient means to test the effectiveness of transformation vectors using transient expression analysis. DNA transfer into protoplasts can be accomplished by physical or chemical methods and does not rely on the use of biological vectors, thus the construction scheme for transformation vectors is relatively simple. Multiple gene constructs can be delivered into protoplasts in a single transformation experiment by including 2 or more plasmids in the transformation mixture. Finally, transgenic plants produced from a single protoplast should have a homogeneous genetic background eliminating problems associated with chimeric regenerants.

Electroporation has been used to transform peanut protoplasts because this technique results in less physical damage to the protoplasts, when compared to polyethylene glycol-mediated approaches (Li et al. 1990, Li-unpublished). A number of studies have been conducted to characterize the major physical parameters of the electroporation process that effect the efficiency of DNA transfer into plant protoplasts (Negrutiu et al. 1990, Tada et al. 1990). However, the use of protocols previously defined for use with other plant species, for electroporation of peanut protoplasts, resulted in very low frequencies of protoplast viability and low levels of transient GUS expression. No transformed plants were recovered despite repeated efforts to do so.

In order to identify more effective conditions for successful transformation of peanut protoplasts using electroporation, a poration medium containing glycine, or its derivative glycylglycine (glygly), as an electroporation buffer reagent was tested. The need for this study was based on the assumption that previously developed poration media contained complex organic acids with strong buffering capacities. The introduction of these molecules into peanut protoplasts appeared to impair cellular processes and result in cell death. Glycine, in contrast, is readily catabolized and utilized by plant cells. Thus, glycine-based poration media were evaluated for their ability to minimize the detrimental effects associated with the use of more stable buffers.

Results pp. indicated that the use of a glycine-based poration medium during the electroporation of peanut protoplasts improved protoplast viability and resulted in a 8-to 430-fold increase in transient GUS expression, when compared to levels of GUS expression achieved using other commonly-employed poration media (Li et al. 1994); The efficient transformation of peanut protoplasts was achieved using a poration medium containing 50 mM glycine or 10 mM glygly, 70 mM potassium glutamate, 0.4 M mannitol at pH 7.3.

To date, a large number of transformed peanut protoplast-derived callus colonies have been recovered. DNA Analysis of callus colonies from protoplasts transformed with the plasmid pBI426 containing the fusion gene for B-glucuronidase (GUS) and neomycin phosphotransferase II (nptII), by Southern hybridization, confirmed the integration of the transferred genes into the peanut genome (Figure 1). In our efforts to produce transgenic peanut plants with resistance to peanut stripe virus (PStV), plasmids containing the PstV coat protein gene have been introduced into peanut protoplasts. High levels of expression of virus coat protein genes have been confirmed by ELISA assay, in transformed peanut protoplast-derived callus colonies (Figure 2). Transgenic peanut plants are being regenerated from transformed protoplasts. Greenhouse studies will be conducted to determine the fecundity of these transgenic peanut plants.

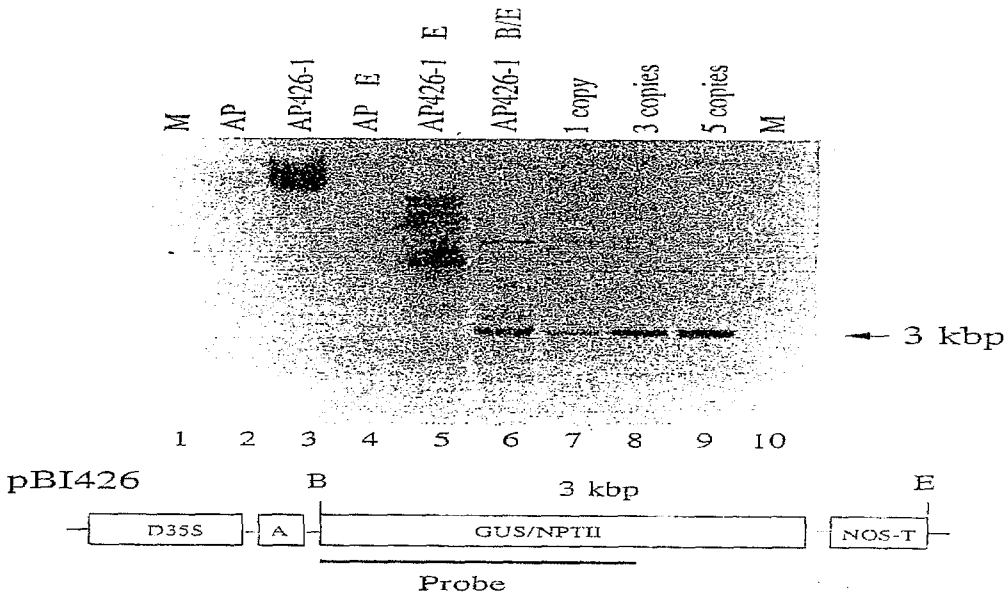

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Figure 1. Southern Blot hybridization analysis of the gnomic DNA isolated from a transformed peanut protoplast colony. Gnomic DNA was isolated from a non-transformed colony (AP) and a kanamycin-resistant protoplast colony (AP426-1) after electroporation, digested with restriction enzymes and separated on an agarose gel. A DNA probe corresponding to the entire GUS gene sequence, as indicated in the lower portion, was used for hybridization. E, EcoRI; B, BainHI; 1, 3 and 5 copies, copy number controls reconstructed with the plasmid pBI426 digested with BainHI and EcoRI.

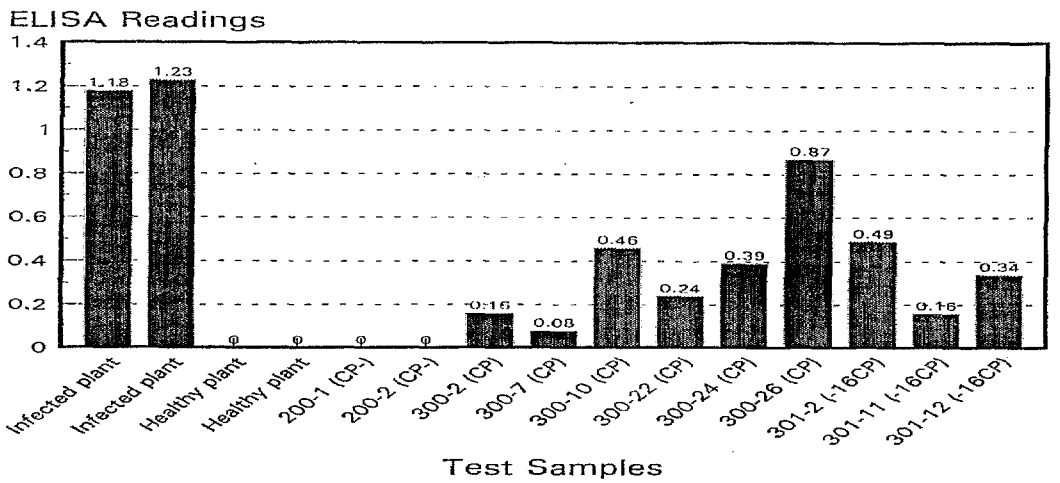

Figure 2. ELISA analysis of the expression of PStV coat protein genes in transformed protoplast colonies of peanut (Arachis hypogaea cv Florunner). Immature cotyledon-derived protoplasts were transformed by electroporation with plasmids pGA3OO and pGA3O1 containing the full length and the ^l6 deletion mutant form of PStV coat protein gene, respectively, and a selectable nptII gene. After selection with kanamycin, resistant colonies, along with positive and negative controls, were analyzed for the presence of expressed PStV coat protein by ELISA.

Agrobacterium-mediated transformation of peanut

Transformation of plants using Agrobacterium-mediated DNA transfer is the most widely used means for the production of transgenic plants. The use of this transformation method, under optimized conditions, results in high transformation efficiencies, transfer of low

copy number DNA fragments of defined sequences, and production of transgenic plants within a relatively short period of time. Previous studies with peanut indicated that infection of peanut cells by Agrobacterium tumefaciens virulent strains can be achieved (Lacorte et al. 1991). Subsequently, transformed tissues and primary transgenic peanut plants have been recovered using Agrobacterium (Eapen and George 1994). However, the inability to produce normal progeny prevented further investigation on the recovered transgenic peanut plants and necessitated further improvements on the transformation system using Agrobacterium.

Based on a previously defined protocol for in vitro plant regeneration from seedling leaf explants of the peanut cultivar New Mexico Valencia A (Cheng et al. 1992), a procedure for efficient transformation by Agrobacterium has been developed (Cheng et al. 1995). Fully expanded leaves collected from 8-day old seedlings were cut into explants and inoculated with Agrobacterium cells pretreated with an extract of wounded tobacco leaf tissue. After cocultivation for 2 days, leaf explants were transferred to shoot regeneration medium containing claforan and antibiotics. Putatative transformants were selected from regenerated plantlets based on the expression of at least two selectable marker genes. By using this method, a large number of transgenic peanut plants have been produced after inoculation of seedling leaf explants with Agrobacterium tumefaciens strain EHA105 harboring the plasmid pBI121 containing the GUS gene and nptII kanamycin resistance gene. Recovered transgenic peanut plants grown to maturity were fertile and produced viable seeds. DNA analysis by Southern hybridization indicated that the transferred genes had been integrated into the nuclear genome of primary and second generation transgenic peanut plants. Histochemical analysis of GUS expression demonstrated that the GUS gene was transmitted to progeny at a single locus in Mendelian fashion in most transgenic peanut plants (Table 2). This Agrobacterium-based peanut transformation protocol reduces the in vitro culture duration period and enables the recovery of transgenic peanut plants within S to 6 months. Current efforts are being focused on ways to utilize this system for the transformation of peanut using various virus coat protein genes.

Table 2. Histochemical analysis of GUS expression in progeny of transgenic peanut plants containing pBI121 produced after Agrobacterium-mediated transformation.

	No. of T_1			GUS+/-	3:1
T_0 Plants	Plants Tested	GUS +	GUS-	Ratio	X_2
1-4	14	12	2	3:1	0.38
1-5	8	7	1	>3:1	0.90
1-9	18	14	4	3:1	0.07
1-10	12	7	5	<3:1	1.77
1-13	20	3	17	<3:1	38.40
1-44	10	10	0	>3:1	3.33
1-45	13	0	13	---	
12-1	28	20	8	3:1	0.19
12-2	8	6	2	3:1	0
17-1	24	19	5	3:1	0.22

ACKNOWLEDGMENTS

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Breeding for Large Peanut Seeds in the Philippines

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INTRODUCTION

Virginia, Valencia and Spanish peanut types have distinct seed size ranges and shapes. Spanish and Valencia cultivars are the predominant improved varieties in the Philippines. BPI P9, UPL Pn 2 and UPL Pn 10 are Spanish cultivars preferred in the country since they are high yielding and have acceptable seed size, shape and color. However, these varieties are all susceptible to the major foliar diseases (late Cercospora leafspot and peanut rust). On the other hand, improved Valencia varieties (e.g., UPL Pn 8 and UPL Pn 12) are resistant to rust and late Cercospora leafspot diseases but have small seed size. Variation in seed size within a genotype varies with maturity at harvest (Williams et al., 1987) and on the position of the seed on the plant. Peanut seed size is an important characteristic that determines both quality and market value of a cultivar in the U. S. peanut industry (Knauft et al., 1991). Uniformity in seed size is desirable for greater efficiency in shelling, blanching, and roasting processes. Seed size distribution could be determined by weighing 100 seeds and by using slotted screens to separate seeds based on diameter.

Screen sizing is the standard procedure for the U.S. peanut industry to characterize seeds for marketing and processing (Davidson et. al., 1982).

Differences in seed size variability were identified in three U.S. cultivars (Florunner, Starr and Florigiant) as shown by Davidson et. al., (1978). Starr has more uniform seed

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size than either Florunner or Florigiant. Some genotypes were less variable than the standard cultivar (Florunner) in the study of Knauft et. al., 1991. Thus, development of cultivars with greater uniformity in seed size seems possible.

Literature review on the genetics of peanut pod and seed size showed that data are few and conflicting. Large pod and seed size have been reported to be dominant to small pod and seed size (Balaiah et. al., 1977 and Layrisse et. al., 1980). Monogenic inheritance was cited for both pod and seed size and modifier genes were suggested for transgressive segregation for seed size (Balaiah et. al., 1977). Pod and seed traits showed largely additive genetic variance, and significant maternal effects were observed (Dwivedi et. al., 1989). Other researchers have also shown additive genetic variance for pod and seed traits (Redoña, 1984; Garet, 1976; Layrisse et. al., 1980; Mohammed et. al., 1978; Swe and Branch 1986; and Anderson et. al., 1993). Redoña (1984) recommended accessions with large general combining ability such as PI 314817 and PI 262129 for hybridization work. He also found genetic correlation between seed yield, weight of pod and seed and number per pod.

Philippine Peanut Varietal Improvement Programs

Peanut breeding began in the early 1900's. Introduced varieties and cultivars were screened and selections were done for high yield and adaptation to local conditions. Promising introductions were grown by peanut farmers and local names were given to adapted and well established selections/introduced varieties.

In 1993, the Bureau of Plant Industry (BPI) at Economic Garden, Los Baños, Laguna initiated a peanut breeding program to develop, multiply and distribute pure seeds of high-yielding peanut varieties. Promising introductions were identified (e.g., Virginia Runner, Florispan, Spanish 163287, etc.) with pod yields of 1.8 to 2 t/ha.

In 1965, BPI staff hybridized promising introductions with native varieties. BPI P9 is a line selection from the cross between E.G. Red and Fante 17. It was released as a Seed board [1]variety in 1971. Although BPI P9 is high yielding, it is susceptible to late

[1]Philippines seed certification agency

Cercospora leafspot and peanut rust which are the two major foliar diseases in the Philippines. Thus, crosses between disease-resistant and high yielding cultivars have been done.

At the University of the Philippines at Los Baños (UPLB), peanut breeding started in 1950. Early works were confined to screening established (e.g., Kinorales, Pangasinan White, San Mateo) and introduced cultivars (e.g., Virginia Bunch, Virginia Jumbo, Valencia). Promising varieties were identified, mostly bunch types with maturity ranging from 105 to 125 days after emergence.

In 1961, breeding work started at UPLB to develop high yielding and disease resistant varieties. Three accessions from South America were identified to be resistant to late leafspot (LLS). These are PI 259747, PI 350680 and PI 341879. A high yielding variety, CES 101 was developed using the pureline selection method and released for commercial production in 1973.

The Institute of Plant Breeding (IPB) was established in 1975. Peanut breeding research was strengthened. The general goal of the program is to develop specific varieties for specific growing conditions.

Two introductions, Moket and PI 314817 yielded high under local conditions across locations. They were released as Seed board varieties in 1976 and 1978 as UPL Pn 2 and UPL Pn 4, respectively. UPL Pn 2 is high yielding, moderately resistant to Sclerotium wilt, tolerant to partial shade conditions but susceptible to rust and LLS diseases. UPL Pn 4 is high yielding and has resistance to both foliar diseases but has small seeds and irregular/nonuniform seed shapes.

The peanut varietal improvement program was intensified with the implementation of the UPLB-P-CRSP breeding project. New disease and insect pest resistant lines/accessions were identified and used in the breeding program to develop large seeded peanut cultivars with these resistances and tolerances to marginal growing conditions such as partial shading, highly acidic soils and drought conditions. Two new varieties UPL Pn 6 and UPL Pn 8 were released in 1986 and 1989, respectively (Table 1).

UPL Pn 6 was released as a recommended variety by UPLB in 1986. It is an IPB line selection from a cross between CES 103 and PI 298115. It has resistance to both rust and LLS diseases, is shade-tolerant and has better seed shape and seed color (Azalea pink) than UPL Pn 4 (pale pink seed coat color). However, pods of UPL Pn 6 (small and compact) are harder to shell manually than UPL Pn 4.

Table 1. Two Philippine seedboard peanut varieties released during the UPLB-FI-CRSP peanut breeding project from 1986 to 1989.

Variety	Seed Yield	Other Characteristics
UPL Pn 6	1.80	Azalea pink seed coat. Resistant to late Cercospora leafspot and rust
UPL Pn 8	1.80	Boiling type (Valencia variety) with long pods (2-3 seeds/pod). Resistant to late Cercospora leafspot and rust. Tolerant to partial shading (40% light reduction). Resistant to *Aspergillus flavus* invasion using the dry seed resistance test. Resistant to *Sclerotium* wilt infection.

UPL Pn 8 is a line selection from the cross of CES 101 and PI 298115. It was released as a seedboard variety in 1989. It has better yield performance than UPL Pn 6 and BPI P9 during the wet cropping season. Also, it has better field resistance/tolerance to *Sclerotium* wilt than the former variety, and it has shade tolerance. It has performed very well in Bohol for a number of years already. UPL Pn 8 was recommended as a boiling type peanut than as a table peanut because of its sweet taste, 3-seededness and long pod characteristics. Its limitations as a table peanut are its nonuniform seed size and shape.

National Cooperative Tests (NCT)

Data (1992-1993) from national cooperative tests across locations of 12 valid yield tests are shown in Table 2. The top yielding varieties were IPB Pn 85-2-40 (1.85 t/ha) and EG Pn

2-1 (1.81 t/ha). The mean 100 seed weights ranged from 40 to 51 g. The entries with large seeds include IPB Pn 83-117-56, JL-24 and IPB Pn 83-169-26 with seed weight ranging from 49 to 51 gm/100 seeds. All the entries were moderately resistant to late Cercospora leafspot and peanut rust. Under inoculated conditions/heavy disease pressure of *Sclerotium* wilt infection at UPLB, it was found that IPB Pn 83 117-56 was moderately resistant.

New Seed board Varieties

JL-24 and IPB Pn 85-2-40 were released as Philippine Seed board varieties in 1992 and 1994 as PSB Pn 1 and PSB Pn 2, respectively (Table 3). PSB Pn 1 is a variety introduced from India in 1985 through the subproject entitled "Performance trial of promising peanut accessions/lines in major peanut growing areas" which performed well in the Philippines. It is a high yielding, early maturing Spanish variety, with smooth thin seed coat, acceptable seed size, shape and color, resistant to invasion by *Aspergillus flavus* (Abilay, et. al., 1990), but is susceptible to rust and late leafspot. In on-farm trials conducted at major peanut growing areas (Isabela, Aurora Province, Cagayan, Ilocos Sur, Pampanga and North Cotabato) it has been the preferred variety by peanut growers/cooperators.

PSB Pn 2 or UPL Pn 12 is a line selection from the three-way cross between (UPL Pn 2 x FESR1) and NC6. This cross was made to improve UPL Pn 2 by incorporating disease resistance by hybridizing it with FESR1 (resistant accession to late leafspot and rust) and NC6 to increase seed size and yield. It exceeded the seed yield of PSB Pn 1 (national check variety) by 12.8%. Its mean seed yield across seven NCT locations is 1.88 t/ha (Table 2). It has resistance to peanut rust, late leafspot and leafhopper damage and moderately resistant to invasion by *Aspergillus flavus*. However, its seeds are smaller than PSB Pn 1. It is a Valencia variety appropriate for boiled peanuts and peanut brittle.

Table 2. Mean seed yield, 100 seed weight, reaction to late leafspot (LLS) and peanut rust of entries in the national cooperative test across locations during the 1992 and 1993 dry cropping seasons.

Entry	Seed Yield (t/ha)	100 Seed Weight(gm)	Reaction to LLS	Reaction to Rust
IPB Pn 83 117-56	1.62	51	3	2.7
IPB Pn 83 169-26	1.55	49	3	2.6
IPB Pn 85 2-40	1.85	40	2	2.0
IPB Pn 85 3-86	1.79	41	2	2.0
IPB Pn 85 10-68	1.78	40	2	2.3
IPB Pn 85 14-60	1.78	41	2	2.2
EG Pn 2-1	1.81	43	2	1.8
EG Pn 3	1.79	42	2	2.0
EG Pn 7	1.80	42	2	2.0
J1-24	1.66	49	3	2.6
BPI Pn 2 (NC)	1.61	50	3	2.4
Mean	1.73	45	2.4	2.2

324

Table 3. Two Philippine Seedboard varieties released in 1992 to 1994.

Variety	Seed Yield	Other Characteristics
PSB Pn 1 (UPL Pn 10 or JL-24)	1.66	Early maturing Spanish variety. Smooth, thin seedcoat which makes it easy to shell Large seed size and oblong seeds Pink seedcoat Resistant to A. flavus Resistant to leafhopper damage Susceptible to rust and late CLS High seed viability Preferred variety in major peanut growing areas
PSB Pn 2 (UPL Pn 12)	1.88	Resistant to peanut rust, late CLS and leafhopper damage Moderately resistant to A. flavus invasion Suited for boiled peanut, peanut brittle and butter manufacture Irregular seed size and shape Smaller seeds than UPL Pn 10

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Breeding Peanut to Fit Into Thai Cropping Systems

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INTRODUCTION

Peanut (Arachis hypogaea L.) is an important food and oil crop in Thailand. The crop is grown by small farmers in all parts of the country. It is a relatively minor crop despite its role as a source of cash income, as a major source of protein in human and animal diets, and of biological nitrogen in cropping systems. The peanut crop is grown in upland areas in the rainy season and in paddy fields following rice in the dry season. The major growing areas are in the north, northeast, and central regions. Over 100,000 ha of peanut are planted annually in Thailand. Planted area varies from year to year with a slight decreasing trend in recent years because of drought and lack of labor. Yields average about 1.4 t ha1 with a total production of 140,000 t. Over 90% of peanut production is used for domestic consumption. A small amount of shelled and boiled-dried peanuts is exported, but a significant amount of peanut cake is imported for animal feed. Thailand is thus a net importer of peanut. The average yield of peanut obtained in Thailand is low due to various constraints to production. Improved cultivars that fit into cropping systems and improved crop management practices are needed to overcome these constraints. This paper describes Thai cropping systems and progress in peanut breeding in Thailand.

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PEANUT CROPPING SYSTEMS USED IN THAILAND

Cropping Pattern

The crop is generally grown in upland areas in the rainy season, in paddy fields following rice in the dry season, and in draw-down areas along within the post-rainy season (Patanothai et al., 1987). About 60% of peanut is planted in upland areas (Table 1). Upland production is divided into two cropping patterns: monocropping (28%) and double cropping (32%). When monocropping, farmers usually grow peanut in the early rainy season (May-August) while double-cropped peanuts may be grown as the first crop (16%) in the early rainy season (May-August) or as the second crop (16%) in the late rainy season (August-November). About 38% of peanut is grown in paddy fields (Table 1). This crop is generally planted following rice in the dry season (January-April) with irrigation (35%) and without irrigation by utilizing soil moisture (3%). Production of peanut in paddy fields can be expanded by growing peanut before or after rice without irrigation. Only 2% of peanut is grown in draw-down areas along the river banks (Table 1). This crop is planted in the post rainy season (November-March).

Table 1. Peanut planted area in various Thai cropping systems (data taken only from major peanut production area).

	Area and cropping systems	Production area (ha)	Percentage
1.	**Upland**	52,603	60.3
	1.1 Monocropping	24,619	28.2
	1.2 Double cropping	27,984	32.1
	1.2.1 first crop	14,200	16.3
	1.2.2 second crop	13,784	15.8
2.	**Paddy Field**	32,921	37.7
	2.1 Under irrigation	30,318	34.7
	2.2 Without irrigation	2,603	3.0
3.	**Draw-down area**	1,680	2.0
	Total	**87,204**	**100**

Constraints to Production

Constraints to production vary across different cropping patterns as indicated in Table 2. Erratic rainfall and drought are the major constraints to peanut production in Thailand because the majority of production is rain fed (Jogloy et al., 1992). Only 35% of production is under irrigation, mainly in paddy fields. Biotic factors such as rust, leafspot, Aspergillus flavus, weeds, and insects contribute to low yield in the rainy season.

Aspergillus flavus usually is not a problem in peanuts grown in the late rainy season and dry season.

Table 2 Constraints in various cropping systems, breeding objectives and breeding work of individual institutes.

Cropping Systems	Constraints	Breeding Objectives	Institutes 1/		
			DOA	KKU	KU
Upland					
monocrop	1. Rust & leafpot	1. Resistance to rust, leafspot	**	**	-
	2. *A.flavus*	2. Resistance to *A.flavus*	*	-	**
	3. Insects	3. Resistance to Insects	*	-	-
	4. Weeds	-	-	-	-
	5. Drought	-	-	-	-
		4. High yield	**	**	**
		5. Large seeded type	**	*	**
		6. Boiling type	**	*	-
Double cropping					
first crop	1-5	1-6			
Second crop	1,3,4	1-4,6 and			
	Drought	7 Earliness	**	**	-
Paddy field					
After-rice					
irrigated	3-4	3-6			
unirrigated	5	8 Breeding for after rice unirrigated conditions (4,6)	-	*	-
Before-rice	3-5	9 Breeding for before-rice unirrigated conditions (4,6,7)	-	*	-

1/ DOA = Department of Agriculture, KKU = Khon Kaen University and KU = Kasetsart University
** more emphasis, * less emphasis.

REEDING WORK

Breeding Objectives

The goal of Thailand's national peanut breeding program is to develop peanut cultivars with resistance to major diseases and insects, tolerance to abiotic stresses and suitability to the cropping systems of Thailand. Breeding is needed to remove the production constraints in various cropping systems. Specific breeding objectives have been identified to remove those constraints (Table 2). Our objectives are to develop peanut cultivars with high yield, early maturity, and resistance to rust, leafspot, A. flavus, and insects. Apart from main rainy season and dry season, emphasis has been placed on developing peanut cultivars suitable for the before- and after-rice rain fed growing conditions. We also have worked to improve large-seeded and boiling-type peanut.

National Coordinated Breeding Program

Peanut breeding has been conducted mostly by the Department of Agriculture (DOA) in the Ministry of Agriculture and Cooperatives and by two agricultural universities, Khon

Kaen University (KKU) and Kasetsart University (KU). In 1982, a coordinated breeding program between the DOA, KKU, and KU was formulated with the aim to combine efforts and effectively utilize the strengths of the three institutes. The program has received financial support from the International Development Research Center (IDRC) of Canada and the Peanut Collaborative Research Support Program (Peanut CRSP) of USAID.

DOA researchers conduct research addressing all breeding objectives with testing mostly done in the main rainy season and the dry season with irrigation. KKU emphasizes breeding for resistance to rust and leafspots as well as developing cultivars suitable for the before- and after-rice growing conditions (Table 2). KU emphasizes breeding for large seed and resistance to A. flavus. Promising lines from the three institutes are channeled through a uniform testing program under the responsibility of the DOA. KKU and KU also cooperate in conducting the coordinated yield trials (Fig. 1).

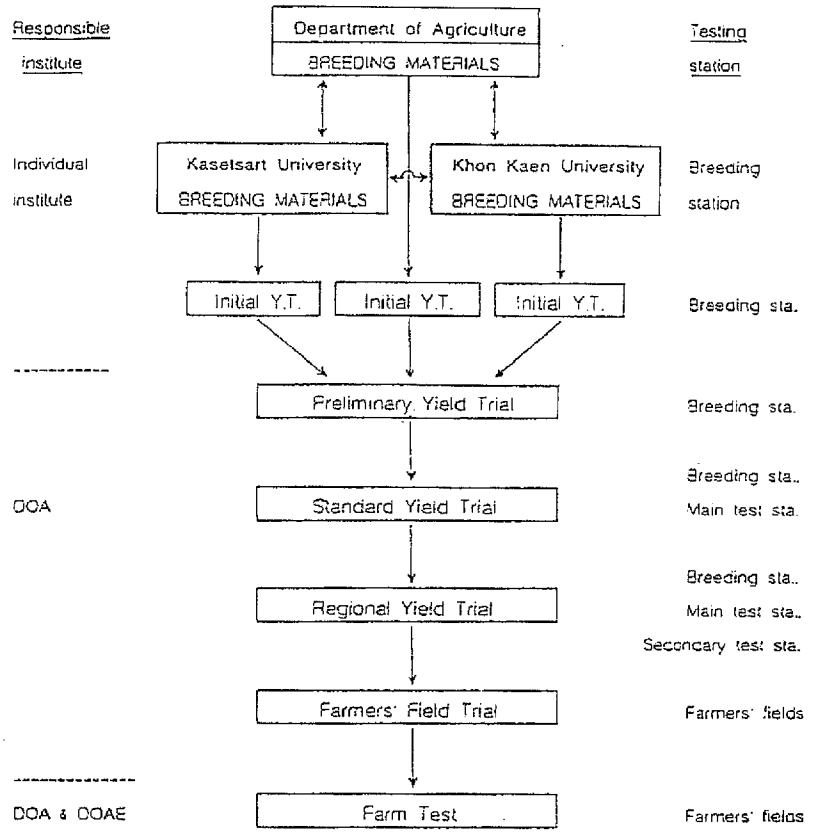

Figure 1. Testing scheme in the coordinated program.

Progress of Work

Breeding materials were introduced mainly from North Carolina State University (NCSU) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Introductions, local collections, and hybrid populations made in Thailand were divided into groups and screened for the various breeding objectives (Fig. 2). Breeding material was exchanged among the breeding stations of the three institutes. Initial selection and yield testing were done separately by individual institutes, and promising lines were entered into the coordinated yield testing scheme (Fig. 1).

352

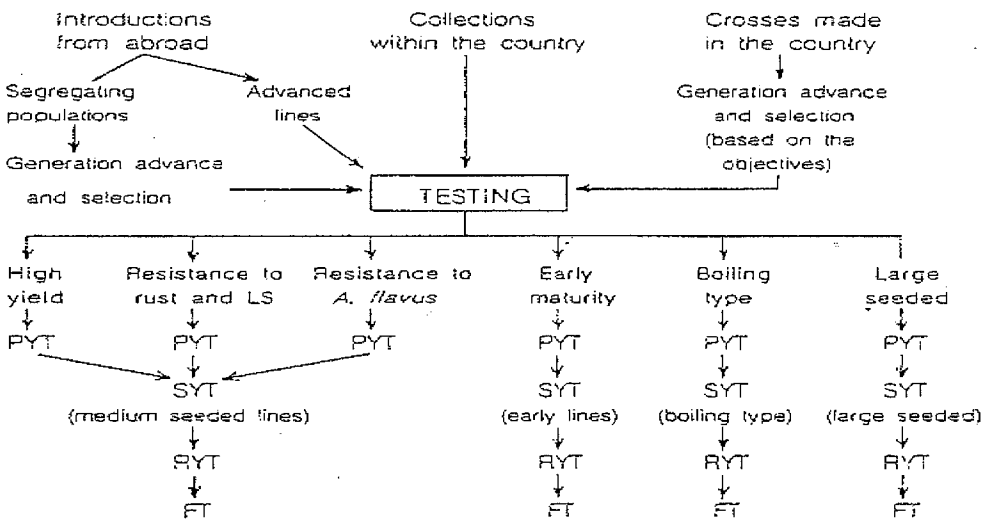

Figure 2. Flow of materials and testing system in the coordinated program.

Progress in the individual breeding objectives is summarized below.

Breeding for high Yield.

Breeding materials that did not possess the required characters for other breeding objectives were placed in the high yielding group. Screening and yield testing were conducted in each year. Significant progress has been made. Several promising lines have been identified in various yield testing stages and two high yielding peanut cultivars have been released by the DOA, Khon Kaen 60-1 and Khon Kaen 4. Khon Kaen 60-1 was released in 1987. It yields 5% more than the commonly grown cultivar Tainan 9. This cultivar has similar characteristics to Tainan 9 except that it has higher yield and has larger seed size (Toomsan et al., 1989). Khon Kaen 4 was selected from the cross of Taiwan 2 with UF 71513-1. It showed better performance in fresh pod, dry pod, and seed yield than the check cultivar Khon Kaen 60-2.Seed yield and seed size of this cultivar were equivalent to those of Khon Kaen 60-1.Khon Kaen 4 was released as a high yielding, boiling type cultivar for farmers in 1995.

Breeding for Earliness.

Certain cropping systems would benefit from development of a high yielding cultivar with early maturity, preferably 80-85 days. Crosses were made and segregating materials were introduced followed by evaluation for yield and maturity. Advanced lines were tested in farm trials in 1988. (MGS9 x Chico)-12-16-5 was the best among the early maturity lines. Its yield was equivalent to that of Tainan 9 but its seed size was smaller. (MGS9 x Chico)-12-16-5 was not released to farmers; however, it has been used as the best source of earliness in breeding programs.

Breeding for Resistance to Rust and Leafspots.

Rust and late leafspot are the most important economic diseases of peanut in Thailand. At KKU, rust and leafspot nurseries were established in the rainy season to screen breeding materials for resistance to both diseases. Advanced lines were tested in intermediate yield trials by KKU, where (M145 x NCAc 17090)-B2-B1-B2-2B1-48C-3 and (M145 x NCAc 17090)-B2-B1-B2-2B1-39C-2 were among the best lines tested. They yielded 50-60% higher than those of the common cultivar Tainan 9 over three testing sites. The two breeding lines have moderate resistance to rust but are susceptible to leafspot like Tainan 9. Seed size of those two lines is smaller than that of Tainan 9. Presently, improvement of seed size of those two lines is continued in breeding programs.

Breeding for Resistance to A. flavus.

Breeding for resistance to A. flavus is an area of emphasis at KU and DOA. Breeding materials have been screened by inoculating rehydrated dry seed. Laboratory evaluations revealed that percentage of seed infection and aflatoxin production were different among tested entries; however, the amount of toxin production on all lines was quite high (38-30,000 ppb). Among the tested lines, P1 337394F appeared to have the best resistance and should be further investigated (Waranyuwat and B hum I bham on, 1990).

Improvement of Large-Seeded Type Peanut.

Breeding materials including lines and segregating populations were evaluated for yield, seed size, and seed quality. High yielding lines with large seed and low percentage of shrivelled seed were selected for subsequent evaluation of yield and stability. Several promising lines were tested in the regional yield trial by DOA. One cultivar, RCM 387,

was used as genetic stock for seed size improvement and one cultivar, Khon Kaen 60-3, was released to farmers by the DOA in 1988. RCM 387 yielded 19% more and had 50% larger seed size than the common cultivar Tainan 9 (Patanothai et al., 1987). Seed coat color of RCM 387 is red so that it is not accepted by the consumer. RCM 387 is being used as a genetic stock for seed size improvement in breeding programs. Khon Kaen 60-3 is a large-seed virginia-type cultivar released by the DOA in 1988. The line was developed at North Carolina State University where it was released under the name NC 7. Evaluation and selection of this line was well performed in Thai growing environments. This cultivar yielded 20% more and had 100% larger seed than Tainan 9 (Watayanont et al., 1989). Improvement of Boiling-Type Peanut. In Thailand, peanut is normally consumed after boiling. The characteristics of boiling type are large and long pods with three seeds, good pod appearance, and good taste. Local cultivars were collected and breeding materials were introduced. Evaluation and selection was performed for high yield and for boiling type characters. Several promising lines have been tested in various yield evaluation stages. A cultivar, Khon Kaen 60-2, was released by the DOA in 1987. In 32 tests, this cultivar produced an average fresh pod yield 12% higher than that of the common local cultivar S.K. 38. It also has better pod characteristics for boiling type than S.K. 38 (Toomsan and Sompee, 1989).

Breeding for Insect Resistance.

Breeding for resistance to insects is in the initial stage. Several resistant lines have been identified by our entomologist and passed on to the DOA breeder for testing of agronomic performance and yield stability.

Breeding for the Before-Rice Unirrigated Growing Conditions.

In Thailand, the rainy season is from May to September. In the early season (May-July), farmers still cannot grow rice because of inadequate water, especially in the upper paddy fields. However, there generally is enough moisture to grow a short-duration field crop. Peanut is well adapted in this condition, but the maturity of the most commonly grown peanut, Tainan 9, is too long for before-rice. Early maturing lines were screened in before-rice growing conditions in paddy fields. Several promising lines were identified. Among them, 69 PYS 170 (C-124) had the best performance in this condition. The cultivar gave an average dry pod yield 21% higher than check cultivar Tainan 9 over 25 tests;

however, seed size of this cultivar was slightly smaller than that of Tainan 9. This cultivar will be recommended to farmers for the before-rice growing condition without irrigation.

Breeding for the After-Rice Unirrigated Growing Conditions.

Peanut may be grown in paddy fields following rice without irrigation by utilizing residual soil moisture. Only a small part of Thailand's crop is produced under these conditions; however, expansion of peanut production in this system is possible. All breeding materials, lines, and segregating material were evaluated and selected under these conditions. Promising lines were selected and evaluated over years and seasons. Several promising lines were identified. (MGS x Robut 33-1)-5-3-1-6 was among the best selections. It yielded 16 and 13% more than the commonly grown cultivars Tainan 9 and Khon Kaen 60-1, respectively. Seed size of this selection was larger than that of Tainan 9 and Khon Kaen 60-1. This cultivar will be recommended to farmers for the after-rice growing conditions without irrigation.

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336

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Australian Centre for International Agricultural Research (ACAIR), Australia
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346