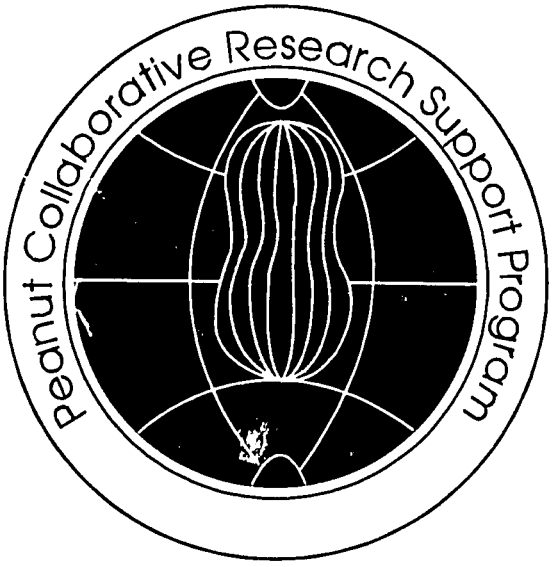
PD-ABI 168

Improving Global Production and Use of Peanut

for Economic Growth, Human Health and Nutrition, and Environmental Sustainability



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The Peanut Collaborative Research Support Program

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EXECUTIVE SUMMARY

INTRODUCTION

The Collaborative Research Support Program (CRSP) was created to implement Title XII of the United States Foreign Assistance Act of 1975. The goal of Title XII is to prevent famine and to establish freedom from hunger through land-grant university involvement in international development. To help attain these goals, the Peanut CRSP was established in 1982 to enhance the research capability of developing countries through training and research support, and to support research at U.S. land-grant institutions.

Peanut is grown in most countries, both developing and industrialized, from 40°N to 40°S latitude. Biological and physical environmental constraints to peanut production and use are similar worldwide, which gives great potential for mutually beneficial collaborative research to relieve these constraints.

As world grain production has reached levels consistently near demand, there has been a shift in consumer demand from staple grains to more nutritive, high-protein foods such as peanut. Improved peanut productivity and processing can improve human nutrition and economic development in semi-arid and sub-humid tropical and subtropical environments. Furthermore, peanut cultivation may enhance the agricultural environment as it plays a significant role in increasing the sustainability of agricultural systems.

BENEFITS OF PEANUT PRODUCTION AND USE

Environmental enhancement

- The peanut crop canopy provides nearly full ground cover. Whether grown alone or in sequence with other crops, peanut cultivation reduces exposure of soil to erosion from rainfall or wind.

- The closed peanut canopy also suppresses weeds to reduce weed pressure, especially when peanut is intercropped with a grain crop. In either case, reduced weed pressure reduces need for environmentally-harmful chemical weed control.

Economic growth

- Peanut provides a source of cash income for small-holder farmers, and rural and urban processors in developing countries.

- Biological N fixation by peanut reduces dependence on purchased N fertilizers.

- Often, the peanut crop is processed within the village or country that produces the crop. Thus, peanut production stimulates local food processing industries and adds value to the crop.

- Weed-controlling attributes of the peanut canopy reduce the cost needed for labor-intensive hand weeding or for chemicals to control weeds.

- Peanut is a versatile crop that provides growers with many options to spread risk. With a short growing season, peanut fits well as a cash crop within a large range of cropping systems. It may be grown as monoculture where the rainy season is short, in sequence with grain crops, or beneath a long-lived orchard crop such as banana or coconut.

Improved human health and nutrition

- Peanut has special potential as a famine prevention crop. It may be planted late in a rainy season if the previous crop has failed.

- At 25% protein and 45% oil, peanut provides an inexpensive, high-protein, high-energy food for humans and livestock. It is one of the most nutritive crops available as a complement to cereal grains.

- Peanut supplies a high-quality, healthy vegetable oil for cooking. Supply of cooking oils is often inadequate in developing countries.

CONSTRAINTS ASSOCIATED WITH PEANUT PRODUCTION, PROCESSING, AND USE

While peanut offers many benefits to growers, processors, and consumers, there are still several important constraints associated with peanut production and use. The Peanut CRSP was started in 1982 to address a set of global constraints to sustainable peanut production and use. Those constraints served as the initial basis for planning and organizing the Peanut CRSP in 1980 to 1982. Based on past Peanut CRSP accomplishments and the assessment of the External Evaluation Panel in 1989, the following constraints associated with peanut production were confirmed to be valid for the current 1990 to 1995 phase of the program.

Environmental

- Dependance on chemicals to control insect pests and diseases.

- Peanut cultivation in the Sahel region of West Africa may be related to southward expansion of the Sahara Desert.

- Inadequate diversity in cultivated peanut germplasm grown in developing countries and the U.S.

Socioeconomic

- Low productivity or yield loss from disease, drought, insects, and nematodes.

- Local resource management situations may prevent efficient production and use.

- Insufficient local food supply or inadequate food technology prevents growers, processors, or consumers from exploiting the full potential of peanut because it is not considered as a primary food source.

- Information not available to potential beneficiaries of new peanut production and use technologies.

- Economic losses resulting from mycotoxin contamination.

Health and nutrition

- Health hazard from mycotoxins in contaminated peanut.

- Methods needed to incorporate peanut and peanut products into safe and nutritious processed foods.

Research capacity and tools

- Inadequate numbers of trained research and support personnel in host countries.

- Research tools using molecular biology are not readily applicable to peanut. These tools enable efficient and effective germplasm improvement with respect to resistance to pests and diseases, tolerance to abiotic stresses, seed quality and quantity, and adaptation to growing season. Thus, molecular genetic tools will enhance our capacity to overcome constraints related to environment, economic growth, and human health and nutrition.

In short, the Peanut CRSP enhances the potential of peanut as a cash crop for human food and animal feed in developing countries and the United States. The Peanut CRSP contributes to increasing rural incomes, sustained productivity of agricultural land, and improved health and nutrition of peanut consumers. Furthermore, the Peanut CRSP contributes to enhancing the research capacity of developing country institutions. Collaborative research on peanut is producing new and improved technology that improves the well-being of people in developing countries and the United States.

THE GLOBAL PLAN

Peanut is a global crop. The crop is widely distributed and important to both developing and industrialized countries. Biological and physical constraints to peanut production are similar worldwide. Research is needed to develop technologies that relieve constraints to peanut production and use, particularly in developing countries with marginal food and protein supply.

For a global crop with global research needs, the Peanut CRSP can catalyze the collaborative efforts of researchers and administrators from diverse groups, including developing countries, U.S. institutions, international agricultural research centers, non-governmental organizations, and donor agencies. The synergism of this collaboration multiplies the impact of Peanut CRSP accomplishments.

Global thrusts

Sustainable production and delivery of food for human consumption are still primary problems in the developing countries. Based on the potential contribution of peanut to sustainable, nutritious food production, the Peanut CRSP has three global thrusts:

1. To develop sustainable agricultural production and food delivery systems that are profitable, environmentally-sound, and relieve important constraints to peanut production and use.

2. To resolve resource management situations that restrict appropriate research or diminish efficiency of systems for peanut production and use.

3. To communicate research outputs to beneficiaries in developing and industrialized countries.

Peanut CRSP benefits and beneficiaries

The benefits of Peanut CRSP collaborative research are adequate quantities of affordable, healthy, nutritious food for rural and urban consumers, increased incomes for peanut growers and processors, and environmentally-sound production and processing systems. Beyond these immediate benefits of improved peanut technologies, community and national benefits ensue from greater profitability of the agricultural sector and a healthier population.

Developing country beneficiaries

- Small-holder farmers, including rural women
- Food processors
- Rural and urban consumers

United States beneficiaries

- Peanut growers
- Processors, marketers, exporters
- Rural and urban consumers

Research strengthening

Progress toward accomplishment of our three global thrusts depends on improved capacity for collaborative research. In host country institutions, the Peanut CRSP trains research and support personnel, and provides critical research equipment. Training has emphasized degree and short-term, non-degree training at host country and U.S. institutions. In both host country and U.S. institutions, the Peanut CRSP supports research activities and facilitates communication among researchers.

Cooperation and coordination

While the Peanut CRSP is the only international program that focuses solely on peanut, there are other research organizations that conduct some peanut research. Since its inception, the Peanut CRSP has enhanced research and technology transfer through cooperative relationships with other international organizations. These relationships enhance cooperative research planning to avoid redundancy across programs, and joint conduct of workshops and symposia to communicate research results. Some organizations with which the Peanut CRSP cooperates are:

- ICRISAT — the International Crops Research Institute for the Semi-Arid Tropics
- ISC — the ICRISAT Sahelian Center (ISC)
- CIRAD-CA — the French Center for International Agricultural Research and Development, Annual Crops Program
- IDRC — the Canadian International Development and Research Centre
- ACIAR — the Australian Centre for International Agricultural Research

SELECTED MAJOR ACCOMPLISHMENTS -- July 1992 through June 1993

Environmental enhancement

- Two breeding lines were released in Texas with resistance to rootknot nematode.

- Two breeding lines are ready for release by the Philippine Seed Board. IPB Pn 85 2-40 is leafhopper and rust resistant. IPB Pn 85 10-68 is leafhopper and late leafspot resistant and has moderate rust resistance.

- North Carolina released 'Robut 33-1 x NC 2214' and 'J11 x (M13 x NC 3083)', two hybrids with excellent resistance to leafhopper.

- Four interspecific hybrids were released in North Carolina as germplasm sources for resistance to early leafspot, the most important peanut disease worldwide. This germplasm has great potential for reducing fungicide use in the U.S. and for increasing yields in developing countries.

- A data base on peanut cultivar evaluation for resistance to insect pests has included results from the Philippines and Thailand.

- Methods have been developed to reduce insecticide application through a need-based approach. Data from pheremone traps support decisions in North Carolina, whereas data from field scouting support decisions in the Philippines and Thailand. These methods can significantly reduce pesticide use, but they do not significantly increase profits.

- Insect ecology studies have shown that thrips, the vector for tomato spotted wilt virus disease, overwinter in maize fields, not in peanut fields. Thus, control of this important disease vector must include fields surrounding peanut fields, not only the peanut fields.

Economic growth

- *Tricograma* and *Bacillus thuringensis* application in the Philippines need for pesticide application to control *Lepidopterous* insects and increased profit nearly 3-fold.

- In Burkina Faso, ash application increased peanut yields by 221% to improve profitability.

- The Thai Seed Board released 'Khon Kaen 4', a profitable, boiling-type peanut variety.

- Two medium-duration varieties with resistance to rosette and one high-yield short-duration variety without resistance were identified and seed increased for release to farmers in Nigeria.

- The high seed quality breeding line N90013 was confirmed to be moderately resistant to *Cylindrocladium* black rot, a major disease problem in North Carolina.

- Data sets have been developed in Texas to test and apply PeanutGro, a crop simulation model. This model will allow efficient environmental characterization and risk analysis.

- A survey of peanut virus diseases in Thailand identified two economically important diseases -- bud necrosis, which is related to tomato spotted wilt virus, and yellow spot.

- The farmer cooperative in San Antonio, Belize has been using an experimental peanut drier. Farmers use it to dry both peanut and corn. The drier improves peanut seed quality and value. The cooperative also sells drier use to non-member farmers. Further improvements for lower cost and easier portability are being developed in Georgia.

- A pedal-operated thresher was introduced from Thailand to Jamaica. It is light weight, independent of electrical or gasoline supply, and constructed from local materials. Preliminary results are highly favorable. One local manufacturer is already interested in producing the thresher.

- Fast, energy-efficient, and lowcost methods for microwave peanut roasting were developed.

- New peanut butter formulations have been developed in Georgia to improve quality and consumer acceptance in Belize. The formulations use palm oil or alternate peanut cultivars to prevent oil separation and to improve flavor.

- 'Musty' flavor is associated with n-methyl pyrrole. Research in Alabama showed that the compound varies across peanut genotypes. Thus, germplasm evaluation and selection against n-methyl pyrrole can improve peanut flavor and seed quality.

Improved human health and nutrition

Mycotoxin reduction:

- Methods were developed in Texas to screen for norosolenic acid, an aflatoxin precursor. Screening for norosolenic acid will allow easier evaluation of germplasm for resistance to *Aspergillis flavus* infection or aflatoxin production.

- A gene that controls an enzyme in the aflatoxin synthesis pathway, verA, was cloned, sequenced, and characterized.

- Three peanut varieties from Ghana were identified which appear to reduce *Aspergillis flavus* growth and aflatoxin production.

- A strong relationship was shown between termite damage to pods and aflatoxin levels. Termite damage increases with delay in harvest and with decreased soil moisture. Three termite-resistant peanut lines have been identified, NCAc343, a high-yeilding cultivar, and lesser yielding NCAc2240 and NCAc2243.

Food processing:

- Hydrogen peroxide treatment was developed in Georgia to reduce aflatoxin levels in peanut seeds and treated seeds were still of high enough quality for use in peanut brittle.

- A high-protein 'idli' (breakfast food common in South Asia) was developed in Alabama using defatted peanut flour. The improved idli has 63% more protein than traditional idli. Similar methods are being used to develop a more nutritious 'toe' (traditional food of West Africa).

- A traditional Thai sweet snack, 'tuub taab', was produced with 50% ground roasted peanut to improve its nutritional value. The improved snack has high consumer acceptance, long shelf-life in aluminum packaging, and 14% protein content.

- Nutritious, delicious extruded snacks with peanut flour or with a peanut-sweet potato mixture have been developed and tested in Thailand and Georgia.

- A high-protein, peanut-based curd similar to tofu was developed through Philippine-Georgia collaboration. It has a one-week shelf life with refrigeration.

- A high-protein non-dairy food spread (similar to cheese spread) was developed for the Philippine market. It has a shelf life of at least 6 months without refrigeration.

Molecular genetics

- A system was developed in Georgia to regenerate peanut plants from tissues bypassing the callus stage using diazuron. This system greatly improves our capacity to introduce novel genes into peanut germplasm.

- Improved protocols were developed for selection of peanut plants with desirable transgenic traits.

- Plasmid vectors for peanut transformation are under construction to allow recovery of PStV capsid protein, TSMV nucleoprotein, and bean chitinase, either singly or in combinations.

Manpower development

- Staff of the University of the Philippines trained 30 Filipino technicians and farmers on peanut seed production.

- Staff of the Thai Department of Agriculture and Khon Kaen University trained 30 extension personnel in peanut production technology.

- Two institutes in Ghana became partners in the mycotoxin management project: the University of Science and Technology in Kumasi and the Food Research Institute in Accra.

- Four students completed Ph.D. degree programs in U.S. universities. Seven students with full Peanut CRSP support and three with partial Peanut CRSP support are continuing Ph.D. programs in U.S. universities, and one student is continuing a Ph.D. program in a host-country university.

- Two students completed M.S. degree programs in U.S. and two in host-country universities. Three students are continuing M.S. programs in U.S. and seven in host-country universities with full Peanut CRSP support. Three students are continuing M.S. programs in host-country universities with partial support.

- Ten B.S. students are conducting research in Peanut CRSP activities in host-country institutions.

- Three collaborators have come to the U.S. for short-term training and 17 have participated in short-term training in various host-country institutions.

COMMUNICATIONS

Workshops

- Sixty people attended a workshop on "Improving Production and Quality of Peanut" in Mandeville, Jamaica 12-14 January 1993. The major output of the workshop was improved communication among peanut growers, processors, researchers, extension agents, and Department of Agriculture administrators. This workshop was the first time that many of these groups had met. Farmers attending the workshop decided to form a farmers' group to request Extension Services to improve communications.

- Seventy people attended a workshop on "Transfer of Peanut Production and Utilization Technologies" at Kasetsart University, Thailand 23-24 March 1993. The workshop proceedings (128 pp) summarize 10 years of Peanut CRSP research in Thailand.

- The Third West Africa Regional Peanut Workshop was held in cooperation with the ICRISAT Sahelian Center September 14-17, 1992 in Ouagadougou, Burkina Faso. Peanut CRSP participants included: Olin Smith, Mike Schubert, Bharat Singh, Robert Lynch, and James Demski from the United States; Ousmane Ndoye and Amadou Ba, Senegal; S. Boye-Goni and O. Aladi, Nigeria; Idrissa Dicko and Phillipe Sankara, Burkina Faso; Amadou Mounkalia, Niger; and guest Ms. Kafui Kpodo, Ghana. The major output of the Workshop was a review of on-going research and recommendations for future priority research in the Region.

Special Publications

Demski, JW, DVR Reddy, S Wongkaew, ZY Xu, CW Kuhn, BG Cassidy, DD Shukla, N Saleh, KJ Middleton, P Sreenivasulu, RDVJ Prasada Rao, T Senboku, M Dollet, and D McDonald. 1993. Peanut stripe virus. Information Bulletin no. 38. Peanut CRSP, Griffin, GA and ICRISAT, Patancheru, Andhra Pradesh, India. 16 pp.

Haruthaithanasan, V, W Wattanatchariya, P Chompreeda, S Wattanatcharlya, N Thongsiri, and C Oupadissakoon. 1992. Technology transfer: development of peanut processing in Huay-Bong-Nua Village, Thailand. Research Report 92-03. Peanut CRSP, Griffin, GA. 20 pp.

Purcell, JC, RL Moxley, and GC Wheelock. 1992. The economic impact of Peanut CRSP in Jamaica: performance of CARDI/Payne cultivar. Research Report 92-02. Peanut CRSP, Griffin, GA. 10 pp.

Subrahmanyam, P, S Wongkaew, DVR Reddy, JW Demski, D McDonald, SB Sharma, et DH Smith. Field Diagnosis of Groundnut Diseases. Information Bulletin nol. 36. ICRISAT, Patancheru, Andhara Pradesh, India. 79 pp. (English)

Subrahmanyam, P, S Wongkaew, DVR Reddy, JW Demski, D McDonald, SB Sharma, et DH Smith. Diagnostic au champ des maladies de l'arachide. Information Bull. no. 36. ICRISAT, Patancheru, Andhara Pradesh, India. 79 pp. (French)

PEANUT CRSP ADMINISTRATION AND MANAGEMENT

The Peanut CRSP Management Group includes: the Management Entity at the University of Georgia with a Program Director, Administrative Secretary, and a part-time accountant; the Board of Directors with representatives from Alabama A&M University, The University of Georgia, North Carolina State University, Texas A&M University, and ICRISAT; the Technical Committee with representatives from the above four universities; an External Evaluation Panel with seven members being considered in a reorganized Panel; an AID/R&D/AGR Program Manager; and a BIFADEC liaison.

Management Entity

The Management Entity is responsible to US AID and to the participating U.S. and host country institutions for fiscal and programmatic activities.

Activities:

- Provided logistical and managerial support to Investigators, including program planning, travel, and equipment purchase.

- Prepared necessary reports including; Annual Report for 1992, quarterly reports, quarterly Newsletter, and Annual Work Plans and Budgets.

- Published two special articles: 1) The economic impact of Peanut CRSP in Jamaica: performance of CARDI/Payne cultivar. Research Report 92-02; 2) Technology transfer: development of peanut processing in Huay-Bong-Nua Village, Thailand. Research Report 92-03.

- Arranged Board of Directors and Technical Committee Meetings.

- Arranged and participated in Annual Peanut CRSP Meeting in Norfolk, VA July 10-11, 1993 with the American Peanut Research and Education Society Meeting July 7-10.

- Participated in CRSP Council activities to promote all CRSPs, to foster cooperation among CRSPs, and to seek inter-CRSP research opportunities.

- Coordinated CRSP contributions to the International Arachis Newsletter.

- Participated in a US AID Symposium on the Impact of Technology on Agricultural Transformation in Africa, October 13-17, 1992 in Washington, D.C..

- Attended CGIAR Centers Week Meetings in Washington, D.C. October 28-30, 1992.

- Traveled to Kingston, Jamaica, January 11-14, 1993 to participate in and present a paper in the Workshop "Improving Production and Quality of Peanut in the Caribbean."

- Traveled to Ghana January 18 to February 3, 1993 to finalize and sign agreements with the University of Science and Technology, and the Food Research Institute for collaboration with the Texas A&M Mycotoxin Project and the Alabama A&M Food Technology Project.

- Visited with collaborators and administrators at Texas A&M March 8-10, 1993.

- Traveled to Washington, D.C. April 1, 1993 to meet with AID and NASULGC Administrators on program planning for CRSP Council Meeting. Prepared slide presentation for CRSP Council and participated in the AID and Congressional Educational Meetings on April 13, 1993.

- Barbara Donehoo retired as Administrative Secretary on April 30, 1993 after 10 years service to the CRSP and was replaced by Belinda Purser.

Board of Directors

The Board is the policy making group in the CRSP and is responsible for establishing the general directions for the CRSP as carried out by the Management Entity. The Board also acts on recommendations from the Technical Committee on budgets, programs, and other CRSP concerns.

Activities:

- Conducted conference call meeting on June 30, 1993.
- Considered recommendations from the Technical Committee and approved 1993-1994 Work Plans and Budgets.
- Elected Dr. Johnny Wynne, North Carolina State University as Chair for a two-year term. Also, elected Dr. Onuma Okezie, Alabama A&M University as Vice-Chairman for a two-year term.

Technical Committee

The Technical Committee is responsible for formulating program and budget plans for recommendation to the Board. They are also responsible for internal evaluations of the program and advising the Management Entity and Board of any concerns.

Activities:

- Conducted two meetings during the year: Norfolk, VA on July 10-11, 1992; and April 26-27, 1993 to consider Work Plans and Budgets for 1993-1994.
- Dr. Tom Isleib, North Carolina State University was elected Chair and Dr. Manjeet Chinnan, The University of Georgia, vice-Chair.

External Evaluation Panel

The External Evaluation Panel is designed to give an unbiased view of how the CRSP is progressing toward meeting its objectives.

- Reviewed and provided the Management Entity with an evaluation report of CRSP activities for 1992-93. This review was done through reports and published information without site travel. A similar report was prepared the previous year.
- Dr. Alan Norden traveled to Malawi with the Program Director to evaluate the potential for Malawi as a CRSP site.
- A new External Evaluation Panel is being developed. Dr. John Cherry, Director, USDA/ARS Eastern Regional Research Laboratory, will be the only returning member. Dr. Johnny Pendleton, University of Illinois (retired);

Dr. Alan Norden, University of Florida (retired); and Dr. Ray Hammons, USDA/ARS, Tifton, Georgia (retired) were the other External Evaluation Panel members. All four served the CRSP well, beginning with the extensive review in 1989 that was a part of the successful proposal extending the Peanut CRSP five years from 1990-1995. We thank them for their dedicated service to the CRSP, and wish them well in any future endeavors.

US AID Program Manager

The Program Manager, Dr. Robert Schaffert, AID/R&D/AGR, interacted with the CRSP on a continuing basis, and provided the primary linkage for the CRSP with AID. Dr. Phillip Warren replaced Dr. Schaffert during the year.

Activities:

- As an ex officio member, participated in the Board and Technical Committee Meetings.
- Provided necessary actions on travel clearances, equipment purchases, etc.
- Coordinated and promoted CRSP Council activities for the Peanut CRSP.
- Provided liaison with the CRSP for all information from AID important to the functioning of program.

BIFADEC Liaison

The liaison, Mr. William Fred Johnson, provides a link with BIFADEC for information and actions important to the Peanut CRSP.

Activities:

- Provided information regularly to the CRSP, including participating in the monthly CRSP Council Conference calls.
- Attended the Annual CRSP Meeting and Technical Committee Meeting in Norfolk, VA July 10-11, 1992.

PEANUT CRSP IN RELATION TO EXPORT COMPETITION

Host countries of the Peanut CRSP do not compete in the edible peanut export market. Some West African countries, particularly Senegal, export peanut oil and oil meal, but the United States does not export oil or oil meal. The U.S. Department of Agriculture, Foreign Agricultural Service data lists minor amounts of peanut export from some host countries, for example, from Mali. This export is probably not export of edible peanut, but oil seed being shipped to a mill in another country for extraction.

PLANS FOR 1993-1994

Research and Training

Research and training in the Peanut CRSP will continue toward five major outputs: 1) reduced dependence on chemical pesticides through improved disease and pest resistant cultivars; 2) more profitable, sustainable peanut production through better adapted, higher quality, and higher yielding cultivars; 3) improved human nutrition through increased use of peanut products; 4) improved human health through prevention of exposure to mycotoxins; 5) more profitable peanut processing through improved post-harvest handling systems.

While most research in 1993-1994 will follow the plan established in 1990, there are several proposed changes to the research program.

- A new food processing activity is beginning in Ghana through collaboration with Alabama A&M University. Research will emphasize improved methods for producing peanut butter and more nutritious weaning foods based on composite flours.

- Research on technology transfer methods for food processing is being established in collaboration with the Visayas State College for Agriculture in Baybay, Leyte, Philippines and University of Georgia.

- Crop simulation modeling research will begin in Texas now that basic data sets have been developed. These models are needed for a new activity to compare soils and climates of West Africa and Texas for environmental factors related to drought, disease, and mycotoxin incidence. Thus, the models may be used for environment characterization and risk assessment.

- Research emphasis on post-harvest systems will shift from Eastern Caribbean to Southeast Asia. The focus in Southeast Asia will begin on establishing strong linkages between Thai researchers in peanut production and processing.

- Economic models will be developed to assess peanut food processing in Thailand.

External Evaluation

The External Evaluation Panel will review the entire Peanut CRSP during the 1993-1994 period. This evaluation will include site visits to host country collaborators in West Africa, Asia and the Caribbean. The purpose of the evaluation this year will be twofold: 1) to assess progress of the Peanut CRSP toward meeting the goals and objectives stated in the current five-year program plan; and 2) to establish a basis for a proposal for a new five-year extension of the Peanut CRSP.

Proposal for a New Five-Year Extension

Scientists participating in the Peanut CRSP have made great progress in developing new technologies for peanut production and processing. There are, however, new and continuing problems facing peanut growers, processors, and consumers: 1) Mycotoxins are still significant health hazards; 2) There is great scope for reducing dependence on chemical pesticides; 3) Peanut products have great, untapped potential for improving human nutrition.

Upon the conclusions and recommendations of the External Evaluation Panel, the Management Entity will lead the effort to develop a proposal for a new five-year extension. In developing a proposal for extension, the management Entity will seek inputs from all Peanut CRSP stakeholders, including growers, processors, researchers, international agricultural centers, donors, and non-governmental organizations in the U.S. and host countries.

Peanut CRSP Management

With approval of US AID and the Peanut CRSP Board of Directors, we will search for and fill the position of Assistant Director. The primary responsibilities of this position will be to assist the Peanut CRSP Director in managing the Management Entity office, preparation of reports, and preparation of the proposal for a new five-year extension of the Peanut CRSP.

TX/BCP/WA
Disease-Resistant Peanut Varieties
for Semi-Arid Environments
Texas A&M University

Institut Senegalais de Recherches Agricoles, Senegal
Universite de Ouagadougou/Institut Developement Rurale, Burkina Faso
Institut Economie Rurale, Mali
Institut Nationale de Recherches Agronomiques du Niger

O. D. Smith, Principal Investigator, TAMU.
L. Cisse, ISRA; P. Sankara, UO-IDR; D. Soumano, IER;
A. Mounkaila, INRAN, Co-Principal Investigators;
J. C. Mortreuil, O. N'Doye, ISRA; C.E. Simpson,
A.M. Schubert, W.J. Grichar, TAMU, Co-Investigators.

INTRODUCTION

Peanut cultivars that will successfully resist or tolerate the harsh environments of the Sahel of West Africa are important for a sustainable agriculture in that region. Highly restrictive ecological zones with varied lengths of growing seasons, intermittent drought, soils with low moisture holding capacity and fertility, diseases, arthropods, weeds, and other factors limit production and degrade quality potential. Production of the crop is relegated to small fields, and growers have very limited financial resources for crop production and protection. The development and utilization of improved varieties is the preferred and most efficient means of improving peanut quantity and quality.

The 1992 growing season was short and with extended intermittent droughts in Senegal, but was more favorable in other areas of the region such as in Niger. Rainfall at Bambey was particularly deficient and poorly distributed (341 mm with over 77 days without rain). Disease pressures also varied within the region. Clump virus and Macrophomina caused losses estimated as high as 70% and 30%, respectively, at Bambey. Leafspot pressure was light in the drier areas but increased in incidence and severity in the areas of better rainfall. Rust appeared late in the growing season.

Tests in West Africa are hand planted, at plant spacings of 15 cm within rows spaced 40 and 60 cm apart. No irrigation, pesticide, or herbicide were used except where indicated. Pre-plant applications of 20 to 30 kg/ha of phosphate was common to most test sites. Harvest is by hand but most places now have USDA Federal-State Inspection Service equipment for shelling and grading.

Seeding rates in Texas vary according to the purpose of the tests: for yield 5 to 7 cm within rows spaced 91 cm apart to spaced plants positioned 30 to 60 cm apart within rows spaced 91 cm apart. Soil fertility was supplemented with fertilization preplant, on the preceding cover-crop, or both. Supplemental irrigation was provided except at Waller or for special studies.

MAJOR ACCOMPLISHMENTS

Highly significant (221%) seed yield increases resulted from the ash treatment in the genotype x soil amendment study on the Farakoba Station in Southwest Burkina Faso. 46% and 37% increases, respectively, resulted from the application of $CaSO_4$ and P. Genotype x soil amendment effects were also significant. The experimental site and plot layout were repeats of 1991 so the effects of the soil amendments were cumulative.

Two breeding lines derived through interspecific hybridization (TxAG-6 and TxAG-7) with resistance to rootknot nematode (Meloidogyne arenaria) were released as germplasm lines by the Texas Agricultural Experiment Station.

Three Texas lines selected in Niger in 1991 for greater apparent tolerance to drought than 55-437 were included in the 1992 crossing block.

Although drought periods and Macrophomina reduced stands about 40%, Fleur 11 produced more than 50% higher seed yield than 55-437 at Bambey in 1992 (990 kg/ha compared to 695, respectively). Higher yield and larger seed size enhances its acceptance by growers, but seed supplies are limiting. The variety provides potential for increased income and nutrition to farmers in central Senegal. However, the new cultivar has no fresh seed dormancy and is more susceptible to Aspergillus flavus than 55-437.

Breeding lines from Fleur 11 crossed with germplasms having superior fresh seed dormancy and A. flavus resistance have been selected in Senegal that have at least 90% dormancy one month after harvest, but they yield less than Fleur 11.

T31-89, selected in Niger from Texas line Tx874737, has produced larger seed and higher yields than RMP-12 at Maradi (low rainfall) and Bengou (high rainfall) and is being evaluated in farmer's fields at both locations in 1993.

Seed of five germplasm lines introduced from Peru (US 494, US 497, US 496, US 459, and US 479) have been given to INERA and incorporated into their hybridization program.

GOAL

The goals of this project are: 1) develop peanut lines adapted to important ecological aspects of Sahelian West Africa and Texas that are resistant to pathogens that cause economic loss and effectively utilize available moisture, 2) identify cultural practices that improve the potential of peanut production in these environments, and 3) strengthen peanut improvement programs in the collaborating countries through encouragement and training in peanut research.

OBJECTIVES

- Develop, increase, and release peanut varieties with increased stability and improved productivity in important ecological areas of Sahelian West Africa and Southwest U.S.A.

- Assess the potential usefulness of various candivars and cultivars in Sahelian West Africa and identify localized differences which must be addressed in the development of peanut varieties for the region.

- Enlarge the germplasm resources of the collaborative peanut improvement programs.

- Assess and monitor the occurrence and epidemiology of yield limiting diseases in West Africa and Texas.

- Develop improved methods of evaluating disease and drought tolerance.

- Assess chemical quality, aflatoxin suppression, and arthropod response characteristics in the evaluation of candivars.

- Encourage participants and increase the expertise of host country scientists in the development and culture of improved peanut varieties.

APPROACH

Field screen and test selected populations and breeding lines derived from drought tolerant and short-growth duration parentage for identification and verification of potentially useful drought tolerant, short-growth duration, and agronomically desirable genotypes.

Continue population development and selection involving early maturing, disease resistant (leafspot, rosette virus, rust, soil borne diseases), drought tolerant, and agronomically productive parentage for evaluation and further selection in collaborating country programs.

Interact with other CRSP projects, especially those active in West Africa, to increase research effectiveness and gain needed information on quality factors, including aflatoxin production, of elite breeding lines and germplasm, soil characteristics in relation to differential variety performance and cultural management, rosette virus resistance, and reactions of elite germplasm and breeding lines to arthropods.

Continue cooperative and collaborative research with ICRISAT, CIRAD-CA and other regional programs in addressing the important constraints to peanut production in West Africa.

Evaluate the disease reactions of select germplasm lines and checks in Burkina Faso with relatively high rainfall where disease pressure is conductive to effective evaluation and screening.

Assist and encourage host country scientists in achieving project goals and developing their own peanut research programs.

ORGANIZATION AND PERSONNEL

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RESEARCH ACCOMPLISHMENTS

Advanced Line Performance Tests

Tests were conducted in the country of each participant but test entries varied among and within countries. Cooperators grow new accessions two or more years at their primary location and, on the basis of observation and preliminary data, select lines for the more advanced and multiple location trials.

Multiple-Test Yield Trials

Fleur 11 and Tamspan 90 were included with entries from ICRISAT and other programs in the ICRISAT Regional Variety Trial at nine locations. Both cultivars were only average in performance compared to other entries in the tests.

Burkina Faso. Twenty-eight breeding lines, and two U.S. and three local checks were evaluated at Gampela, Saria, Tenkodogo, Bobo Dioulasso, and Niangoloka. Emergence was good at all locations. Termites caused some plant death at all locations during the vegetative stage. Leafspots were recorded at all locations, heaviest at Niangoloka, with all entries susceptible. Rust was heavy at Niangoloka and was present at Bobo Dioulasso.

Average test pod yields ranged from 465 kg/ha at Niangoloka to 2305 kg/ha at Tenkodogo. Variety x location interactions occurred, the greater differences in relative performance being between those at Niangoloka and Bobo Dioulasso compared with those at sites further North and East. Entry yields at Tenkodogo ranged from 3149 to 1718 kg/ha with the highest yielding local check being KH149 at 2789 kg/ha.

Differences among entries in pod, total kernel (TK), and total sound mature kernel yields were highly significant at all locations. Average grades, determined following USDA inspection guidelines, ranged from 58% at Tenkodogo to 39% at Bobo Dioulasso where severe drought occurred during October, late season

termite activity was high, and pod fill was poor. A total of 232 plants were noticeably attacked by termites between August 18 and harvest. Short season entries seemed to be affected the most. The Niangoloka test sustained damage from rosette virus, rust, and the leafspots. One or more local checks were among the top statistical yield group at all locations except Niangoloka and Bobo Dioulasso.

Thirteen entries were selected for continued testing in 1993. The five-station mean yields for three of the superior entries are shown in Table 1. The three TX89- lines are from crosses made in Senegal and are closely related. Fleur 11, released in Senegal in 1992, was not in the highest statistical yield group at any of the 1992 test sites. Yields were similar and the percentage of sound mature kernels (SMK) was lower. TX874263 showed superior performance in 1991 but, like Fleur 11, had not filled as well by harvest as TS32-1.

Table 1. Mean yield for selected entries grown in five locations in Burkina Faso.

	Pods	Seed (TK)	SMK
	kg/ha		
TX896314	2053 a	1343 a	1065 a
TX896315	2048 a	1273 a	992 a
TX896317	1910 a	1313 a	993 a
Fleur 11	1545 cd	984 f-h	708 f-h
TX874263	1535 cd	956 g-i	646 h-k
TS32-1	1548 cd	1068 d-f	866 bc
Florunner	1614 bc	1113 c-e	871 bc

Mali. Seven tests of three short-duration varieties were conducted in on-farm situations in the area surrounding the Same Agronomic Research Station. Two varieties new to the area, JL-24 (ICRISAT) and QH 243-C, were compared with local varieties and 47-10. One test was not harvested because of drought. JL-24 with average pod, seed, and vine yields of 1,070, 675 and 2,045 kg/ha exceeded 47-10 by 57, 80 and 22%, respectively. QH 243-C performed similarly to the local check. Farmer's expressed satisfaction with JL-24 in this first year of testing. Repeated testing is planned.

Short-cycle entries were compared at Katibougou, Cinzana and Same for adaptation and performance. The tests, arranged in lattice designs, included three replications each, and were planted 18 July. Tests sizes varied from 14 to 23 entries, and consisted primarily of ICRISAT lines plus local checks. Several periods of drought occurred at all locations, and *Cercospora* was severe at Katibougou. Yields were satisfactory at all locations, and particularly good at some locations where all entries yielded in access of 2000 kg/ha. JL-24 had the highest yield of 2,844 kg/ha followed by two lines with 2600 kg/ha of pods.

Senegal. Four oil and five edible varieties and selections were evaluated in tests at three locations in the zone of Nioro du Rip: Diamaguene, Medina Sabakh, and the Nioro station. The entries were planted in a Fisher block arrangement with six replications. The principal purpose of the tests was to make evaluations of PC79-79, a selection for oil production, and an edible line H75-0, both of which had superior performance records on the Nioro station. In these on-farm trials, PC79-79 was no better than 28-206 and poorer than 73-33 in pod yield; and equal to 28-206 but superior to 73-33 in forage yield. Leafspot scores were significantly lower for the line than for the checks with an end of season score of 7.2 (ICRISAT scale) compared to 8.0 and 8.5 for the two cultivars. This might have some effect on forage quality.

H75-0 was compared with GH 119-20, the predominant edible cultivar of the region, NC 7 (introduced into Senegal for 1992 by NOVASEN), 73-33, and a Senegal selection 73-27. During 1990-1992, H75-0 exceeded GH 119-20 by 22% in pod and 26% in vine yield plus averaging 3% higher in shelling percentage. However, in these three tests it was not statistically different from GH 119-20 in pod yield, superior in vine yield, and inferior in shelling percentage. NC-7 was the poorest entry for pod and vine yield, and equal to H75-0 in shelling percentage. Rainfall was below normal and irregular for the region during the 1992 season and might have been a factor. Leafspot scores of H75-0 and GH 119-20 were equal, and higher than that for NC 7 at each of the four reading dates between 60 and 105 days after planting.

Three-year (1990-1992) summaries of data for PC79-79, H75-0, and checks in tests at Nioro are shown in Table 2. Checks 28-206 and 73-33 are the principal commercial cultivars for oil production in the area, and GH 119-20 is the principal for edible cultivar. PC 79-79 and H75-0 have shown considerable pod yield advantage over the check varieties.

Table 2. Three-year average yield and grade data for select entries grown in three test series at Nioro, Senegal, 1990-1992.

Variety Selection	Yield (kg/ha) Pod	Yield (kg/ha) Forage	TK %	SMK %	g/100 seed
(OIL)					
PC79-79	2410	3870	66	44	44
28-206	2150	3800	64	43	42
73-33	2260	3100	68	51	48
(EDIBLE)					
H75-0	2610	4370	61	47	77
GH 119-20	2150	3420	58	38	73
73-27	2190	3460	59	44	74

Texas. Ten advanced breeding lines and checks with foliar and soilborne disease resistant parentage were compared in 4-replicate tests at Bryan and Stephenville. Average pod yields exceeded 3700 kg/ha at both locations. One line, TX896100, was advanced to regional trials and two other lines in other studies at Stephenville and Bryan.

Single-Test Yield Trials

Burkina Faso. Thirty breeding lines received from Texas and three local checks were compared in a 4-replicate test near Kombissirri. The mean yield for the 33 entries was 1436 kg/ha and ranged to 1843 kg/ha. However, the best entries in the test were not statistically different (P=0.05) from TS32-1 and CN94 C for yield of pods, total seed, or sound mature kernels.

Mali. Thirty-four semi-early entries including varieties and TX lines were compared in a two-replicate test at Sotuba for adaptation and performance. Sowing was delayed and drought after flower initiation affected peg and pod development. *Cercospora* was present but nominal in severity. Yields were poor.

Niger. Twelve breeding lines and checks were planted March - June, 1992 for dry-season evaluation. Selections from this planting included T31-89, taken from the large-seeded breeding line TX874337. T31-89 compared subsequently in short cycle tests at Maradi (low rainfall) and Bengou (high rainfall) exceeded the check in yield at both locations.

Twelve germplasm lines selected for high water retention, compared with 55-437, were grown to evaluate performance under drought stress. Insufficient moisture stress developed for the intended comparisons but yields of the germplasm lines ranged to 20% above the check.

Senegal. Seventy-six entries were compared for stand establishment and persistence, leafspot reaction, forage yield, and pod yield and grade at Nioro. The entries were divided among seven tests with 9 to 16 entries each arranged in a lattice design with 3 to 6 replications. *Cercospora* ratings were made on four dates at 15-day intervals beginning 60 days after planting (dap) using the ICRISAT scale. Two tests (25 entries total) were of large-seed edible lines, one involved entries with seedcoat *A. flavus* resistance, and the others were selections from crosses targeted at agronomic adaptation and yield.

Entry differences in stand establishment, persistence, leafspot reaction, yield, and grade were apparent. The percentage of surviving plants on an entry basis, compared to the number of seed planted, ranged from 42 to 85%, leafspot scores ranged from 4.9 to 7.5 at 90 dap, and 5.9 to 8.9 at 105 dap. Pod yields were generally in the range of 1000 to 1700 kg/ha and forage yields from 2500 to 3600 kg/ha.

Texas. Twenty-eight spanish candivars plus checks were compared under rainfed conditions at Waller. Yields averaged 3450 kg/ha as moisture stress was averted until late pod fill by frequent and timely rains. Late-leafspot prevalence and severity was high late in the season. Seventeen lines were retained for further evaluation under more Texas rainfed growing conditions.

Ten select breeding lines from PI 342169 (an unadapted germplasm with very small leaflets) x adapted runner and spanish parentage were compared a final year for leaflet size and agronomic performance in yield trials at Bryan. No benefit was apparent from the reduced leaflet size. Yields of lines with the small and normal leaflet sizes were within similar ranges, and grades were poorer for the small-leaf lines. Pod disease caused considerable loss in several small-leaf lines during the three years of the study.

Genotype x Soil Amendment Test

Burkina Faso. The second year of a planned five-year cooperative study with Soil Management CRSP regarding the effects of selected soil amendments on the agronomicperformance of three cultivars was conducted near Bobo Dioulasso. Baseline soil analyses indicated no major elemental deficiencies. Soil pH at the 20 cm depth was measured as 4.8, with slight reduction in acidity above and below that zone in the soil profile. The 1992 test was conducted on the same site and with the same plot layout as in 1991; thus, the responses relate to cumulative rather than single application effects. Soil amendment applications consisted of 1) 600 kg/ha $CaSO_4$, 2) 50 kg/ha P_2O_5, 3) combination of the gypsum and phosphate, and 4) 2 T/ha ash.

Highly significant increases (>200%) in yield resulted from the ash treatment for all three cultivars. Lesser response was found for the addition of CaSO4, and P with average increases of 38 and 46%, respectively. Differences in the degree of response to gypsum and P were found among the cultivars, although those differences were dwarfed by the magnitude of the response by all entries to the ash. Leaf tissue samples were collected and have been analyzed but data tabulation and interpretation is not complete at this writing. The test is being repeated in 1993.

Disease Screening and Evaluation

Leafspot

Burkina Faso. Emergence was extremely poor in the disease evaluation tests and no meaningful evaluations were possible.

Texas. Forty-eight lines were selected as resistant to leafspot from 250 germplasm lines tested at Yoakum. The 48 lines were selected for additional examinations of disease reaction and other traits. This brings the total lines tested to 2,750 with 186 selected for further examination. Four of the introductions have been used in the production of hybrids.

Four selection regimes designed to increase leafspot resistance are being evaluated and subsequently compared with their predicted responses. The first two regimes consist of selection in the F_2 generation using components of leafspot resistance and the Florida scale, respectively. The third and fourth regimes are replicates of the first and second selection regimes in the F_3 generation. Parents in the study consisted of eight inter- and intraspecific lines selected for their resistance to leafspot. Preliminary results from the F_2 selections suggested that variability existed both within and among crosses. The background of selected plants differed between the first two selection regimes. This summer, selection is underway according to regimes 3 and 4. The goal of the study is the determination of a leafspot selection scheme that can be successfully effected in a recurrent selection program.

The random amplified polymorphic DNA (RAPD) technique was used to evaluate *Arachis batizocoi*, *A. cardenasii*, and *A. hypogaea* (cv Florunner component line), TP 129 (a complex hybrid of the above species), BC_2F_2, BC_3F_2, and two advanced interspecific lines from the introgression program. The objectives of the study were: to determine the relative genetic contribution of the wild species to the advanced interspecific lines using similarity indices based on RAPD markers, and to determine if informative DNA markers are correlated with important traits such as disease resistance. Of 200 primers tested, 150 yielded two to five bands of sizes generally less than 1900 bp. The large proportion of RAPD variants is indicative of the presence of abundant molecular genetic diversity in the peanut germplasm. The level of polymorphism based on RAPD bands was higher between *A. hypogaea* and the wild species than between *A. hypogaea* and the interspecific progenies. RAPD based similarity indices revealed that *A. chacoensis* and *A. cardenasii* are genetically more distant to the intra- and interspecific lines. DNA segments were successfully transferred from the wild species to the cultivated. Evidence of linkage between any of these RAPD markers and traits of interest has not yet been established.

Sclerotinia Blight

Texas. Productive, *Sclerotinia* blight-resistant runner-type varieties are needed for peanut production in North Texas and Oklahoma. Nine breeding lines selected previously for disease reaction were compared with checks for yield, grade, and disease incidence in a 4-replicate test under heavy *Sclerotinia* disease pressure at Stephenville. Four were selected for further disease and agronomic evaluations.

Twenty-four F_2 derived families were evaluated with check varieties in 3-replicate tests in Texas and Oklahoma in tests with varied disease pressure. Simultaneous space-plantings were made of these and 19 sister families for individual F_4 and F_5 plant selection.

A total of 305 lines were selected from 1800 lines that were field tested for *Sclerotinia* resistance during the 1992 crop year. Criteria for selection included disease incidence, area under disease progress (AUDP) curves, visual

disease rating, plant growth habit, canopy density, and pod and seed characters.

Off-season greenhouse generation advance was made of 725 F_3 and 104 F_5 to F_7 progenies and seed were prepared and planted for 1993 field evaluations and increases.

Southern Blight

Texas. Twenty-one breeding lines and cultivars, mostly runner, were planted at a site on the Yoakum station with a field history of moderate to heavy southern blight disease pressure. The soil was a Strabor loamy sand with 1% organic matter and pH of 7.0. 100 seed/row were planted in 2-row x 6.1 m plots arranged in a RCB design with four replications. Disease hits (target sites) were counted immediately after digging: October 16 for Spanco and Tamspan 90; October 21 for TX874337, TX896100, and C-304; and November 6 for all other entries. Tamspan 90 had the least number of target sites (0.5), while TX874337 had the highest (11.5). Although Florunner had the median rank in the test (4.8), none of the lines were statistically superior (P=0.05) for disease hits. TX896062 and GAT-2842 comprised the top yield group in the test.

Vine size, and pod distribution, shape, and size were the principal criteria used for the selection of 183 F_2 plants from a population formed from a cross of early maturing runner cultivars and a southern blight resistant derivative of PI 365553. Principal criticism of the resistant parent is medium shell thickness and slightly extended growth cycle.

Aspergillus flavus and aflatoxin

Senegal. The crosses 73-33 x PI337409 and 28-206 x PI 337409, and PI337409 and 73-27 x DHT 200 are being evaluated, The cross 79-2 x PI337409 seems better than the others in regard to yield and tolerance to leafspot. This cross will be proposed for multilocational trial in 1994.

Burkina Faso. Seed samples were collected and submitted to AL/FT/BF project for analyses in Burkina Faso. Results are pending.

Texas. Twenty-four spanish genotypes were tested at the Yoakum station for resistance to colonization by *A. flavus*. The 4-replicate test seeded April 30 was comprised of 2-row plots, 3.05 m long spaces .91 m apart. Total rainfall during the months of May through September were 197.6, 84.3, 50.3, 59.2, and 34.8 mm, respectively. Supplemental irrigation was provided as needed for the first 60 days after planting, after which moisture was from rainfall only. Supplemental inoculum of an aflatoxin producing strain of the fungus on a peanut medium was sprinkled over the rows on July 20. Peanuts were dug September 9, partially field and then forced-air dried, and sampled. Aflatoxin levels were determined by using kits from the Neogen Corporation. Aflatoxin levels averaged 20 ppb and ranged from approximately 50 ppb for Fleur 11 to near zero for Tamspan 90.

Twenty-eight runner-type breeding lines and checks were tested in a similar manner for *A. flavus* colonization and aflatoxin production. The test was planted April 30 and dug September 22. Aflatoxin levels ranged from near zero to 20 ppb. Statistical differences were found but repeat testing will be required for meaningful interpretation because of the nature of the problem and the low aflatoxin levels.

Tamspan 90 is a spanish cultivar with useful levels of partial resistance to several soilborne diseases. In several previous studies, as suggested in the 1992 test at Yoakum described above and in previous annual reports, aflatoxin levels in seed of the cultivar have been comparatively low. Also, as cited in previous TX/MM/S annual reports and published by Szersen and Pettit, Tamspan 90 has been found to produce a unique protein reaction in isozyme studies in that

when challenged by the Aspergillus fungus, even under drought stressed conditions, a unique band was formed. However, on occasions, the variety has shown susceptible reactions. Tamspan 90 is comprised of 38 F_8 sister lines and aflatoxin production was not a criterion in the selection. Hence, we have questioned whether individual lines might differ in susceptibility to fungal colonization and/or aflatoxin production and, if so, whether sampling might have been a factor in previous results. A 4-replicate test of the 38 component lines, Starr, Pronto, J-11, and 55-437 was grown under dryland culture near Waller, TX. However, growth conditions for the crop was favorable and fungal development failed. Subsequently, the Tamspan 90 lines and check cultivars were grown in the greenhouse and near full-size immature and mature seeds were challenged with mutant strains of A. flavus and A. parasiticus. Cotyledons inoculated with the mutant in petri dishes, in collaboration with Drs. Keller and Beremand, Peanut CRSP Mycotoxin project, were rated for orange coloration, a result of norosolenic acid, which develops in the interrupted aflatoxin biosynthesis pathway of the mutant. Varied coloration among lines resulted from challenge of fresh, immature (92 dap) seed with the fungus. Repeat of the test at 100 dap when the seeds were light pink and more mature produced no fungal growth nor norosolenic acid production. Subsequent tests in the spring on a portion of the lines was conducted using fresh mature greenhouse grown and mature, dried, 1992 field harvested seed. No A. parasiticus grew on the freshly harvested seed, but notably varied fungal growth and coloration occurred, on a component line basis, with ratings of 1 to 5 in a scale of 1 to 5 among stored seed. The study is being continued using 1993 field grown seed for both fresh and stored seed analyses.

Nematodes

Texas. Germplasm lines TxAG-6 and TxAG-7 with resistance to the rootknot nematode and early and late leafspot were released. TxAG-7 was derived through interspecific hybridization involving Arachis hypogaea crossed to an amphiploid hybrid between A. batizocoi, A. cardenasii, and A. chacoensis. The amphiploid hybrid is TxAG-6. These lines are being used to incorporate the three resistances into cultivated peanut.

The fourth backcross was made in the root-knot nematode resistance introgression program.

Rust

Burkina Faso. Plant stands were too poor for good comparisons.

Senegal. Rust appeared late in season.

Rosette Virus

In response to previous External Evaluation Panel recommendations for increased emphasis on rosette virus, resistant x adapted line crosses were made and F_2 seed were produced in 1991.

Texas. In 1992, decision was made following counsel with investigators on the Peanut Virus and Insect Management projects to establish rosette virus screening capabilities in Burkina Faso. Subsequently, 288 F_2 plants were selected in Texas, on the basis of agronomic characters, for possible rosette virus screening in Burkina Faso.

Burkina Faso. Preparations were set in place for the planting of 160 Texas lines with rosette resistant x susceptible line screening. Personnel from IDR travelled to Zaria, Nigeria to observe and be trained in rosette virus screening by Dr. Phindile Olorunju, IAR and Co-PI of the Peanut CRSP virus project. Aphids collected from virus infected plants are under increase and field planting of the peanuts have been arranged after consultation and training with Peanut Virus

collaborators.

Spotted Wilt Virus

Texas. Thirty-seven F_4 and F_5 families were compared for tomato spotted wilt virus (TSWV) infection using AUDP curves, and for yield, grade, and other agronomic traits in replicated field tests in South Texas. Most of the families derived from selection in the *Sclerotinia* resistance program because of their Southern Runner and/or Tamspan 90 parentage. Both of these cultivars have shown considerably less TSWV injury than other commercial cultivars of the area. Statistically significant differences were found among lines for TSWV reaction, but none of the lines had significantly less disease than Southern Runner. Incidence of the virus in Tamspan 90 was similar to that in Southern Runner.

Seventy-three Florunner x Southern Runner F_3 progeny rows, each bordered by Tamrun 88, were grown for family and plant selection in a TSWV disease prone area of South Texas. Disease pressure was good with disease incidence among families ranging from 0 to 98%. Twenty-nine families had a lower disease incidence than the maximum plot incidence among four repetitions of Southern Runner. Fifty-eight plant selections were made from selected F_3 families.

Selections were made among several hundred F_2 plants each of populations with Southern Runner, NC 343, Marc-1, and Tamrun 88 as parents for plant-to-row evaluations under natural SPW disease pressure. About 600 plant rows, each bordered by Tamrun 88, have been planted for field virus reaction and agronomic evaluation in 1993.

Termites

Texas. A total of 371 selections were made from 193 F_3 plant rows and five F_2 populations from termite resistant x susceptible parents grown under irrigation at Bryan. Seed from 113 selections were transported to Burkina Faso for initial termite injury evaluation in collaboration with the GA/IM/BF project.

Backcrosses of termite resistant x adapted line susceptible hybrids were made to adapted susceptible parents.

Germplasm Collection and Conservation

Texas. Seed were multiplied of 82 new accessions which were collected in Brazil in 1992 and introduced as new germplasm. The lines represent new sources of germplasm which were not represented previously in the US germplasm collection. The seed produced will be used for storage and field evaluations of agronomic characters and disease resistance.

Mali. Seventy collections of cultivated peanuts were made in 1992 jointly by the IER Co-PI and ICRISAT collaborators in the South and Southwest region of Mali. Seeds collected will be used for seed increase and observation of traits that might be useful in the breeding program.

Niger. The national peanut collection of Niger consists of varieties that yield better than the local check, 55-437. Fifty percent of a total of 143 varieties in the collection are Texas A&M selections or provided by the Peanut CRSP.

Drought Tolerance

Mali. Fifteen lines from ICRISAT and a local check variety were compared in a 3 replicate, 4x4 lattice design experiment under drought stressed conditions near Same. Rainfall totalled less than 600 mm. Average yields exceeded 1000 kg/ha of dried pods. Lines cc 221 (1760 kg/ha), ICGV 86475 (1599 kg/ha), ICGV 86744 (2073), and 55-437 (2063) were the superior lines for yield.

Texas. In 1991 and 1992 soil, weather, and crop growth data were collected for use in testing and verifying PNUTGRO and other crop growth and production system models under Texas conditions. The most intense collection of data was at Yoakum with leaf number, leaf area, leaf weight, stem weight, pod and kernel weight, pod and kernel number, and pod and kernel sizes. Weather and yield data from research plots at other locations will be used in less rigorous tests of the model after coefficients are verified. Both the 1991 and 1992 studies to test and adapt the PNUTGRO Model to south-central Texas yielded good growth analysis data. Soil series occupied by these tests have not been utilized previously in the DSSAT model and their attributes have to be entered manually. Final soil data are being refined and adapted to the DSSAT standard. Initial simulation runs have been encouraging. Limited data sets from other experiments are being adapted to the DSSAT format for inclusion in the simulations.

Eight cultivars under five moisture levels were studied at Yoakum in a 4-replicate RCB design under a line-source irrigation gradient system. Irrigation supplemented the 216 mm of rainfall during the growing season. Pod disease caused some loss of pods under the higher moisture levels. Pod yields differed among the cultivars in the treatments that received supplemental water as shown in the yields for three water levels (Table 3). Runner varieties exceeded the spanish in yield at the higher water levels, but not at lower levels, and the entries did not differ in yield without supplemental moisture. Yields increased with the addition of water for all runner entries and Tamspan 90. Response to added water among the other spanish-type entries was inconsistent.

Table 3. Pod yields (kg/ha) for peanut entries as affected by water supply in irrigation gradient study at Yoakum, 1992.

Entry	Water Supply mm[1]		
	610	280	216
	kg/ha		
Tx874337	3860 a*	2454 ab	2397 a
Georgia Runner	3587 a	1693 bc	1734 a
Tamrun 88	3277 a	2050 abc	1883 a
Marc 1	3263 ab	2788 a	2082 a
Southern Runner	3114 ab	2098 abc	2148 a
Tamspan 90	2651 bc	2069 abc	1771 a
Fleur 11	2306 c	1542 bc	1847 a
Sn 55-437	2130 c	1389 c	1636 a
Starr	2043 c	2741 a	2355 a

*Values within columns followed by the same letter are not different (P=0.05)

Allelopathy

Texas. Oats, wheat, and rye are common winter cover crops in Texas for sandy peanut fields. Questions have been raised regarding allelopathy, especially as to possible differential peanut cultivar response to different cover crops. Seeds of eight peanut cultivars were compared in the laboratory for germination and radicle fresh weights when germinated on filter paper with extracts from the three cover crops. Extract concentrations were prepared on the basis of 10 ml of water per g of ground straw. Two tests, each with three replicates at each of two temperatures (28 C and 22 C) were conducted. At 28 C, GK-7 germination was significantly enhanced by rye and oat extracts as compared to the other 7 cultivars. The increase in radicle weights, as a percent of radicles in a distilled water treatment, were significantly greater for GK-7 than for the other cultivars in all three extracts. At 72 C the trend was similar but differences were not significant at P=0.05.

Quality

Niger. Oil content determinations revealed that Texas lines Tx872616 and Tx872607 (54% oil) had 12.5% higher oil content than 55-437 (48% oil). T31-89, which has large seed, was measured as 41% total oil.

Texas. One or two pound samples of sound mature kernels of 92 entries were supplied in duplicate from replicated plots to the AL/FT/BF project for quality analyses. Sample analyses, and data summarization and interpretation are not complete.

A total of 157 F_2 selections were made from six high oleic x adapted spanish populations and planted as F2:3 plant rows under irrigation for continued selection in 1993.

PRESENTATIONS AND CONFERENCE PARTICIPATION

N'Doye, O. 1992. Le point de la recherche sur les cercosporioses de l'arachide au Senegal. Presented at the Third Regional Groundnut Workshop for West Africa, Ouagadougou, Burkina Faso. September, 1992.

Sankara, Philippe, O.D. Smith, and M. Ouedraogo. Evaluation of U.S. peanut varieties in Burkina Faso. Presented at Third Regional Groundnut Workshop for West Africa, Ouagadougou, Burkina Faso. September, 1992.

Smith, O.D., C.E. Simpson, L.P. Wilding, M. Ouedraogo, G.E. Aiken, P. Sankara, and O. N'Doye. Breeding disease resistant varieties for semi-arid environments. I. Adaptation and response. Presented at Third Regional Groundnut Workshop for West Africa, Ouagadougou, Burkina Faso, September, 1992.

Schubert, A.M., O.D. Smith, G.E. Aiken, and A.J. Jaks. 1992. Breeding disease peanut varieties for semi-arid environments II. Drought tolerance and avoidance. Presented at Third Regional Groundnut Workshop for West Africa, Ouagadougou, Burkina Faso, September, 1992.

Starr, J.L. and C.E. Simpson. 1992. Reaction of Arachis intraspecific hybrid TP-135-4 to the northern root-knot nematode Meloidogyne hapla. Presented at Annual Meeting American Peanut Research and Education Society, Suffolk, VA.

Philippe Sankara, Mahama Ouedraogo, C.E. Simpson, A.M. Schubert, W.J. Grichar, and O.D. Smith participated in annual meeting of APRES, Suffolk, VA. July, 1992.

Philippe Sankara and Mahama Ouedraogo participated in International Congress on Crop Science, Ames, IA. July.

Amadou Mounkaila participated in Third Regional Groundnut Workshop for West Africa, Ouagadougou, Burkina Faso. September, 1992.

TRAVEL - OVERSEAS

Philippe Sankara travelled to Virginia, Iowa, and Texas for conference participation and research review and planning, July, 1992.

A.M. Schubert and O.D. Smith travelled to Ouagadougou, Burkina Faso for participation in Third West African Groundnut Conference sponsored by ICRISAT and Peanut CRSP.

PUBLICATIONS

Grichar, W.J. and O.D. Smith. 1992. Interaction of tillage and cultivars in peanut production systems. Peanut Sci. 19:95-98

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Woodard, K.E., and C.E. Simpson. 1993. Characterization of Sclerotinia minor isolates from sclerotinia blight of peanut in Texas. Plant Disease 77:576-579.

Kretschmer, A.E., Jr., C.E. Simpson, T.C. Wilson, and W.E. Pittman. 1993. Evaluation of wild nut-producing Arachis species for forage. Jour. Int. Grassland Congress. (in press).

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Akem, C.N., H.A. Melouk, and O.D. Smith 1992. Field evaluation of peanut genotypes for resistance to sclerotinia blight. Crop Protection 11:345-348.

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Subrahmanyam, P. J.P. Bosc, Hama Hassane, D.H. Smith, A. Mounkaila, B.J. Ndunguru, and P. Sankara. 1992. Groundnut diseases in Niger and Burkina Faso. Oleagineux 47:119-133.

Smith, D.H., G.D.C. Pauer, and F.M. Shokes. 1992. Cercosporidium and Cercospora leafspots of peanut (groundnut). p 285-304. In: H.S. Chaube, J. Kumar, A.N. Mukhopadhay, and U.S. Singh (eds.) Diseases of Vegetables and Oil Seed Crops; Plant Diseases of International Importance. Prentice Hall, Englewood Cliffs, New Jersey 07632.

PLANS FOR 1993/1994

Training - degree oriented

- Ph.D. training: Texas A&M University
  Mahama Ouedraogo, Burkina Faso. Level 2, University of Ouagadougou, 1987; M.S. Texas A&M University, 1990.

- M.S. training: Texas A&M University
  Yolanda López, Colombia. Biologist (Genetics), Universidad del Valle, 1975.
  Jason Goldman. B.S. Rutgers University. 1992.

- Agricultural Engineer training, University of Ouagadougou
  Mr. Yanogo Philippe

Training - Short term

- Lassane Belem and Dr. Philippe Sankara, Burkina Faso. One week of additional training in rosette virus resistance evaluation with Dr. Phindile Olorunju, IAR, Zaria, Nigeria.

Research

Host Countries

- Single and multiple location advanced line and variety trials will be conducted in Senegal (2 locations), Burkina Faso (4 locations), Mali (3 locations), and Niger (2 locations). Multiple location test entries will not be the same in all tests. Individual collaborators select entries based upon performance in preliminary tests in their specific countries.

Senegal

- Continue studies on adaptation and utilization of Fleur 11. Good seed yield and seed size accelerating its acceptance but fresh seed dormancy and susceptibility to *A. flavus* is a concern.
- Continue selection and evaluation among lines selected for dormancy among progenies derived from crosses of 73-30 and widely grown, non-dormant Senegalese varieties.
- Evaluate single plant derived selections from Fleur 11 that have shown superiority over Fleur 11 in preliminary yield trials. Continue evaluation and selection of lines with good stable yield, seed quality, and haulm production from segregating populations of spanish peanuts for the short season, lower rainfall regions of Sahelian West Africa.
- Conduct multilocational trials in region of Nioro, with special emphasis on PC79-79 and H75-0.
- Continue selection and evaluation of lines with useful levels of rust resistance.
- Continue evaluation of germplasms and segregating populations for leafspot resistance at Nioro.
- Examine and select among gamma ray treated 28-206 for high yield, pod size, and leafspot resistance.

Burkina Faso

- Continue soil amendment x genotype study on acidic soil at the Farakoba Station in southwest Burkina Faso. Treatments include three varieties and soil amendments of ash, gypsum, and lime.
- Screen and select among 160 $F_{2:3}$ plant rows for reaction to rosette virus.
- Continue evaluation of lines and germplasms for reaction to rust and

for usefulness in Burkina Faso.

- Evaluate 113 F_3 families from F_2 plants selected from termite resistant x adapted susceptible crosses for reaction to termites in collaboration with the GA/IM Project.
- Analyze selected entries of the multilocational trial at selected locations in Burkina Faso for aflatoxin content in collaboration with the AL/FT/BF project.
- Complete soil and leaf tissue chemical analyses and make interpretations of data as related to genotype x soil amendment study at Farakoba in conjunction with Soil Management CRSP researchers.
- Foliar disease resistance trials will be conducted in Senegal and Burkina Faso, and Mali.
- Germplasm multiplication and classification will continue in Mali, Senegal, and Niger.
- Off-season variety x A. monticola F_1 generation advance will be made and F_2 generation evaluations will be made during the rainy season.
- Continue evaluation and selection among twelve F_7 populations from rosette virus resistant and short growth duration parentage at Tarna and Bengou.
- Two trials of confectionery peanuts will be evaluated at Bengou and Tarna.
- Increase and make preliminary evaluations on WAPEP entries from Texas.

Mali

- Characterize and evaluate 70 A. hypogaea germplasms collected during Oct.-Nov. 1992.
- Multiply seed of short and mid-length growth duration breeding lines and varieties which have been determined worthy of joint IER and extension service on-farm field testing.

Niger

- Screen for earliness and drought tolerance at Tarna (low rainfall) and Bengou (high rainfall) the 60 entries received for WAPEP in 1991 and 1992.
- Screen for insect resistance at Tarna and Bengou.
- Test and increase seed in farmer's fields T31-89.

Texas

- Identify and characterize improved leafspot resistant germplasm: a) 150 more introductions will be evaluated for leafspot reaction at Yoakum TX; b) Agronomic and leafspot reaction evaluations will be made on 13 introductions selected in previous screening tests for leafspot reaction, and vine and fruit characters.
- Enlarge and enhance the germplasm resources of the collaborating peanut improvement programs: a) Leafspot and agronomic evaluations will be made on $F_{2:3}$ progeny of crosses among 8 leafspot resistant interspecific and hypogaea derived germplasms; b) RAPD analyses will be made on leafspot resistant parental and backcross interspecific progenies in search of improved procedures in breeding for leafspot resistance; c) Advance generation, field evaluate for disease reaction, and select among BC_2F_2 and BC_2F_3 interspecific derived populations under natural early-leafspot infestation at Yoakum and enhanced late-leafspot disease at Bryan; d) Produce F_2 seed of selected recently introduced runner-type x adapted runner populations; e) Advance generation, increase seed, and select among populations from crosses among varieties and parental lines with termite and/or rosette resistance; f) Hybridize and advance to F_2

generation populations of adapted x unadapted genotypes with aflatoxin resistance, rosette virus resistance, sclerotinia resistance, leafspot resistance, quality factors, and/or short duration; g) Increase seed of approximately 10 wild species lines at Yoakum that are very poor seed producers at Stephenville.

- Develop through hybridization and selection populations, breeding lines, and candivars with improved resistance to soilborne diseases: a) Some 1250 F_3 to F_8 families derived from sclerotinia resistant and susceptible parents will be evaluated for sclerotinia blight reaction under field conditions managed for enhanced disease development; b) Runner-type lines selected preliminarily for sclerotinia reaction and agronomic traits will be evaluated agronomically in the absence of sclerotinia for acceptability; c) Advanced lines, derived from crosses of lines selected through the leafspot and the pod rot resistance programs will be compared for yield, grade, and disease incidence in S. rolfsii inoculum enriched soil; d) About 180 F_3 progenies of agronomically selected F_2 runner-type plants will be field evaluated for southern blight infection under disease enhanced conditions.
- Assess the relative aflatoxin suppression of candivars and cultivars: a) Tamspan 90 component lines will be grown at two field sites and compared for A. flavus infection and aflatoxin production; b) Tamspan 90 component lines will be challenged and evaluated under laboratory conditions for reaction to NOR A. parasiticus mutant; c) Short duration breeding lines will be evaluated in replicated dryland field test for yield, grade, A. flavus infection, and aflatoxin contamination.
- Enhance effectiveness in selection for drought tolerance: a) Multi-year data from the line source irrigation gradient system study at Yoakum will be analyzed and summarized for extrapolations to peanut improvement for Texas and West Africa; b) Data acquisition and analysis will continue with appropriate crop growth and farming system models. Data from the line-source irrigation gradient experiments, and from 1993 data collection points in West Texas will be tested in these models; c) Climates, soils, and cultural practices for peanut production in West Texas will be studied for similarities and relevant research thrusts applicable to priority objectives of the CRSP program.
- Screen and evaluate hybrid derived populations involving virus resistance: a) Obtain second-year yield and spotted wilt disease evaluations on 22 runner-type breeding lines with low spotted wilt disease scores in 1992 tests; b) Make plant progeny evaluations and re-selections on 58 duplicated F_4 plant rows from F_3 families with low disease incidence in 1992; c) Initiate spotted wilt screening on 220 runner-type $F_{2:3}$ plant rows from parents with spotted wilt disease resistance and insect resistance or earliness.
- Dr. A.M. Schubert transferred to the Texas A&M University Agricultural Research and Extension Center at Lubbock on July 1, 1993. Climates and soils in West Texas will be studied with emphasis towards identifying similarities with conditions in West Africa. Data will be collected from several automated weather stations scattered throughout the Southern High Plains, and the Northern and Southern Low Plains peanut growing areas. Heat unit accumulations and weather patterns which might affect drought stress and disease and mycotoxin problems are of particular interest.

NCS/BCP/TP
Peanut Varietal Improvement
for Thailand and the Philippines

North Carolina State University
University of the Philippines at Los BaÑos
Thailand Department of Agriculture
Khon Kaen University
Kasetsart University

Thomas G. Isleib, Principal Investigator, NCSU
Aran Patanothai, Principal Investigator, KKU, Thailand
Remedios M. Abilay, Principal Investigator, UPLB, Philippines

INTRODUCTION

Improved peanut cultivars are essential in an integrated plan to augment yields and profitability of peanut for farmers in Thailand, the Philippines and North Carolina. Crop environments and cultural practices used in peanut production vary greatly among and within peanut-producing areas. In Thailand, peanut can be produced during a brief period of the rainy season before rice planting, after rice harvest using residual soil moisture, or in upland field conditions during the rice-producing rainy season. Irrigation may also allow some farmers to produce peanut during the dry season. Similar conditions are present in the Philippines where the duration of the rainy season can vary between three and six months over areas where peanut is grown. The most productive growing season in the Philippines continues to be after rice, but breeding efforts are needed for peanut to fit in other cropping systems including the shaded floors of coconut groves and upland areas with acid soils.

Constraints to production vary from place to place and system to system. In almost any situation, foliar fungal pathogens, soil-borne pathogens, and arthropod pests would destroy the peanut crop if uncontrolled. The highly capital-, chemical-, and energy-intensive production system used to achieve control in the United States is not practicable nor desirable for growers in Thailand or the Philippines where integrated programs of disease and pest management must be used. The prevailing regulatory philosophy in the United States emphasizes conservation, food safety, and environmental protection, leading to reduced use of pesticides, leading to more emphasis on the integrated approach. Host plant resistance to economically important pests must be a salient feature of this approach.

ACCOMPLISHMENTS

Philippines

Two breeding lines (IPB Pn 85 2-40 and IPB Pn 85 10-68) from the Institute of Plant Breeding (IPB) were recommended for seed increase during the May 1993 pre-seedboard meeting at La Granja Experiment Station at La Carlota City prior to their release as Philippine seedboard varieties. Both breeding lines are selections from three-way crosses.

IPB Pn 85 2-40 is a selection from the hybridization of (UPL Pn 2 x FESR 1) with NC 7. It is high yielding, resistant to late leafspot and peanut rust. It was consistently the top yielder across 12 locations in national cooperative trials conducted during the 1991-92 and 1992-93 dry cropping seasons. This breeding line exceeded the seed yield of UPL Pn 10 or PSB Pn 1 by 12%.

IPB Pn 85 10-68 is a derived line from the cross between (Accession 12 x BPI P9) and NC 7. This release is high-yielding, resistant to leafhopper and late leafspot and moderately resistant to peanut rust. Three years of data (1991-93)

from national cooperative trials indicated that seed yield of this line was 7.5% higher than the national check variety. However, its seed weight is lower than the national check variety (BPI Pn 2) and the latest seedboard variety (UPL Pn 10 or PSB Pn 1).

Four new IPB breeding lines were selected from the 1992 and 1993 dry season general yield trials based on seed yield, seed size, and resistance to rust and late leafspot and entered as new entries in the national cooperative tests (NCT) across eight locations for 1993 wet cropping season. These entries are IPB Pn 87 26-29, IPB Pn 87 26-4, IPB Pn 88 30-34 and IPB Pn 88 21-24.

On-farm trials of four to five cultivars including the native variety at Pampanga and Isabela indicated that UPL Pn 10 and UPL Pn 2 were the preferred varieties by peanut growers because of their high yielding trait and acceptable seed size, shape and color. Massive seed production of the two varieties are on-going at Ilagan, Isabela; Guagua and Mexico, Pampanga. Pilot production of UPL Pn 10 and UPL Pn 2 at major peanut-growing areas as well as at new potential sites will be initiated this coming dry cropping season which starts in late October or nearly November.

Peanut breeders gave technical training on peanut seed production of technicians and farmers of Dilasag, Aurora Province; Guagua and Mexico, Pampanga; Ilagan, Isabela; and Tuguegarao, Cagayan.

Thailand

(Taiwan 2 x UF 71513-1) was released as 'Khon Kaen 4', a high yielding boiling-type peanut. (Taiwan 2 x UF 71513-1) performs better than the check cultivar Khon Kaen 60-2. This promising line gave 10% higher pod yield than the check.

Two high yielding cultivars [(Tainan 9 x Ah24439)-14-4-13 and Moket x Ah-12-8-16] were identified in the regional yield trial. Two superior large-seeded type peanuts, Kanto No. 38 and (NC 7 x RCM 387)-1-1, were identified in the 1992 regional yield trial. (MGS-9 x Robut 33-1)-5-2-2-4 was identified as the promising line in the farm trial before-rice growing season. Several promising lines of various breeding objectives in different yield testing stages were identified by DOA and KKU.

More than 30 extension personnel were trained on peanut production technology by the staff of DOA and KKU. Three M.S. and two B.S. students were involved in the project as student trainees.

United States

Two Thai students, Wootisuk Butranu and Anan Hirunsalee, received support from the CRSP program for training at NCSU. Mr. Hirunsalee is a doctoral candidate in the Department of Plant Pathology whose funding under the Rotary Foundation's Freedom from Hunger program expired at the end of June, 1992. Mr. Butranu was identified by the Thai Peanut Improvement Program as the individual they wished to receive postgraduate training in fungal pathology.

Moderate resistance to *Cylindrocladium* black rot (CBR) was confirmed in N90013, a large-seeded virginia line selected from a cross between two common cultivars, NC 7 and NC 9. N90013 is comparable to NC 10C, the only resistant cultivar available to peanut producers, in yield but has much superior grade characteristics. Several other lines from the NC 7 / NC 9 cross were also found to exhibit intermediate levels of CBR resistance.

Four interspecific hybrids selected from an *Arachis hypogaea* / *A. cardenasii* cross were released as germplasm resources for resistance to *Cercospora arachidicola* (early leafspot). The four selections are significantly more resistant than

cultivated lines for *C. arachidicola*, but are not immune to the pathogen. Three of the lines also have moderate levels of resistance to *Cercosporidium personatum* (late leafspot). The selections have potential for major savings to the farmers for decreasing costs of fungicides and should reduce chemical application and residues in the field.

Improved protocols for selection of transgenic peanut plants from embryogenic cultures treated by microprojectile bombardment were developed as were several new culture procedures as adjuncts to transformation protocols, including culture of embryonic axes and immature leaflets isolated from unimbibed peanut seeds. A study was begun which will determine the effects of various *in vitro* culture procedures on the performance of elite peanut lines cultured as part of the gene transfer process.

Complex plasmid vectors for peanut transformation are under construction. These include improved vectors for genes encoding bean chitinase and capsid proteins from peanut stripe virus (PStV) and tomato spotted wilt virus (TSWV). These vectors will greatly enhance the efficiency of the transformation process. In addition to continuing work on protocols for peanut transformation via the biolistic process, we have also initiated studies on *Agrobacterium*-mediated peanut transformation. We have initiated large-scale transformation experiments designed to recover transformed plants which express PStV capsid protein, TSWV nucleoprotein, bean chitinase, singly or in combination.

GOALS

To increase yields and quality of peanut in the U.S. and cooperating Asian countries while decreasing the dependency on chemical inputs. This should improve not only the economic situation for farmers but also have a positive impact on the ecology and sustainability of agriculture. Breeding efforts need to be directed toward development of cultivars that fit current and future cropping systems and marketing potential.

OBJECTIVES

North Carolina

1. Aid in the identification of useful genotypes and implementation of material in crossing programs for use in the Philippines and Thailand.

2. Obtain greater understanding of the interrelationships between peanut host and pathogen or environmental stress that occurs in peanut-growing areas of the Philippines, Thailand, and the United States.

3. Improve breeding and selection techniques. Break barriers prohibiting incorporation of desired traits into adapted material via interspecific crossing and molecular engineering techniques. Improve screening techniques for resistance to pests and tolerance to stress.

Thailand

1. To develop peanut cultivars that can be established in specific cropping systems and seasons. Cultivars with high yields, early maturity, large seeds, resistance to rust, leafspots, *Aspergillus flavus*, *Aspergillus* crown rot, *Sclerotinia* stem rot, TSWV, stripe virus, and insects and drought tolerance would be incorporated for specific growing seasons and cropping environments.

2. Provide information on plant pathology required for development and utilization of disease-resistant cultivars.

3. Develop cultivars for the boiling-type market.

Philippines

1. To develop peanut cultivars that have high yields, resistance to rust, leafspots, *Sclerotium* wilt, *Aspergillus* sp., peanut stripe virus, and insect pests, and tolerance to drought, shade, and acid soils.

2. Identify peanut genotypes adapted to present cropping systems and potential new systems such as mixed cropping in coconut or palm nut groves.

ORGANIZATION AND PERSONNEL:

A. U.S. Lead Institution: . . . . . North Carolina State University, Raleigh

Principal Investigators: . . . . . Dr. Thomas G. Isleib, Dept. of Crop Science

Co-Principal Investigators: . . . . . Dr. Marvin K. Beute, Dept. of Plant Pathology
Dr. H. Thomas Stalker, Dept. of Crop Science
Dr. Arthur K. Weissinger, Dept. of Crop Science

Research Associates: . . . . . Dr. Barbara Shew, Dept. of Crop Science

Technicians: . . . . . Ms. Joyce Hollowell, Dept. of Plant Pathology
Ms. Tracy Jones, Dept. of Crop Science
Mr. Donald Parry, Dept. of Crop Science
Ms. Gerry Phillips, Dept. of Crop Science
Mr. Philip Rice, Dept. of Crop Science

Institutional Representative: . . . . . Dr. J.C. Wynne, Director, North Carolina Agricultural Research Service

B. S.E. Asian Counterpart Institutions: . . . . Thailand Dept. of Agriculture (DOA)
Kasetsart University (KU), Thailand
Khon Kaen University (KKU), Thailand
University of the Philippines at Los Baños (UPLB), Philippines

Coordinator (Philippines): . . . . . Dr. Crisanto Escaño, PCARRD, Philippines

Coordinator (Thailand):.. . . . . Mr. Sophon Sinthuprama, Director, Field Crops Research Institutes

Assistant Coordinator (Thailand): . . . . . Dr. Montien Somabhi, Director, Khon Kaen Field Crops Research Center

Principal Investigator (Philippines): . . . Dr. Remedios M. Abilay, UPLB, Philippines

Principal Investigator (Thailand): . . . . . Dr. Aran Patanothai, KKU

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Mr. Apolonio M. Ocampo, IPB
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	Mr. Edwin E. del Rosario, UPLB (11/1/92-6/30/93)
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	Dr. Duangchai Choopanya, DOA
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	Mr. Sopone Kittisin, DOA
	Mr. Preecha Surin, DOA
	Ms. Soomjintana Toomsan, DOA
	Dr. Sopone Wongkaew, KKU
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Research Assistants (Philippines):	Ms. Maria Jesu-Christa M. Estrada (7/1/92-5/15/93)
	Ms. Leonila A. Lantican, UPLB
	Ms. Gina Maramara, UPLB (6/1/93-6/30/93)
Cooperating Agencies in the Philippines:	. Ilagan Experiment Station, Ilagan, Isabela;
	University of Southern Mindanao, Kabacan, North Cotabato
	Bicol Experiment Station, Pili, Camarines Sur
	Quezon Agricultural Expt. Station, Tiaong, Quezon
	Philippine Coconut Authority, Bago Oshiro, Davao City
	Mayor's Office and Department of Agriculture, Guagua, Pampanga
	Aurora Integrated Area Development Project, Baler and Dilasag, Aurora Province
C. USAID Project Officers:	Mr. K. A. Rushing, USAID, Manila
	Ms. T. Hiranraks, USAID, Bangkok

APPROACH

Peanut germplasm is being introduced from the U.S.A., Indonesia, and India to Thailand and the Philippines. Observations on agronomic potential, disease and insect resistance, maturity, drought tolerance and other agronomic traits of the introduced germplasm are made in unreplicated nurseries. Selected lines are grown in preliminary replicated tests to identify lines for further testing at multiple locations within each country and then to on-farm trials. In addition to identifying lines for potential release as new cultivars, the tests identify parents for hybridization programs.

Crosses between germplasm with desired traits and locally adapted cultivars are made to transfer desirable traits to adapted germplasm. Pedigree, backcross and bulk breeding procedures are being used to develop improved cultivars. Hybrid populations appropriate to the environments of Thailand and the Philippines are being developed at NCSU and in both countries. Late generation material is evaluated in both countries for potential use in cropping systems peculiar to Southeast Asia such as acid upland soils, shaded floors of tree-crop plantations, or growth in paddies on residual moisture following harvest of a preceding rice crop. Promising breeding lines are tested at multiple locations in coordinated yield trials by the DOA in Thailand and by institutions cooperating with IPB in the Philippines.

In addition to exploiting the natural genetic variation within the cultivated species in the US and the Host Countries, novel genetic information is brought into *A. hypogaea* in two ways: interspecific hybridization to introgress desirable characters from the wild species, and genetic transformation using microprojectile

bombardment or *Agrobacterium tumefaciens*. In utilizing the wild diploid species, barriers of ploidy are broken by chromosome doubling either before or after hybridization, then hybrids are backcrossed to cultivated parents. Transformation is being used to achieve resistance to peanut stripe virus by incorporating genes encoding viral capsid protein genes.

Short visits to both Thailand and the Philippines will be made as needed by the principal investigators to review progress, redefine objectives, plan for the next year and provide technical assistance. Short-term visits of Thai and Filipino collaborators to NCSU, ICRISAT or collaborating countries will be made as needed. Both degree and short-term training will be provided based on need and available funding.

RESEARCH ACCOMPLISHMENTS IN DETAIL

I. U.S.

A. Breeding

1. Intensive selection for large-seeded adapted lines with resistance to *Cylindrocladium* black rot (CBR).

a. 1992 CBR F_2 Nursery and 1993 CBR $F_{2:4}$ Selection Nursery. Twenty-two F_2 populations from a factorial mating of four sources of resistance to CBR with six breeding with superior seed attributes and high yield were screened for resistance in a naturally infested field in Martin County, NC. Ratios of susceptible and resistant plants observed in the F_2 populations conformed to one of two ratios: the 3:1 ratio characteristic of completely dominant resistance or the 9:7 ratio characteristic of susceptibility governed by two recessive genes, each epistatic to the other. Progeny of 70 F_2 plants selected on the basis of resistance and pod and seed characteristics from 21 crosses were sent for increase by single-seed descent in a winter nursery at the USDA Tropical Agriculture Research Station at Mayaguez, Puerto Rico. $F_{2:4}$ families were planted on infested soil in Bertie County in May, 1993.

b. 1992 CBR $F_{2:4}$ Selection Nursery and 1993 CBR $F_{4:5}$ Family Test. Visual selection for resistance and pod attributes was practiced among and within 140 $F_{2:4}$ families derived from 18 crosses made in 1990. $F_{4:5}$ progenies were planted in a replicated test at Bertie County in 1993.

c. 1992 CBR $F_{4:6}$ Family Test. One-hundred-ninety-seven $F_{4:6}$ families and checks were evaluated for CBR incidence in a completely random design with unequal replication to allow for variable seed number. Eighty-three families were found to be intermediate in CBR incidence to NC 10C, the only resistant cultivar available to growers, and NC Ac 18016, a highly resistant check. These families were increased on uninfested soil at the Peanut Belt Research Station in Lewiston, NC, and 32 resistant families screened for pod and seed characters were retained for further testing.

d. 1992 Convergent Cross CBR Test. Fifty-six $F_{4:6}$ families derived from 28 crosses involving resistant parents were tested for CBR resistance in a replicated test at Martin County. Eleven exhibited CBR incidence comparable to NC 10C and were retained for further testing in 1993. These populations were developed as part of Dr. T.M. Halward's doctoral research program. Ancestry of each cross included 50% derived from the cultivar NC-V 11, 25% from a CBR-resistant parent, and 25% from another parent carrying earliness, drought tolerance, or resistance to leafspot.

e. 1992 and 1993 CBR Advanced Test. Fifteen $F_{4:7}$ families selected from four crosses were compared with checks for CBR resistance in a replicated test at Martin County and for yield and market grade

at Lewiston. Also included in the test were five lines previously found to exhibit resistance to CBR. Six families combined acceptable levels of CBR resistance with acceptable agronomic performance. One of the "old" lines, N90013 selected from a cross between cultivars NC 7 and NC 9, was also retained. N90013 has an intermediate level of CBR resistance comparable to NC 10C but has excellent market grade compared with NC 10C. N90013 was entered in the Peanut Variety and Quality Evaluation program jointly conducted by North Carolina State University and Virginia Polytechnic Institute and State University. In this program, entries are evaluated in replicated tests at four sites with two digging dates at each site. Data from this program serve as the basis for cultivar release decisions in the two states. N90013 was similar to NC 7 in yield and market grade in the 1992 PVQE trials. The 1993 CBR Advanced Test includes 48 lines selected from the 1992 CBR Advanced Test, CBR $F_{4:6}$ Family Test, Convergent Cross CBR Test, and Advanced Line CBR Test.

f. 1992 Crossing Program and 1993 CBR F_2 Nursery. Ten lines with superior resistance to CBR were crossed in a factorial mating with six agronomically superior lines. F_1 seeds were sent to the winter nursery in Puerto Rico. F_2 plants were planted on infested soil in Bertie County in 1993 to be challenged with the pathogen.

g. 1993 Crossing Program. Nine $F_{4:6}$ families selected from the 1992 CBR $F_{4:6}$ Family Test (see section IA1c) were crossed as females with three agronomically superior lines (including N90013 and N91048) in a factorial mating in the summer of 1993. F_1 seeds will be sent to the winter nursery in Puerto Rico. This represents the first mating cycle in this program in which selections from an earlier cycle were used as parents.

h. 1992 and 1993 Advanced Line CBR Test. Fifty-six advanced breeding lines evaluated in the cultivar development testing program for a second or later year in 1992 were also tested for CBR resistance in a replicated trial at Martin County. Partial resistance of N90013 was confirmed, and four additional lines selected from the cross of NC 7 with NC 9 were found to exhibit partial resistance. These lines were placed in the 1993 CBR Advanced Test for comparison with lines specifically selected for CBR resistance.

2. Selection for resistance to early leafspot (*Cercospora arachidicola*).

a. Preliminary replicated testing of resistance was conducted for two populations.

1) 1992 Leafspot Preliminary Test. Twenty-one $F_{4:5}$ families derived from a mating between GP-NC 343 and NC 9 were grown in a replicated test without chemical control of leafspot at Lewiston. In September, plots were rated for defoliation using the nine-point ICRISAT scale. Single-plant selections were made within plots of entries with the lowest defoliation scores. Selections were also made in plots of N92074L and N92084L, two NCSU breeding lines used as resistant checks. These lines exhibit resistance to leafspot but were heterogeneous for pod and seed characteristics. Progeny from 54 selections were planted in a replicated leafspot test at Lewiston in 1993.

2) 1992 Convergent Cross Leafspot Test. Forty-two F_4-derived lines from a convergent mating incorporating leafspot-resistant lines with lines carrying earliness, CBR resistance, and drought resistance were grown in a replicated test without chemical control of leafspot at Lewiston. Only three lines exhibited resistance to leafspot coupled with acceptable agronomic traits to warrant inclusion in the 1993 Leafspot Advanced Test of agronomic performance with and without chemical control of leafspot in the 1993 season.

b. 1992 Leafspot Advanced Test. Eighty-four F_4- and F_5-derived families from a program of recurrent selection for resistance to early leafspot were evaluated for defoliation, yield, and market grades in replicated tests at Lewiston in the 1992 growing season. Two reps were grown with chemical of leafspot and two without. Fifteen families entered in the test for the first year in 1992 were retained for further evaluation in 1993 Leafspot Advanced Test. Based on combined data from 1991 and 1992, eight families combining leafspot resistance with acceptable agronomic characteristics were transferred to Dr. M.K. Beute for evaluation of the mechanism of resistance in the 1993 season. Seven of the eight were entered in the 1993 Advanced Yield Test as part of the conventional cultivar development program.

d. Six families selected on the basis of defoliation scores and agronomic performance in 1991 were intermated in the greenhouse in 1992 to initiate the third cycle of recurrent selection for leafspot resistance. F_1 seeds were sent to the winter nursery for increase in the winter of 1992-93, and F_2 populations were planted in the 1993 season. part of each F_2 population was planted in an area in which leafspot will be controlled through application of fungicide while part was planted in an area without chemical control to allow for selection in the presence of the pathogen.

e. Nine lines selected from the 1992 Leafspot Advanced Test for their combination of resistance to early leafspot and superior agronomic performance were crossed with five runner lines bearing resistance to late leafspot. The runner parents were obtained from Dr. Daniel Gorbet of the University of Florida's Marianna Agricultural Research Center.

3. Selection of early-maturing large-seeded virginia lines with good storability.

a. 1992 Populations have been developed from crosses of virginia cultivars with F435, a spanish line with an extremely high ratio of oleic to linoleic acid in the fatty acid profile of the oil. F_4 populations derived by single-seed descent from the initial crosses of F435 with five virginia-type cultivars were grown at Lewiston. Progeny were submitted to the Department of Food Science for analysis of fatty acid profiles. BC_2 plants produced in a crossing program in 1991 were planted to produce BC_2S_1 plants for evaluation of O/L ratio.

b. 1992 Fatty Acid Test. Sixty-one $F_{6:7}$ families selected from 30 crosses of virginia cultivars in current use with sources of high O/L ratio were compared for agronomic performance in replicated tests in the 1992 growing season. Sixteen lines were retained for inclusion in the 1993 Advanced Yield Test.

c. 1992 Early Maturity Advanced and Preliminary Tests. Twenty-five advanced F_5-derived selections from crosses of NC 7 with NC 9 and Florigiant were evaluated for performance at early (September 15) and conventional (October 1-7) digging dates. Seven lines with superior yield and grade at the early digging were retained for inclusion in the 1993 test and also to be entered in a test of early-maturing lines conducted by R.W. Mozingo at Virginia Polytechnic Institute. Eleven lines selected from the late digging, including four also selected on the basis of performance at the early digging date, were entered in the 1993 Advanced Yield Test. An additional 87 $F_{5:8}$ families from the cross of NC 7 / NC 9 were be re-tested at early and late digging dates to measure the components of genetic variation in the population.

4. Recurrent selection for resistance to *Aspergillus* species. F_2 progeny of crosses among families previously identified as exhibiting one or more mechanisms of resistance to *A. parasiticus* were grown at Lewiston in the summer of 1992. Plots were harvested by single-seed descent and F_3 progeny were planted in 1993. Individual plants will be harvested and

$F_{3:4}$ progeny evaluated for resistance to dry-seed infection and aflatoxin production. Families exhibiting one or another form of resistance will be intermated in a second cycle of recombination.

5. Incorporation of pest resistance from wild species into *A. hypogaea*. F_2 progeny were grown of crosses between large-seeded lines and tetraploid lines derived from an interspecific cross of *A. hypogaea* PI 261942-3 with *A. cardenasii* 10017. These lines include some resistant to leafspots and some with resistance to nematodes and insect pests. Single-seed descent and single-plant selection were performed and F_3 populations planted in 1993 as part of a program of inbred line selection.
6. Assay current advanced material with variation in storability for chemical and market quality. Lines submitted to the PVQE program were evaluated for fatty acid profile. These lines were all derived from a cross between NC 7 and NC 9 and all but one were intermediate between the two parents. The exception, N91070, was comparable to NC 7 in O/L ratio but was inferior from the standpoint of agronomic performance.
7. Recurrent selection for productivity in a population derived from elite germplasm.
   a. $S_{1:3}$ families from the 88 surviving crosses of the fifth cycle (C_5) of recurrent selection were tested for yield and market grade in the 1992 growing season in replicated tests at Lewiston and at the Upper Coastal Plains Research Station at Rocky Mount, NC. The 40 highest-yielding lines were identified and $S_{1:4}$ plants used as parents in a crossing program to initiate the sixth cycle of recombination.
   b. Selection for pod and seed characteristics was performed in $S_{1:3}$ populations from C_6 using single-pod harvest. $S_{1:4}$ populations were planted in the field in the 1993 season. These populations represent the "milking" stage of the recurrent selection program.
   c. Nine lines selected from 63 F_5-derived families from the fourth cycle (C_4) of the recurrent selection program were evaluated in the 1992 Advanced Yield Test at two sites, Lewiston and the Border Belt Tobacco Research Station at Whiteville, NC. None of these lines were competitive with selections from the NC 7 / NC 9 cross.
8. Recurrent selection for yield in a population derived from an interspecific cross. The fourth cycle of selection was performed in a population initiated by crossing *A. hypogaea* PI 261942 or 261943 with *A. cardenasii* PI 262943 (GKP 10017). The sterile hybrid was treated with colchicine to create a fertile allohexaploid which spontaneously lost chromosomes, returning to the tetraploid level. The initial cycle of this recurrent selection program was initiated with lines selected from among the original tetraploid revertants. In each cycle, ten parents with superior yield and acceptable pod and seed size and shape have been crossed in diallel fashion, S_0 plants have been grown in the winter nursery at Puerto Rico, and $S_{0:2}$ families have been tested for yield. In 1992, the 43 surviving families from C_4 were tested at Lewiston and and Rocky Mount. Only two of the families exceeded the yield of NC 9 and none of the families was greater in value per hectare than NC 9. Pod size, seed size, and meat content of the families were significantly less than those of the cultivars used as checks, resulting in lower calculated support price and lower value per hectare.
9. Evaluation of insect-resistant lines from W.V. Campbell's program. 210 lines developed at NCSU or introduced from ICRISAT have been under evaluation for resistance to the North Carolina arthropod pest complex as part of the CRSP project NCS/TP/IM. These lines were evaluated for resistance to thrips (*Frankliniella fusca*), corn earworm (*Heliothis zea*), potato leafhopper (*Empoasca fabae*), Southern corn rootworm (*Diabrotica undecimpunctata*), and lesser cornstalk borer (*Elasmopalpus lignosellus*) in a field without chemical control of insects. Populations of *H. zea*, *D. undecimpunctata*, and *E. lignosellus* were low in 1992 resulting in less than ideal conditions for evaluation of

resistance. The screen confirmed the multiple resistance of lines previously identified by ICRISAT as resistant to the insect complex of Southern Asia. Several selections developed at NCSU were also resistant to multiple insect species. These lines have been distributed to collaborating Host Country Institutions, but seed maintenance facilities at those sites are poor. Seed for NCSU, Thailand, and the Philippines was harvested from the plots at NCSU. Lines with superior resistance to one or more pests but lacking commercially acceptable yield, seed or pod characteristics were planted to be crossed with agronomically superior lines in 1993.

B. Plant Pathology and Molecular Biology

1. *Cercospora* leafspots. Thirteen genotypes derived from crosses between wild *Arachis* spp. and virginia peanut were evaluated in the field in 1992 for resistance to Cercospora leafspots. Ten of these lines also were evaluated in 1991 and NC 6, NC 7, Southern Runner, and GP-NC 343 were included as checks in both years. Genotypes were planted in six replicate plots, and individual plots were bordered on all sides by soybeans or cotton. A plant infected with *Cercosporidium personatum* was placed in each plot in August. Natural inoculum of *Cercospora arachidicola* was present at levels sufficient to initiate early leafspot epidemics in susceptible genotypes. Incidence of early leafspot caused by *C. arachidicola* and late leafspot caused by *C. personatum* was estimated weekly and percent defoliation also was determined. Areas under disease progress curves for early leafspot (AUC-E), late leafspot (AUC-L), and defoliation (AUC-D) were used to compare the genotypes. In 1991, all test genotypes had smaller AUC-Es than the most resistant check, GP-NC 343, and five had AUC-Es that were less than half that of GP-NC 343. Rankings of genotypes by AUC-E generally were consistent between 1991 and 1992, but higher levels of disease in 1991 allowed better discrimination among lines. Several lines had resistance to late leafspot that at least equalled that of Southern Runner, but three had AUC-Ls that were significantly larger in at least one year. All test genotypes had significantly less late leafspot than the susceptible cultivars NC 6 and NC 7. Standard cultivars had AUC-Es and AUC-Ls three to 15 times greater than the most resistant lines. Some of the best-ranked genotypes in each disease category had poor rankings in one of the other categories, but some genotypes had resistance to early leafspot and defoliation far superior to that in commercial cultivars, along with late leafspot resistance equal to that in Southern runner.

   Eight cultivars of virginia-type peanut were planted in field plots in 1992. Six replicate plots were bordered on all sides by nonhost cotton. Standardized areas under the disease progress curve were calculated from percent defoliation (AUC-D) data and from estimated incidences of early leaf spot caused by *Cercospora arachidicola* (AUC-E) and late leaf spot caused by *Cercosporidium personatum* (AUC-L). In 1992, AUC-E ranged from 32% for NC 6 to 77% for NC 10C and AUC-L ranged from 3% for Agratech VC-1 to 22% for NC 6. Defoliation (AUC-D) varied less, ranging from 19% for NC 6 to 30% for NC 10C. NC 7, currently a popular cultivar in North Carolina, had significantly smaller AUC-E and significantly larger AUC-L than Florigiant, which previously dominated. These results and field observations suggest that *C. personatum*, which is the more difficult disease to control, may become increasingly important in the foliar disease complex in North Carolina. Adjustments in fungicide spray schedules and monitoring of leafspots may be required.

2. *Aspergillus* and aflatoxin studies. Microplots were planted in 1993 with 20 genotypes in 10 randomized complete blocks at the Sandhills Research Station. Inoculum of *Aspergillus parasiticus* was added to plots at late bloom and irrigation was discontinued to create conditions favorable for infection. At digging, all uninjured, mature pods will be picked from each plot and the entire sample shelled by hand. Genotypes will be evaluated for colonization by *Aspergillus parasiticus* and for toxin

production. Many plots failed to produce seeds in a similar test in 1992.

3. Root-knot nematodes. Twelve peanut genotypes were evaluated in field microplots for resistance to *Meloidogyne arenaria* in 1991 and 1992. Five of the test entries were derived from a cross of PI 261942 (susceptible) x *Arachis cardenasii*. *A. cardenasii* is a diploid species with partial resistance to *M. arenaria*. The parental lines and a second diploid species, *A. chacoense* (NC 10602), also were included. Additional lines evaluated were PI 259572, PI 259639, NC 18000, and the susceptible cultivar Florunner. Microplots were fumigated with methyl bromide (1991) or metam-sodium (1992) before planting. Calibrated suspensions of freshly-extracted nematode eggs were used to infest plots in each year. Nematodes were extracted and counted from soil samples taken twice in each year. At digging, pods and roots were rated visually for nematode damage, and roots were removed for further assay. Roots were washed, weighed, and processed for extraction of eggs. In 1991, four of the five entries from the interspecific cross had ratings and transformed counts of eggs/g root, eggs/root system, and nematodes/500 ml soil less than or equal to those for the resistant wild parent, *A. cardenasii*. All counts and ratings were significantly less than for the susceptible parent. In 1992, 2 of the 5 entries had egg counts less than or equal to the wild parent and 3 of the entries had significantly smaller counts than the susceptible parent. Florunner and NC 18000 were highly susceptible and PI 259572 and PI 259639 were intermediate in both years. *A. chacoense* consistently appeared slightly more resistant to *M. arenaria* than *A. cardenasii* although differences were not significant.

   Field microplots were infested with single populations of *Meloidogyne arenaria* races 1 (MA1) and 2 (MA2) and a 1:1 mixture of the two races. Plots were planted to MA1-susceptible peanut (Florigiant), *M. incognita*-resistant tobacco (McNair 373), and susceptible tobacco (Coker 371-Gold) to characterize interactions of the two nematode races and to elucidate their population dynamics as affected by peanut-tobacco rotations. Penetration and reproduction of MA2 on peanut, and that of MA1 on resistant tobacco, were very limited. The two races reproduced similarly on susceptible tobacco. In mixed populations, MA1 was dominant on peanut and MA1 was dominant on tobacco cultivars. The degree of dominance of MA1 on susceptible tobacco was less than that on resistant tobacco. Peanut root damage caused by MA1 was limited by the presence of MA2. Nematode survival after the first season was quite high, especially for the eggs of MA1 on peanut. Crop rotation also affected the population dynamics of different nematode races. Very low numbers of MA1 and MA2, resulting from a nonhost the previous year, increased rapidly on respective second-year, suitable hosts. Multiplication of MA2 was greater on resistant tobacco than on susceptible tobacco when following peanut.

   Results of tests on interactions between *M. arenaria* race 1 (MA1) and *M. hapla* (MH) on five peanut genotypes (Florigiant, NC 7, NC 6, NC Ac 18416, and NC Ac 18016) for two years indicated that MA1 was dominant to MH in mixed infestations. During the first season, penetration and reproduction of MH population were lower than that of mixed (0.5:0.5, or 1:1) populations and lower or similar to that of MA1 population on most peanut genotypes, except on NC 6 on which penetration and reproduction of different nematode populations were similar. MA1 and mixed populations caused more damage to peanut roots and pods than MH. However, survival of MA1 during crop-free period was lower than that of MH or mixed populations. At mid-season of the second year, MH population had greater rates of increase than other populations on all peanut genotypes. The full-mixed (1:1) population in soil declined during Year 2 except on NC 6. The lowest numbers of soil nematodes were detected on peanut plants with poor growth. Future research will include population dynamics for Year 3 in peanut-tobacco rotations

(Study 1), and noncropping of peanut genotypes (Study 2). Additional experiments will focus on effect of root-knot nematode species/races interactions on peanut nodulation.

4. Soil-borne fungi.

a. *Sclerotium* wilt and *Sclerotinia* blight. Sixteen peanut genotypes were planted in disease nurseries for evaluation of resistance to *Sclerotium rolfsii* and *Sclerotinia minor*. Genotypes also were evaluated separately for resistance to *Cylindrocladium* black rot. Ranks of genotypes by disease incidence were significantly correlated. Genotypes having partial resistance to all three pathogens and good agronomic characteristic were identified for further evaluations.

Research on the effects of several "conservation tillage" practices (currently being promoted in eastern North Carolina) on severity of three yield-limiting soil-borne pathogens of peanut was initiated in 1992. A study was established using field microplots at the Central Crops Research Station, Clayton, to compare conventional tillage (clean plowing) with a simulated no-till practice (addition of wheat straw as surface debris). Three soil-borne pathogens (*Sclerotinia minor, Sclerotium rolfsii, Cylindrocladium crotalariae*) were used to infest soil at two inoculum levels for each tillage system. Two cultivars (NC 7, NC 10C) with different levels of disease resistance were planted in both tillage and inoculum treatments. Soil temperature was monitored at a 2-cm depth in soil, in both tillage treatments, at hourly intervals. Disease incidence was evaluated monthly and pod rot data were taken at harvest. Tests will be continued for several years to determine the effects of treatments on inoculum dynamics in soil.

To complement studies of no-till in microplots, we are also currently involved in a project with Dr. George Naderman, an Extension soil scientist. In field situations we are comparing no-till methods to other conventional tillage practices. In Chowan County (in cooperation with county agent Mike Williams) we compared levels of disease incidence, pod rot and yields of NC 7 using seven different tillage practices. Two different conservation tillage methods were used: a no-till with fluted coulter and a no-till with sub-soiler. Five other conventional tillage practices were included in these comparisons. Similar evaluations were made on plots planted with Florigiant at the Lewiston field station; comparing five tillage treatments. These treatments included one no-till treatment and four conventional treatments, one of which included use of the fungicide Terrachlor and the insecticide Lorsban. We hope to use these types of field tests to give us more information about the use of cover crops and conservation tillage methods in peanuts as they pertain to different soil properties and cultivars.

A new program was initialized in 1992 to evaluate the benefits of modifying peanut canopy morphology on the overall control strategy for Sclerotinia blight at the farm level. Previous studies at NCSU illustrated that the currently available level of resistance in our breeding program is not sufficient to control disease if canopy growth-characteristics provide a conducive environment for Sclerotinia epidemics. Currently recommended fungicides do not provide adequate control when environmental conditions (temperature, moisture, canopy density) are conducive for disease. A new fungicide, Fluazinam, is highly active against *S. minor* but there is concern about timing of application and penetration of canopy for maximizing efficacy. Research addressing rates of fungicide required and time of applications (pre-inoculation or post-infection) has been initiated in greenhouse studies using a modified detached-stem technique under periodic misting. Field test will utilize four peanut genotypes (NC 7, VA 81B, NC Ac 18016, and a spanish line from Texas) with diverse canopy morphologies and metabolic resistance

levels. Mechanical pruning treatments will be utilized to alter microclimatic environments beneath canopies (differing "naturally" by phenotypes). Application of Fluazinam will be imposed (as a sub-treatment) on the genotype-by-pruning treatments. Data will be collected weekly by counting numbers of "hits" (active lesions). A separate field trail will be conducted to determine whether plant debris left from pruning will influence the incidence or severity of *S. rolfsii* (debris may serve as a "food-bridge" for infection) in the field.

b. *Cylindrocladium* black rot (CBR). Periderm formation in root tissue has been identified as a mechanism of CBR resistance, but this phenomenon cannot fully account for what is observed under field conditions. Several studies have indicated that various root parameters (root length, density, number of laterals, etc.) are responsible for field-resistance in other crops. We are currently investigating the role of various root growth parameters in CBR resistance in peanut. A grid-intersect technique has been employed to estimate root length. This year the method was fully tested by comparing grid-intersect counts with root length individually measured with a ruler. A high linear correlation resulted, reinforcing our confidence in the more efficient grid-intersect method as an accurate estimate of root length. Uninfested-soil experiments involving genotypes that differ in CBR resistance were replicated in the greenhouse.

The resulting root length estimates agree with a previous run of the experiment, supporting the hypothesis that resistant genotypes avoid contact with the pathogen by producing less roots than susceptible genotypes. However, root wet weight, dry weight, and root volume estimates did not correlate strongly with root length. We initiated a second set of greenhouse experiments to study changes in rooting pattern when the pathogen is present at different levels in the soil profile. These studies should yield information indicating whether resistant genotypes are able to compensate for root-pruning effects of the pathogen by exploiting soil levels below those where the pathogen naturally exists. Data has only been partially collected. Field roots collected during the 1991 growing season (using a monolith technique for recovering roots) were analyzed using the grid-intersect method to determine root length present at different soil depths. Preliminary data analysis agrees with data from greenhouse studies of plants in uninfested soil. That is, resistant genotypes produce less root than susceptible genotypes, indicating that an avoidance mechanism does operate in field resistance to CBR.

5. Bioenginsering for control of tomato spotted wilt and stripe virus. There are now in the literature numerous accounts of resistance to plant pathogenic viruses of several types, mediated by the expression of various viral gene products in the host plant. We are attempting to transfer into peanut chimeric genes encoding the capsid protein of PStV and the nucleoprotein of TSWV.

Successful utilization of a transformation system for peanut is dependent upon a tissue culture regeneration system. Embryonic leaves of peanut have been demonstrated to be a useful target for introduction of foreign genes into peanut via microprojectile bombardment. Culture conditions that optimize the number of cells participating in the formation of the shoot meristem will ultimately lead to an increase in the probability of a transgenic shoot. While a rudimentary protocol for peanut transformation was developed just prior to the preparation of the 1992 Annual Report, we have continued to work on improved protocols for various aspects of the peanut gene transfer system. These improvements potentially include the replacement of biolistic DNA transfer with *Agrobacterium*-based protocols. Use of *Agrobacterium* is expected to increase the number of independent transformants and sharply decrease

transformation costs.

a. Embryonic leaves of genotypes representing all the botanical types of peanut were evaluated for response under various tissue culture parameters. A limiting factor in many plant transformation systems lies within the *in vitro* culture performance of the crop species. In peanut, like other recalcitrant species, genotype specificity is a significant parameter in regeneration frequencies obtained, regardless of explant source. A genotype survey was conducted by evaluating 70 diverse genotypes of peanut for regeneration frequencies from embryonic leaflets. Four independent surveys were conducted. Three surveys evaluating 20 genotypes per survey and 1 survey evaluating 10 genotypes were conducted (40 explants per genotype). For each survey explants were assessed for callus proliferation, root production and bud formation at two weeks. All explants were subsequently transferred to fresh media and measured for callus, root and shoot formation at 4 weeks in culture. Within each survey 2-4 genotypes were selected based on number of shoots recovered. Selected genotypes were then reevaluated together and shoot-formation frequencies were measured at 4, 6 and 8 weeks in culture. The number of shoots surviving transfer out of culture, was determined. Elite culture-performance genotypes were identified, based on shoot regeneration frequencies from embryonic leaflets, representing all botanical types of peanut. Theoretically, a culturally elite genotype will vary across tissue culture parameter tested, but performance of an elite genotype should maintain a relatively higher frequency of shoot regeneration as compared to other genotypes of peanut that previously have been identified as poor culture performers.

   Improved protocols for selection of transgenic peanut plants from embryogenic cultures treated by microprojectile bombardment have been developed. Modifications include reduced selection time on antibiotic (hygromycin), use of a single level of selective agent during selection of transformed callus cultures, and reduction or elimination of selection in liquid media. These significantly improve the efficiency of the system and reduce the time required to produce transgenic plants from from primary explants. We are working now to integrate these modifications with current transformation protocols.

   The selective agent employed in a plant transformation system may influence efficiency of the process by limiting the recovery of escape shoots (plantlets that survive a toxic agent in the growth medium). Previous studies utilizing the antibiotic kanamycin as a selective agent for shoots derived from embryonic leaflets of peanut (in a transformation system utilizing the direct DNA delivery via high velocity microprojectiles) resulted in the isolation of escaped shoots. Investigations were initiated to alter the selective scheme from one of a detoxification mechanism (as with kanamycin) to incorporation of an alternative substrate scheme, the antibiotic methotrexate (MTX). A series of experiments were conducted with the dihydrofolate reductase (dhfr) gene (originally isolated from mouse) that has been shown to have a 200-fold less affinity to MTX as compared to endogenous plant dhfr. Three different stringencies were evaluated for selection. Plants have been regenerated on the least stringent selection protocol and are currently being evaluated for presence of the foreign gene sequences. One plant and two shoots have developed under the intermediate selection pressure; only "potential" bud formation has occurred under the most stringent pressure.

b. We have made significant progress toward preparing enhanced plasmid vectors for use in producing virus-resistant transformants. First, we have successfully amplified a partial clone of a gene encoding a nucleoprotein from tomato spotted wilt virus, using as template a

clone obtained from Dr. James Moyer (NCSU). Additional restriction sites were engineered into the clone to facilitate combining the gene with various regulatory sequences to optimize its expression in peanut.

A construct containing DNA for capsid protein of peanut stripe virus was obtained from John Sherwood of Oklahoma State University and Rick Nelson of the Noble Foundation in Ardmore, OK. We re-engineered both hygromycin phosphotransferase and peanut stripe virus capsid coding sequences, and have fused these chimeric genes into a single vector. This new construct is expected to increase transformation frequency, as well as increasing the probability of recovering useful genotypes among the transformants.

We have made substantial progress toward development of an *Agrobacterium*-based transformation system for peanut, which could replace the relatively inefficient microprojectile-based system now in use. Moderate levels of infection have been obtained by inoculating immature (seedling) leaflets with wild-type strain A281, the progenitor of the disarmed strain EHA 105. Infection was scored by measuring callus growth which occurs when inoculated leaflets are plated on hormone-free media. Clear evidence of infection by this strain has permitted us to move ahead confidently with plans to develop this system.

Using biolistic transformation protocols, we have begun an intensive effort to produce virus resistant genotypes by introducing chimeric genes into embryogenic cultures of several commercial peanut varieties. Cultures of cv. Toalson, Florunner and Tifrun have been treated. Numerous experiments are now in progress, including approximately 1,500 bombarded embryogenic callus masses. Additional materials are being added periodically to generate a constant flow of transformed lines for evaluation.

A new Ph D student, Ms. Geeta K. Menon, was recruited for the project. She joined the lab 1 September 1992, and has assumed responsibility for all peanut stripe virus and tomato spotted wilt virus experiments.

C. Cytogenetics

1. Evaluating germplasm for disease and insect resistances

a. *Cercospora arachidicola* and *Cercosporidium personatum* resistances. Four interspecific hybrids selected from an *Arachis hypogaea* x *A. cardenasii* cross were released as germplasm resources for resistance to *Cercospora arachidicola* (early leafspot). The four selections are significantly more resistant then cultivated lines for *C. arachidicola*, but are not immune to the pathogen. Three of the lines also have moderate levels of resistance to *Cercosporidium personatum* (late leafspot). Seed size of all lines is moderately small. The selections have potential for major savings to the farmers for decreasing costs of fungicides and should reduce chemical application and residues in the field.

The above four selections were hybridized with cultivated lines which had been previously identified as resistant to *C. arachidicola*. The first generation hybrids where then backcrossed to the cultivars NC 5 and NC 6 to increase seed quality and size. Several selections made from these crosses have higher levels of leafspot resistance than either parent plus increased seed size. Thirty-two interspecific hybrids were planted at Lewiston, NC for additional evaluations for resistance to *C. arachidicola*. Disease ratings were made during the last week of August and just prior to harvest in late September when the average numbers of lesions per leaf, defoliation and a visual ratings were made on three plants per plot. Most lines had ratings of 2-3 on a scale of 1 (no disease) to 9 (dead plants). The best lines will be retested during 1993. In addition, 12 of the interspecific hybrids were planted in 200 seed plots to evaluate disease progression for both *C. arachidicola* and

C. personatum during the growing season. Natural inoculation for *C. arachidicola* and *C. personatum*-infected plants were used to increase disease levels. Significant differences were observed among genotypes for rate and total infection for both pathogens. High levels of resistance in several lines were verified for *C. arachidicola*, whereas moderate levels (comparable to the resistant cultivar Sunrunner) was observed for *C. personatum*.

Because seed quality and size are not acceptable in most of the interspecific hybrid selections described above, backcrosses were made with cultivars NC 6, NC 7 and NC 9. First generation hybrids were planted in the field for seed increases to advance generations. Segregating populations will be used to made additional selections for leafspot resistance and seed size. Nine additional F_1 hybrid combinations were produced to introgress disease resistance into acceptable market types.

c. Advanced generation interspecific hybrids at the tetraploid chromosome level were evaluated in the greenhouse for resistance to *Meloidogyne arenaria* (root-knot nematodes). Five genotypes with high levels of resistance were identified. These advanced generation hybrids were derived from the species *A. cardenasii* and *A. chacoense*. To confirm resistance levels identified in the greenhouse, field microplots were used to test the lines so that uniform inoculation levels could be evaluated. The very high levels of nematode resistance observed in the greenhouse continued to be expressed in the field. The interspecific hybrids were also grown in replicated field experiments in Georgia. These results placed interspecific hybrids in the resistant group, although field variation for nematode population densities made data analyses very difficult. In comparison to nematode resistance reported in cultivated germplasm, the interspecific hybrids are believed to have significantly higher levels of resistance. They are being planted in the field for analyses of morphological traits which will be used for official germplasm releases.

One nematode-resistant entry, CS2, appeared to be segregating in the field for resistance in 1991. A greenhouse evaluation of individual plants of this line was conducted to determine whether the field data were due to inoculum variation or genetic differences among plants. The line appears to be segregating in a 3:1 ratio of resistant to susceptible plants.

To determine the inheritance of nematode resistance, five interspecific hybrids were crosses to three susceptible cultivars and F_1 plants were grown in the field for seed increase. Cuttings were made from the F_1s, rooted and evaluated for nematode resistance in the greenhouse. The amount of galling, number of egg masses and number of eggs were scored. Two nematode-resistant cultivated plant introductions from the Georgia program were evaluated in the same test, and also crossed with the interspecific hybrids. Evaluations of F_1 hybrids indicated that the resistance in advanced hybrid derivatives is dominant, and the genes conditioning resistance is different from those found in the cultivated lines. Segregating populations will be tested in the greenhouse during the coming year to estimate the number of genes conferring resistance. In addition, because the interspecific hybrid lines have very small pods and seeds, selections will be made from remnant seeds of the genetic study to increase yields and quality.

d. Tomato spotted wilt virus-resistance

1) 50 accessions of *Arachis* species and seven advanced generation interspecific hybrids were tested for resistance to tomato spotted wilt virus. The experiment was a cooperative effort with Dr. Mark Black of Texas A&M University because incidence of the disease is greater at his location. Several wild species exhibited apparent immunity to the virus. The best hybrid, NC 2

/ *A. chacoense* 10602, showed only 6% infection while the susceptible check showed 46%. Other hybrids exhibited moderate levels of resistance. Seeds were harvested on resistant plants of interspecific hybrids as an initial procedure to select and preserve potentially resistant lines. A seed increase of resistant wild species accessions and interspecific hybrids was planted in 1993 to allow for testing on a larger scale.

2) Cross were made between TSWV-resistant diploid *Arachis* species and *A. hypogaea* cultivars. Triploid hybrids will be colchicine treated to restore fertility and generations advanced to create tomato spotted wilt virus-resistant lines which are cross compatible with cultivars.

e. Insect resistance. Sixteen advanced generation interspecific hybrids with the wild species *A. cardenasii* and *A. duranensis* were evaluated in replicated tests in the field for resistance to corn earworm, leafhopper and southern corn rootworm. High levels of multiple resistances were observed, and lines will be grown in the field next year to confirm results and to collect data necessary for germplasm release. In addition, four of these lines had been hybridized with either GP-NC 343 or NC 6 and then backcrossed to NC 6 in an attempt to improve insect resistance, quality and yield. More than 450 non- replicated plots were evaluated for insect resistances in the field and single pods from each plant were harvested. Several lines appear to have relatively high levels of insect resistance and seed size increases over the original selections. The best lines will be tested again during the coming year.

f. Resistance to *Cylindrocladium* black rot. *Arachis monticola* is a tetraploid wild species closely related to the cultivated peanut and hybrids between the two species are fertile. A preliminary report of resistance to the soil-borne pathogen *Cylindrocladium personatum* indicated that at least one accession of *A. monticola* is highly resistant to the pathogen. Six accessions of this species were acquired and tested in two replicated experiments in the greenhouse for resistance to *C. personatum*. Four of these accessions had very high levels of resistance, which were comparable to or better than the best known cultivated line, NC 3033. Because NC 3033 has been a poor parent in the North Carolina breeding program, hybrids were made between the resistant *A. monticola* accessions and both a virginia-type and spanish-type cultivar. Studies are planned to determine the heritability of resistance and to selected for improved breeding lines for cultivar improvement.

2. Introgression of germplasm from wild *Arachis* species into *A. hypogaea*.

a. Pathways for introgression. A program to introgress germplasm from *Arachis* species to the cultivated peanut has been underway for more than 20 years at North Carolina State University. Because only a limited number of interspecific hybrids result in lines with desired wild species traits, an investigation was undertaken to increase the frequency of desirable hybrid derivatives.

1) Two cultivated lines were hybridized with the three species *A. cardenasii*, *A. stenosperma* and *A. batizocoi*, representing annual and perennial A-genome and B-genome species, respectively. In addition, these species have desired resistances for foliar pathogens and insect pests, and hybrid derivatives should have beneficial progenies. Sterile triploid hybrids were colchicine treated to restore fertility at the 60-chromosome level and resulting progenies self-pollinated and backcrossed to the respective cultivated parent; the process is being repeated for five selfing generations to estimate timing and rate of introgression. During the past year, hexaploids were advanced to the C_3 generation and backcrosses made with C_1 and C_2 hexaploids to produce pentaploids. Because pollen fertility is low, a large

number of pollinations were made in each crossing program to obtain a limited number of hybrids. Crosses with *A. stenosperma* are progressing at the most rapid pace because they are more fertile than other species hybrids. To study the rate and timing of gene introgression, DNA markers are being used to follow chromosome segments through successive generations.

2) The second phase of the introgression study is gene transfer from *Arachis* species raised in chromosome number to the autotetraploid level before hybridization with *A. hypogaea*. Seeds of each of three species (*A. cardenasii, A. stenosperma* and *A. batizocoi*) were colchicine treated. Autotetraploid plant sectors were identified based on reduced male fertility levels. These will be hybridized with two *A. hypogaea* cultivars during the coming year. Crosses were also made between the three wild species to produce interspecific hybrids and create materials to colchicine treat so that amphiploids could be isolated. Because of the genomic make-up of the cultivated peanut, the hypothesis is that combining A and B genome species may promote greater fertility in crosses with the cultivated peanut and increase gene transfers. Because the same accessions are being used as for the first part of the molecular study, DNA markers are already being identified to follow introgression from the wild to cultivated species. Crossing programs are planned for next year to produce hybrids for selfing and backcrossing, and samples will be collected from all the materials for DNA analyses.

3) Pre- and post-fertilization barriers to interspecific hybridization in the genus continue to restrict gene flow among species and efficient utilization of the genetic resources in the genus. An investigation to identify causes of sterility and embryo abortions was initiated whereby pollinations between several *A. hypogaea* cultivars and species from four sections of the genus were made. Young reproductive tissues were harvested from one to 28 days post-pollination and prepared for histological analyses. The preliminary data indicate that several causes of hybrid failures exist for different crosses, but many abort within the first 10 days after pollination. This is before differentiation of the embryo occurs, and embryo rescue is very difficult. The study is continuing as tissues are being sectioned and histologically examined.

4) As a companion study, peg tips are being cultured using several auxin and cytokinin types and levels. Experiments to date have resulted in pod development *in vitro* and the materials are being histologically examined to determine whether embryo growth and differentiation have occurred.

c. During the past year RFLPs (DNA restriction fragment length polymorphisms) were identified to differentiate the three *Arachis* species and two cultivated lines. Initially, 56 RFLP markers were identified differentiating the cultivated and wild species. To date, 30 RFLPs have been used to analyze the respective *A. stenosperma, A. cardenasii* and *A. batizocoi* parents, F_1 hybrids, hexaploids and pentaploid backcross progenies. During the past year we have demonstrated that DNA markers can be followed through different hybrid and polyploid generations. Preliminary data indicate that chromosome segments are lost even in early generation of selfing hexaploids, but it is unknown whether this is due to a chromosome elimination event. Addition germplasm may be lost in pentaploid hybrids which are now being self pollinated to reduce chromosome numbers to the tetraploid level.

The same set of hybrids as described above for the RFLP analyses is being evaluated using RAPDs (Randomly amplified polymorphic DNA). Because these markers can be screened more rapidly, and polymorphisms more frequent, they hold greater promise for tracking

DNA segments. The disadvantage is that many of the RAPDs are multicopy segments and mapping onto specific chromosomes may not be possible. During the past year, more than 200 RAPDs for each of the three species have been identified which will differentiate them from *A. hypogaea*. DNA was also collected from interspecific hybrids for all available materials at different ploidy levels, and they will be analyzed as a group as complete sets become available.

b. Advanced generation interspecific hybrids between *A. hypogaea* and 14 *Arachis* species were grown in the field to increase recombination between the genomes at a high ploidy level.

c. One advanced generation interspecific hybrid population between *A. hypogaea* and *A. cardenasii* is available for investigation. Selections have been made for several disease, insect, yield, seed size traits. Fifty lines, including the ones with agronomic desirable characteristics, are being evaluated for introgression from the wild to cultivated using RAPD markers. Evidence has been collected for several of the lines with genes from *A. cardenasii* which have been transferred to the cultivated genome. In addition, the work indicates that DNA segments are present in the interspecific hybrid lines which were not present in the *A. cardenasii* plant originally used for DNA extractions. Additional plants of this species are being evaluated to determine whether the markers may have originated from a genetically different plant from the same accession. Preliminary data indicate that several of the markers may be associated with genes conditioning insect resistance in peanut, but results must be confirmed in segregating populations. First generation hybrids were between lines with disease and insect resistance and susceptible checks. Second generation progenies have been harvested and are to be used for the analyses.

3. Biosystematic evaluations in *Arachis*

a. To determine the progenitor species of the cultivated peanut and to develop methods to increase the frequency of germplasm introgression to the cultivated peanut, the variation in *A. duranensis* is being studied. First, morphological data were collected and analyzed to determine the visible variability among accessions of the species. Crosses were then made among morphologically variable types. First generation hybrids are being analyzed cytologically. Fertility levels in plants range from semi-sterile to highly fertile. Multivalents and univalents have been identified in several specific hybrid combinations, which indicated that cytological differentiation has evolved within the species.

b. To more effectively utilize resistance genes in section *Erectoides*, species relationships will be evaluated. Hybrids from 1992's crossing program were grown for analysis of pollen fertility and missing combinations of species were made by crossing unique accessions. Cytological analysis of these hybrids is planned.

c. Diverse cultivated types were evaluated for amino acid variation in an attempt to classify varieties and to find associations between amino acids and disease resistances. There was no significant variation among genotypes in amino acid profiles.

B. Philippines

1. Germplasm collection and evaluation for desired genetic traits.

a. Twenty-seven new accessions were acquired from USA and Indonesia. Eleven lines from North Carolina State University (NCSU) showed resistance to late leafspot and peanut rust diseases.

b. A total of 135 accessions from ICRISAT, India which are early maturing, disease-resistant and large-seeded breeding lines were evaluated for both wet and dry cropping seasons. Ten lines had seed yield which exceeded 1.0 ton/ha and 17 lines were identified to be resistant to late leafspot and peanut rust diseases.

2. Hybridization and selection
   a. A second set of six parent half-diallel crosses for shade tolerance was completed.
   b. Thirty crosses were made involving parents with good seed viability, shade tolerance and aflatoxin resistance.
   c. Eighty-one breeding populations (30 F_1, 17 F_2, 26 F_4, 2 F_5 and 6 F_6) were planted in October and 1074 plant selections were planted in individual rows for initial seed increase and line selection.
   d. Sixty-seven populations (6 F_6, 2 F_5, 25 F_4, 19 F_2 and 15 F_1) were evaluated during the dry cropping season. A total of 1704 individual plants were selected from F_5 and F_6 populations. These selections were further tested in the Observational Nursery. A total of 100 lines were selected for yield evaluation; disease and insect pest resistance; and tolerance to shade, acid and drought.
3. Yield trials across testing sites
   a. Upland full sunlight conditions
      1) Preliminary yield trial. Thirty-four promising lines were evaluated in the preliminary yield trial during the 1992-93 dry season. Nineteen lines were selected and elevated to the general yield trial.
      2) General yield trial. General yield trials composed of 25 entries under upland monoculture condition were conducted at the University of the Philippines (Los BaÑos, Laguna), Ilagan Experiment Station (Ilagan, Isabela) and at the University of Southern Mindanao (Kabacan, North Cotabato). Each entry was planted in four-row plots, 5 m long spaced at 50 cm between rows. A randomized complete block design with three replications was used. At UPLB, bean yield ranged from 0.23 to 1.09 ton/ha. Only two entries, IPB Pn 88 30-18 and IPB Pn 88 30-34, out-yielded the check variety, UPL Pn 8, with a bean yield of 0.81 ton/ha. At Ilagan Experiment Station (IES), almost all the entries out-yielded the check variety.

         During the dry cropping season, 24 promising peanut lines were evaluated in the general yield trial at IES and UPLB. Yield tests at Kabacan, North Cotabato were not pushed through. High yielding entries (IPB Pn 87 26-4, IPB Pn 87 26-29, IPB Pn 88 21-24, and IPB Pn 88 30-34) were selected as new entries to the National Cooperative Test (NCT).
      3) Advanced yield trial. Entries in the national cooperative tests were evaluated in the advanced yield trial at UPLB during the 1992-93 dry season. Two breeding lines that performed well in the national cooperative tests are now recommended for seed increase. These are IPB Pn 85 2-40 and IPB Pn 85 10-68. IPB Pn 83 117-56 and IPB Pn 85 3-86 (two high yielding AYT/NCT lines) are also being seed increased because the former has good seed qualities (large seed size and acceptable seed shape), and the latter is leafhopper resistant.
   b. Upland partial shaded conditions
      1) Preliminary yield trials under artificial partial shaded condition. Forty-nine entries were tested during the wet cropping season (October planting) using a split plot design with shade level as main plot and variety as subplot. Pod and seed yield, 100 seed weight, number of pods per plant and shelling percentage decreased under reduced light intensities (52% shade) as compared to full sunlight condition. However, there was an increase in plant height of peanut plants grown under partial shading (52.6 cm) as compared to plants grown in the open (49.7 cm). Seed yield reduction ranged from 35.0 to 91.2% with a mean value of 65.2%. Five entries were observed among the top entries based on both absolute yield and percent yield reduction. Variety x shade level interaction was highly significant.

2) General yield trials of peanut intercropped under coconut. Twenty entries were grown in general yield trials under coconut at Bicol Experiment Station (BEST) at Pili, Camarines Sur; University of Southern Mindanao (USM) at Kabacan, North Cotabato and Quezon Agricultural Experiment Station (QAES) at Tiaong, Quezon during the 1992 wet season and 1992-93 dry cropping season, respectively. Yield data at BEST were so low because of excessive vegetative growth which resulted in very minimal pod/seed production. The same set of entries was supposed to be planted at QAES during the wet season. However, due to excessive rains, land preparation was not feasible. Thus, plots were planted in late October.

   Seed yield at Dagupan, Kabacan, North Cotabato ranged from 0.94 to 1.83 tons/ha with a mean value of 1.32 tons/ha. Three IPB breeding lines (IPB Pn 85 45-54, IPB Pn 85 19-40 and IPB Pn 85 45-30 with respective seed yields of 1.83, 1.74 and 1.65 tons/ha) out-yielded the two check cultivars (UPL Pn 2 and UPL Pn 8 which yielded 1.44 and 1.35 tons/ha, respectively).

   Dry season results at QAES showed that seed yield ranged from 0.48 to 1.05 tons/ha with a mean value of 0.69 ton/ha. UPL Pn 8 was the highest yielder. Three high yielding lines were identified which are IPB Pn 85 45-30, IPB Pn 85 50-66 and IPB Pn 85 27-18 with seed yields of 0.83, 0.78 and 0.78 ton/ha, respectively. Six breeding lines showed resistance to peanut rust. These are IPB Pn 85 24-12, IPB Pn 85 19-40, IPB Pn 85 26-30, IPB Pn 85 42-85, IPB Pn 85 50-22 and IPB Pn 85 50-19. The other entries had moderate resistance to peanut rust.

3) Confirmatory test of shade tolerance. Eight shade-tolerant entries were evaluated in a confirmatory test with UPL Pn 2 as check cultivar. A split plot design was used with four shade levels (47, 30, 20, 0% light reductions) as main plot and varieties as subplot. Varietal differences were highly significant for all the parameters except pod and seed yield on a per-plot basis. Four entries significantly out-yielded the check variety, UPL Pn 2. Variety means under the four shade levels likewise varied significantly except for 100-seed weight. Highest yield was obtained under 0% light reduction (full sunlight/control) followed by 30 and 20% light reduction. Lowest yields were obtained under 47% light reduction. There was no significant interaction between variety and shade level in any of the parameters studied.

4. Screening for resistance to *Aspergillus flavus* invasion. No peanut cultivar showed complete resistance to *A. flavus* although the majority were moderately resistant with incidences ranging from 10-25%. Selection from the pedigree AH 7223 x SK 38 had the least percentage incidence (17%) of *A. flavus*. Line selection from the pedigree Faizpur x Tainan 9 had 19% incidence.

5. Screening for resistance to *Aspergillus niger*. Twenty-three promising entries and cultivars were used in the screening for *A. niger* resistance at the greenhouse. No peanut entry manifested a resistant or moderately resistant reaction to crown rot caused by *A. niger*. All entries tested were either moderately susceptible or susceptible.

6. Screening for acid tolerance. A total of 22 peanut genotypes which included two check cultivars were screened for acid tolerance and high yields at Siniloan, Laguna and UPLB, College, Laguna during the 1991-92 dry season and 1992 wet season.

   Two IPB lines (IPB Pn 86 7-45 and IPB Pn 86 70-44) and UPL Pn 8 (check variety) produced absolute seed yields of 2.14, 2.12 and 2.03 tons/ha, respectively, during the 1991-92 dry season on a very strongly acidic Antipolo clay soil with pH of 4.71 and exchangeable aluminum of 1.38 meq/100 g. Based on relative yields, these three entries are classified as highly tolerant to acidic soil conditions. Seed yield of

the entries tested ranged from 0.74 to 2.14 tons/ha.

During the 1992 wet season, the same set of entries were again screened under acidic soil conditions at two locations (UP Quezon Land Grant at Siniloan, Laguna and College, Laguna). On acidic Antipolo clay, the absolute yield ranged from 0.54 to 1.60 tons/ha. The top two entries were IPB Pn 86 70-74 and IPB Pn 86 70-64 with yields of 1.60 and 1.48 tons/ha, respectively.

On a very strongly acidic Lipa clay loam at College, Laguna with a pH of 4.84 and exchangeable aluminum of 1.98 meq/100 g, the two best yielders were UPL Pn 8 and IPB Pn 86 53-12 with yields of 1.39 and 1.38 tons/ha, respectively. Although 22 entries showed yields ranging from 0.79 to 1.39 tons/ha, varietal differences were not statistically different. This could be due to the fact that only pH and exchangeable aluminum were the only limiting factors while the other elements were available in sufficient quantity. These entries were initially screened and selected under naturally occurring acidic soil conditions where most of the infertility factors related to acidity are present.

It was further observed that the top three yielders (IPB Pn 86 70-45, IPB Pn 86 70-74 and UPL Pn 8) during the dry season also performed well during the wet season. These three entries were the best entries during the 1991-92 dry and wet seasons. The mean seed yields of IPB Pn 86 70-74, IPB Pn 86 70-45 and UPL Pn 8 were 1.63, 1.56 and 1.55 tons/ha, respectively. The top 10 entries from this set of entries will be further evaluated next cropping season using larger limed, unlimed and aluminum-treated plots.

7. Growth and aluminum concentration of peanut cultivars/lines in response to added aluminum on Antipolo clay soil. Twelve promising acid-tolerant cultivars/lines were used in studying peanut response to addition of excessive aluminum (Al) on Antipolo clay soil. A greenhouse tray experiment was set up using 0 and 9 meq Al/100 g as treatments. Five kg of soil were used in each tray. Peanut seeds were planted 3 weeks after treatment application. Each treatment also had a blanket application of 60-240-160 kg $N-P_2O_5-K_2O$ per $2x10^6$ kg. Four plants per entry were maintained for each treatment and these plants were pulled out 21 days after emergence. Length and dry weights of roots and shoots were determined. Then the roots were analyzed for aluminum content.

Analysis of the soil used in the experiment showed that the pH decreased from 4.85 (control) to 3.90 (at 9 meq Al/100 g). The other problems associated with this soil were soluble phosphorus, exchangeable potassium, calcium, magnesium and aluminum.

Peanut cultivars with small reductions in length and weight of shoots and roots when grown at 9.0 meq Al/100 g soil treatment were considered to have greater tolerance to the acidic soil conditions. Thus, cultivars producing at least 80% relative length and weight of shoots and roots were considered to have high tolerance to aluminum and extreme acidity. Based on these parameters, the following groups were identified:

(1) Cultivar with high relative values for shoot length, root length and root dry weight: RLRS 8
(2) Cultivar with high relative values for shoot and root length: FDRS 19
(3) Cultivars with high relative values for shoot and root length and root weight: UPL Pn 10, IPB Pn 24-6; IPB Pn 82 71-23, IPB Pn 82 70-44 and IPB Pn 82 68-87
(4) Cultivars with high relative values for root length: IPB Pn 82 68-77 and UPL Pn 4

Two entries (FDRS 19 and RLRS 8) showed high levels of aluminum tolerance based on relative yields. For root length, 10 entries showed high tolerance to increased aluminum in the soil. Data on the shoot dry weight indicated that no entry produced relative value greater than 67%. It should be noted that, in the previously reported tray

experiment, only the pH and the exchangeable aluminum were the limiting factors. However, the soil that was used in this experiment had infertility factors (e.g., low pH, P, Ca, Mg, K and high exchangeable aluminum) that characterize a naturally occurring acidic soil. However, in this experiment, the effect of P was marked by the application of high rate of P fertilizer.

High aluminum in the soil decreased root dry weight by 14%. Six of these entries showed high tolerance to aluminum. Based on root length, 10 entries showed high tolerance to increased aluminum level in the soil. At higher aluminum content in the soil, cultivars tended to produce longer roots, lighter dry weights while, at slightly acidic soil conditions, shorter roots but heavier dry weight were observed.

The concentration of aluminum and the type of response to high aluminum varied with each entry tested. Two IPB breeding lines (IPB Pn 82 71-33 and IPB Pn 82 68-87) showed increased concentration of aluminum at extremely acidic soil condition or at 9 meq Al/100 g treatment, while the aluminum concentration of the remaining entries decreased. High concentration of aluminum on these two lines seems to indicate that they can tolerate high aluminum concentration in its tissues. It further suggests that these two lines can survive and produce yield at an area characterized as extremely acidic and having high levels of aluminum. It also means wider adaptability to the needs of peanut breeders and farmers.

Evaluation of these entries will be repeated this coming wet season. Analysis of phosphorus, calcium and magnesium on plant samples will also be included.

5. Viability study of promising peanut lines/cultivars. Thirty-eight peanut lines/cultivars were stored in cold (14-18°C) and ambient (27-33°C) conditions as pods and seeds in July 1992. Peanut entries were initially tested for germination prior to storage. All entries were likewise subjected to an accelerated aging test (AAT). Percent germination was taken after 2, 4 and 6 months of storage. For each treatment, germination tests were done on 25 to 50 seed samples in three replications. Sample seeds were treated with fungicides and allowed to germinate in plastic trays lined with moist filter paper.

   Initial seed germination ranged from 93.1 to 100% with an average of 98.6%. Only one entry (IPB Pn 86 20-47) had initial seed germination lower than 95%. Mean germination after AAT was markedly reduced to 44.3 and 63.1% for seeds and pods, respectively. Peanut pods subjected to AAT had better germination than peanut seeds for most entries. EG Pn 7, which is a selection from the cross between BPI P9 x Accession 12, and IPB Pn 85-14-60 had very high germination rates compared to the other entries stored both as seeds and pods. Both genotypes had 90% seed germination after AAT. Under ambient room condition, a sharp decrease in seed germination was observed at the various sampling stages compared to cold room storage. At 6 months after storage, mean germination was 47.2 and 97.1% at ambient condition and cold storage, respectively. Evidently, peanut seeds remained highly viable even after 6 months of storage when stored under cold temperature.

   Correlation analyses were made on seed germination data gathered from AAT at 2, 4 and 6 months after storage. Significant correlation was observed between AAT and 6 months of storage. However, the correlation value was low (r = 0.325). Thus, AAT seems to have limited use in predicting storability trait in peanut. Although correlation value of AAT with 6 months of storage was significant, it could not be used in lieu of actual storage conditions because of its low correlation value.

C. Thailand

1. Department of Agriculture (DOA). Peanut breeding by the DOA covers a broad range of breeding objectives: high yield and early maturity, resistances to rust and leafspot, and improvement of large-seeded and boiling-type peanuts. Activities in 1992 concentrated on yield testing of various groups of materials at different evaluation stages.

Breeding lines selected for the various breeding objectives were initially tested in the preliminary yield trials. Promising lines identified from the preliminary yield trials in the previous year were tested in the standard yield trials. Likewise, superior lines in the previous year's standard yield trials were retested in the regional yield trials, and outstanding lines from the previous year's regional tests were evaluated in the farm trial stage. At the standard, regional and farm trial stages, the lines were merged into four series of trials: medium-seeded type, boiling-type, large-seeded type, and early maturing lines. Yield trials were conducted at the research stations of the Field Crops Research Institute and farmers' fields, both in the rainy season and in the dry season with irrigation.

a. Preliminary Yield Trials

1) High yielding group: Work on breeding for high yield in 1992 included selection in segregating materials and four sets of preliminary yield trials. The segregating materials were progenies of plants selected from seven crosses in the F_3 generation. These materials were evaluated at Khon Kaen; 254 and 135 lines were selected from the F_4 and F_6 generations, respectively. There were four sets of preliminary yield trials with each including 27 lines and three checks. The first and second sets were selected from segregating materials received from KKU. The first set was tested at Kalasin in the dry season of 1992, and it was found that Tainan 9 and [(MGS9 / Chico)-12-16-1 / NC 7]-42 were highest yielding lines. Twelve lines were selected for further testing in a coordinated preliminary yield trial in the rainy season. The second set was tested at Mahasarakam in the rainy season, and it was found that (Moket / NC 9) gave the highest yield. This set was repeated in the dry season of 1993.

   The third and fourth sets were coordinated trials with KKU. Entries were selected lines from DOA and KKU. The third set was tested at Khon Kaen in the dry season. The fourth set was tested at Roi-et and KKU in the rainy season of the same year. (Lampang / UPL Pn4)-8-11-2 gave the highest yield in the third set. Five lines were selected for testing in a standard yield trial in the 1992 rainy season. In the fourth set yield trial, (Tainan 9 / UPL Pn4)-12-14-6 was the top average yielder. This set was repeated in the dry season of 1993.

2) Early maturity. The aim of this breeding objective is to develop high yielding lines of 80-85 days maturity for certain cropping systems. In a preliminary yield trial, 38 tested lines and two checks were evaluated at Kalasin and Roi-et in the dry and rainy season of 1992, respectively. (Tainan 9 / NC Ac 17090)-12-6-3, (Lonyun 6101 / Argentine 8-3) and (TMV3 / NC 7)-5 were the top average yielding lines. Twelve superior lines were selected for further testing in the standard yield trial in 1993-94.

3) Foliar disease-resistant lines. Two preliminary yield trials were conducted in order to evaluate 35 peanut lines at Khon Kaen in the dry season of 1992. [(PI 314817) / TG3 / EC76446(292)]Selection 35 F_6 gave the highest yield. Twenty-seven lines were selected for further testing in the second set. In the second set, the 27 selected lines and two lines from KKU were tested at Roi-et and KKU in the rainy season. It was found that (Moket / Southern Runner) and (NC 17135/Tainan 9//Tainan 9) were the top yielding lines at Roi-et and KKU, respectively. This trial will be repeated in 1993.

4) Insect-resistant lines: Twenty-two insect-resistant lines were identified by the DOA entomologist and transferred to the DOA breeder for evaluation of agronomic performance and adaptation. Fourteen lines were selected for evaluation at Khon Kaen in the

rainy season of 1992. KKIR 9102 and KKIR 9105 gave the highest yields.

5) Large-seeded lines: Only one preliminary yield trial of large-seeded lines was conducted at Khon Kaen in the dry season of 1992. (NC 7 / Tainan 9)-32-4-28 was the top yielding line. Thirteen lines were selected for further evaluation in the 1993 standard yield trial.

b. Standard Yield Trial. Test entries were promising lines selected from preliminary yield trials. Two coordinated standard yield trials were conducted. The first trial was conducted during the dry season at Khon Kaen, Kalasin and Phitsanulok. Eleven lines were evaluated in these trials. (Robut 33-1 / Lampang)-5-17-2 gave the highest average yield. The second trial was conducted during the rainy season at Rayong, Praputtabat, Roi-et, Loei and KKU. (Robut 33-1 / Lampang)-5-17-2 and (Lampang / UPL Pn4)-8-11-2 gave higher yields than those of the checks.

The third standard yield trial consisted of 4 aflatoxin-resistant lines, 7 high yielding lines, 2 crown rot-resistant lines, and 3 checks. The trial was conducted at Kalasin, Phitsanulok and Chiang Mai in the dry season. (Ah65 / NC Ac 17090) gave the highest yield.

The fourth standard yield trial consisted of 8 rust and leafspot-resistant lines, 5 stem rot-resistant lines, and 3 checks. This trial was conducted at Chiang Mai, Sakon Nakorn and Kalasin in the dry season and at Khon Kaen, Loei, Banmai Samrong and Praputtabat in the rainy season. KKU 90303 gave the highest average yield.

Lines tested in the fifth standard yield trial were early maturity lines. This trial was conducted both in the dry and rainy seasons at Khon Kaen, Phitsanulok, Rayong, Ubonratchatanee, Mahasarakam, Srisamrong and Loei. All tested lines gave higher yields than the check, Tainan 9. (Chico / GA 119-20)-8-3-12 gave the highest average yield.

c. Regional Yield Trial. Superior entries from the standard yield trials were selected and evaluated in the regional yield trial at more locations. There were four regional yield trials. The first and second set were coordinated regional yield trials. Seven entries in the first trial were evaluated at Khon Kaen, Phitsanulok and Chainat in the dry season. (Tainan 9 / Ah24439)-14-4-13 gave higher yields than the other lines and checks. The second trial, consisting of 11 lines, was evaluated in the rainy season at Rayong, Chiang Mai, Nakornsawan, Roi-et, Songkla, Loei and KKU. (Moket / Ah24439)-12-8-16 was the best entry.

Entries in the third trial were 7 aflatoxin-resistant lines, 2 high yielding lines and 3 checks. The trial was conducted at Khon Kaen and Phitsanulok in the dry season and at Rayong, Ubonratchatanee, Loei, Mahasarakam and Phitsanulok in the rainy season. High yielding lines were (J11 / Ah24439)-18-11-6, (Tainan 9 / Ah24439)-32-5-11 and (Ah7223 / NC 7)-9-1; but their average yields were equivalent to those of the checks.

Eight large-seeded entries in the fourth regional yield trial were evaluated both in the dry and rainy seasons at Chiang Mai, Khon Kaen, Chainat, Nakornsawan, Petchaboon and Praputtabat. Kanto No. 38 and (NC 7 / RCM 387)-1-1 were the top average yielding lines.

d. Varietal farm trial. Promising entries selected from the regional yield trial were entered in the farm trial conducted in the farmers' fields. In 1992, there were two sets of varietal farm trials. The first set consisted of two boiling-type peanut lines and three checks. This trial was conducted in farmers' fields at Khon Kaen, Kalasin and Nakornsawan in the dry season. One of the new lines, (Taiwan 2 / UF 71513-1), gave slightly higher shelling percentage and dry pod yields than the boiling-type checks, SK38 and Khon Kaen 60-2, but fresh pod yield was slightly lower. This particular line

had larger seed size than those of the checks.

The second set consisted of four high yielding lines and two checks (Khon Kaen 60-1 and Tainan 9). This trial was conducted in farmers' fields at Roi-et, Khon Kaen, Mahasarakam, Loei, Nakornsawan, Banmai Samrong, Songkla and Mukdaharn in the dry and rainy seasons. None of the tested lines performed better than the checks.

e. Boiling type peanut lines. In 1981, eight crosses were made by crossing two aflatoxin-resistant lines from ICRISAT (UF 71513-1 and PI 337394F) with high yielding lines (Taiwan 2, Tainan 9, Moket and Panjab) at Kalasin Field Crops Experiment Station in the rainy season using the pedigree method of selection. Selection in F_2-F_6 generations was conducted at Kalasin in the dry and rainy seasons of 1982-84. (Taiwan 2 / UF 71513-1)-2-17-5 was selected for testing in the preliminary yield trial conducted at Khon Kaen and Kalasin in the rainy season of 1984 and the dry season of 1985. This line was identified as a promising boiling-type line which gave substantially higher yield than the check SK38. It was then promoted to the standard yield trial (1985-87), the regional yield trial (1987-88), and the farm trial (1989-92), respectively. It was also tested in the farmers' fields test in 1990-91. In these trials, SK38 was used as the check variety in 1984-92, and Khon Kaen 60-2 was the check variety in 1988-92. Khon Kaen 60-2 was released by the DOA as a boiling-type peanut variety in 1987. From these trials (Taiwan 2 / UF 71513-1)-2-17-5 gave an average fresh pod yield over 49 tests 3% higher and average dry pod yield over 83 tests 8% higher than the check variety SK38; and this line gave an average fresh pod yield over 33 tests 4% higher and average dry pod yield over 69 tests 10% higher than the check variety Khon Kaen 60-2. (Taiwan 2 / UF 71513-1)-2-17-5 gave higher shelling percentage and had large seed size than the check varieties, SK38 and Khon Kaen 60-2.

2. Khon Kaen University (KKU). Peanut breeding at KKU emphasizes improvement of peanut cultivars for resistances to rust and leafspot, high yields, early maturity and growing before- and after-rice without irrigation. Work done in 1992 included generation of new segregating materials for the individual breeding objectives and yield trials of different groups of materials. The promising lines were selected and handed on to the DOA for adaptability and stability evaluation in different environments.

a. New crosses. In 1992, 11 crosses of high yielding adapted lines were generated. All crosses will be grown for generation advance in the 1993 rainy season.

1) Tainan 9 // ICGS 20 / ICG4994 (NC Ac 2466)
2) {Tainan 9 /3/ [ICGS 20 // (MGS / Robut 33-1)-5-2]}
3) {Tainan 9 /3/ [ICGS 20 // (MGS / Robut 33-1)-5-2]-5}
4) [KK60-3 // (ICGS 20 / ICG4994 (NC Ac 2466)-1]
5) {KK60-3 /3/ [ICGS 20 // (MGS / Robut 33-1)-5-2]-2}
6) {KK60-3 /3/ [ICGS 20 // (MGS / Robut 33-1)-5-2]-5}
7) X52-X-X-3 x B / Chico)-8-1-2 // Local No. 28 T. Pakou /3/ Tainan 9
8) X52-X-X-3 x B / Chico)-8-1-2 // Local No. 28 T. Pakou /3/ Lampang
9) X52-X-X-3 x B / Chico)-8-1-2 // Local no. 28 T. Pakou /3/ KK60-1
10) [(X52-X-X-3 x B / Chico)-8-1-2 / Local no. 28 T. Pakou] / KK60-2
11) [(X52-X-X-3 x B / Chico)-8-1-2 / Local no. 28 T. Pakou] / KK60-3.

b. Breeding for before-rice growing conditions. In the 1992 before-rice season, 16 bulk populations in F_6 generation of crosses involving superior lines under before-rice growing conditions were planted and single plant selection performed.

Five yield trials of selected lines from the 1991 yield testing under before-rice growing conditions were conducted by KKU. These included a farm trial, an advanced yield trial, an intermediate yield trial and two preliminary yield trials. The farm trial was

conducted at Ban Hin-Lad, Ban Koksri, Ban Nong Por, Ban Nong Lub and at KKU using a randomized complete block design with one replication per location. Six tested entries were evaluated in the farm trial, and six peanut lines were tested in the advanced yield trial. The trials were conducted at KKU and Ban Hin-Lad using a randomized complete block design with six replications. The intermediate yield trial and the preliminary yield trials were conducted at KKU. Roi-et and (MGS-9 / Robut 33-1)-5-5-5-4 gave higher yields than Khon Kaen 60-1-7 and 5%, respectively, in the farm trial. ICGS(E)-173 and Local variety no. 22 from T. Nongbuadang were among the top yielding varieties in the advanced yield trial. Both varieties out-yielded Khon Kaen 60-1 in both testing locations. All tested entries performed better than the check variety Khon Kaen 60-1 in the intermediate yield trial. (ICGS4 / RCM 387)F_7-3 and (Lampang / Argentine 8-3)F_7-1 were among the top yielding varieties. (Lampang / ICG2375 NC Acc 2938)F_7-1 was the top yielding variety in the preliminary yield trial I, while (ICG2375 NC Ac 2938 / ICGS4)F_7-1 was the top yielding variety in the preliminary yield trial II. The promising entries were selected from the 1992 yield testing and re-evaluated in the 1993 before-rice growing condition.

c. Breeding for after-rice growing conditions. In the 1991/92 after-rice season, 15 bulk populations in F_6 generation involving superior lines under after-rice growing unirrigated conditions were planted and single plant selection was performed. Five yield trials were conducted. A farm trial was conducted at KKU, Ban Kog Yai, Kranuan, Nakonrachasima and Surin using randomized complete block design with one replication per location. An advanced yield trial was conducted at KKU and Kranuan. Two sets of intermediate yield trials and a set of preliminary yield trials were conducted. No tested entry outperformed the check varieties Khon Kaen 60-1 and Tainan 9 in the farm trial. In the advanced yield trial, ICGS44 was the top yielding cultivar and performed well in both locations (KKU and Kranuan). (Robut 33-1 / Lampang)F_6-4 and ICGS(E)-173 were among the top tested entries in the intermediate yield trial set I, while Local no. 27 from T. Nikomsongkhrao and ICGS(E)-166 were among the top yielding entries in the intermediate yield trial set II. Several tested entries showed yield superiority to Khon Kaen 60-1 in the preliminary yield trial. High yielding entries from all these trials were selected for subsequent testing in the 1992/93 after-rice season.

d. Breeding for high yield. Work under this breeding objective included an observation nursery for evaluation of selected lines from segregating populations and various stages of yield evaluation. In the observation nursery, 110 selected peanut lines from NCSU segregating material, 89 selected lines of segregating material received from ICRISAT and 242 selected lines of local cross material were planted for evaluation. A single row with a replication was conducted. Single plants in the best rows were selected for preliminary yield testing in the 1993 rainy season.

Eight yield trials of lines in the high yielding group were conducted during the 1992 rainy season at KKU. The trials included an advanced yield trial, three sets of intermediate yield trials and four sets of preliminary yield trials. Normal cultural practices were performed in each trial.

In the advanced yield trial, (UPL Pn4 / Lampang)F_6-41 and (UPL Pn / Lampang)F_6-39 were among the top yielding lines. Several tested entries outperformed the check cultivar Khon Kaen 60-1 in the intermediate yield trial sets I and II. (ICGS4 / ICG4994 NC Ac 2499)-3 and (Tainan 9 / Moket)-1 were the top yielding entries in the intermediate yield trial sets I and II, respectively. (Moket / Argentine 8-3)F_8-7 and (Lonyun 6101 / NC 4 x)F_8-1 were superior entries in the intermediate yield trial set III, giving yields

higher than check entries Khon Kaen 60-1 and Tainan 9. Several tested entries outperformed check entry Khon Kaen 60-1 in the preliminary yield trial sets I to IV. (Tainan 9 / UPL Pn4)F_6-16 (Lonyun 6101 / Argentine 8-3)F_5-4 were the top yielding entries in the preliminary yield trial sets I and II, respectively, while [(ICGV30 / JL24) / ICG PRS 193]F_2-4B1-3 and (Khon Kaen 60-1)M3-1-3 were the top yielding in the preliminary yield trial sets III and IV, respectively.

e. Breeding for earliness. A single plant selection was performed on NCSU segregating material in F_6 generation and local cross material in F_4 generation. Fourteen lines of NCSU breeding material and 286 lines of local cross breeding material were selected in the 1991 rainy season. In the 1992 rainy season, a single row (one replicated) was conducted to evaluate progeny of a selected single plant. The best plants in the best row were then selected for preliminary yield testing in the 1993 rainy season.

   A preliminary yield trial was conducted for yield evaluation of received lines from ICRISAT in the 1992 rainy season at KKU. Seventeen tested entries and three checks were evaluated in this trial. Normal cultural practices were performed. Only two tested entries performed better than the check Khon Kaen 60-1. ICGV 86015 and ICGV 86143 were among the top yielding entries.

f. Breeding for resistances to rust and leafspots. An observation nursery was conducted in order to evaluate progeny of single plant selections from the 1991 breeding nursery. One hundred four selected lines from NCSU breeding material and 178 lines selected from local cross material were planted in the 1992 rainy season. The best plants in the best rows were selected for preliminary yield trials in the 1993 rainy season. Work was conducted also on generation advancement of crosses involving foliar disease-resistant lines. Twenty-five F_1 populations were planted for generation advance and plants were harvested in bulk of each cross.

   Three yield trials of foliar disease-resistant lines were conducted in the 1992 rainy season at KKU. An intermediate yield trial and two sets of preliminary yield trials were conducted by KKU. All tested entries were lines received from NCSU and ICRISAT. In all trials, slight infection of rust and leafspot was observed. (Chico / NC 7)-1 and (Chico / NC 7)-2 were among the top yielding entries in the intermediate yield trial. (PI 314817 / TG3 / EC 76446(292) sel. 1 F_6-10 was the superior entry in the preliminary yield trial set I, while Tainan 9 and PI 314817 / TG3 / EC 76446(292) sel. 20 F_6-2 were among the top yielding entries in the preliminary yield trial set II.

g. Improvement of large-seeded type peanut. Single plant selection was performed on the 21 crosses involving large-seeded types. Only 11 large-seeded type peanut lines were selected in the 1991 rainy season. In the 1992 rainy season, 11 lines were planted for yield evaluation in an observation nursery. Superior lines then were selected for the 1993 preliminary yield trial.

h. Improvement of boiling type. In the 1991 rainy season, the single plant selection was performed on local cross-segregating material based on agronomic yield and pod characteristics for boiling-type peanut. The 249 single plants then were grown for evaluation and the best plants in the best families selected for a preliminary yield trial in the 1993 rainy season.

i. Breeding for insect resistance. Eight F_5 populations of crosses involving insect resistance were grown for advanced generation in the 1992 rainy season. This segregating material will be evaluated for insect resistance in the 1993 rainy season.

j. Breeding for increasing biological nitrogen fixation. New crosses were made between high nitrogen fixation lines and adapted lines in 1991. In the 1992 rainy season, 20 F_1 populations of these crosses

were planted for generation advance.

k. Studies in support of cultivar development. An experiment was conducted to estimate gene action on resistances to late leafspot and rust and on agronomic traits to identify the best peanut for resistances to late leafspot and rust and to estimate heritabilities for components of resistance to late leafspot and rust. The study was performed on progenies of cross GP-NC 343, NC 9, Lampang, NC Ac 17135, Tainan 9 and Chico in a half-diallel mating design. The study was conducted in one environment at KKU in the 1989 rainy season. Additive gene action was important for most of the disease-resistant components. The best parents for resistance to late leafspot were GP-NC 343 and NC 9, while NC Ac 17135 and NC 9 were the best parents for rust resistance. Heritability estimates were generally low for all components of resistances to both diseases.

TRAINING

Surname	Sex	Univ.	Department	Degree	Date degree received	Support
U.S. Citizens						
Furman	F	NCSU	Crop Science	PhD	-	Total
Thai citizens						
Nikul Choungam	M	KKU	-	BS	-	Partial
Ratchanee Fangsrikam	F	KKU	-	MS	-	Partial
Tinakorn Khomsa-art	M	KKU	-	MS	-	Partial
Yuparas Kongnen	F	KKU	-	BS	-	Partial
Visit Treesuwanwat	M	KKU	-	MS	-	Partial
Anan Hirunsalee	M	NCSU	Plant Pathology	PhD	-	Partial
Citizens of other Countries						
Bianchi-Hall(Argentina)	F	NCSU	Crop Science	PhD	Sept 1993	Total
Garcia(Argentina)	M	NCSU	Crop Science	PhD	-	Total
Menon(India)	F	NCSU	Crop Science	PhD	-	Total
Rau(India)	M	NCSU	Crop Science	PhD	May 1993	Total
Utomo(Indonesia)	M	NCSU	Crop Science	PhD	-	Partial

Mr. Wootisuk Butranu from Khon Kaen University in Thailand spent twelve months as a visiting scientist at North Carolina State University. Mr. Butranu, a plant pathologist, was attached to Dr. M.K. Beute's project and conducted a series of experiments on *Aspergillus niger*.

R.M. Abilay traveled to North Carolina State University on July 14-21, 1992, to meet with Dr. T.G. Isleib and other peanut collaborators at NCSU regarding the CRSP breeding project in the Philippines. She also traveled to Khon Kaen and Kasetsart Universities on March 21-28, 1993, to consult with Thai peanut researchers and to attend the workshop on peanut production and utilization for the peanut industry at Kasetsart University.

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PLANS FOR 1993-94

I. Research in the United States

A. Breeding

1. Select intensively for large-seeded adapted lines with resistance to *Cylindrocladium* black rot (CBR). The primary constraint to release of cultivars with high levels of resistance to CBR remains the negative association between resistance and commercially acceptable seed size and shape.
   a. Five lines with superior resistance to CBR will be crossed in a factorial mating with two agronomically superior lines exhibiting intermediate resistance. F_1 seeds will be sent to the winter nursery in Puerto Rico. F_2 plants will be challenged with the pathogen on infested soil in 1994.
   b. F_2 populations from a factorial mating of ten sources of resistance to CBR with six breeding lines possessing superior seed attributes and high yield will be screened for resistance in a naturally infested field in Bertie County, NC. Selected $F_{2:3}$ families will be sent for increase to a winter nursery at the USDA Tropical Agriculture Research Station at Mayaguez, Puerto Rico. $F_{2:4}$ families will be planted in the infested area in May, 1994.
   c. Selection for resistance and pod attributes will be practiced on infested soil among and within $F_{2:4}$ families derived from F_2 plants selected during the 1992 growing season. $F_{4:6}$ progenies will be grown in a replicated test on infested soil in 1994.
   d. 141 $F_{4:6}$ families and checks will be evaluated on infested soil for CBR incidence in a completely random design with unequal replication to allow for variable seed number. These families will be increased on uninfested soil at the Peanut Belt Research Station in Lewiston, NC, and resistant families will be screened for pod and seed characters.
   e. 29 F_4-derived families selected will be compared on infested soil with checks for CBR resistance in a replicated test and for yield and market grade at Lewiston. Five of the lines were evaluated in the CBR Advanced Test in 1992 and will be included in the Advanced Yield Test leading to Also included in the test are five lines (N90013, N91020, N91023, N91044, and N91048) derived from a cross between CBR-susceptible cultivars NC 7 and NC 9. These five were found to exhibit partial resistance to CBR.
   f. 88 additional F_5-derived families from a cross between NC 7 and NC 9 will be screened for resistance to CBR.
2. Selection for resistance to early leafspot (*Cercospora arachidicola*).
   a. Preliminary replicated testing of resistance will be conducted for three populations: 41 F_6 progenies of F_5 plants derived from a mating between GP-NC 343 and NC 9, 5 $F_{7:8}$ selections from resistant F_4-derived line N92074L, and 8 from N92084L. These population will be evaluated for defoliation in a replicated test grown without chemical control of leafspot at Lewiston. Superior families will be retained for testing of agronomic performance with and without chemical control of leafspot in the 1994 season.
   b. F_4- and F_5-derived families from a program of recurrent selection for resistance to early leafspot will be evaluated for defoliation, yield, and market grades in replicated tests at Lewiston in the 1993 growing season. Seed from families combining leafspot resistance with acceptable agronomic characteristics for two years will be presented to Dr. M.K. Beute for evaluation of the mechanism of resistance in the 1994 season.
   c. Populations from the third cycle of recurrent selection for resistance to early leafspot will be advanced two generations (F_2 and F_3) by single-seed descent using the field at Lewiston and the winter nursery at Puerto Rico. F_4 populations will be grown without

chemical control of leafspot in 1994 for selection of resistant plants.

d. Families selected on the basis of defoliation scores and agronomic performance in 1991-92 will be intermated with *C. personatum*-resistant runner germplasm obtained from the University of Florida in the greenhouse in 1993. F_1 seeds will be sent to the winter nursery for increase in the winter of 1992-93, and F_2 populations will be planted in the 1994 season.

e. Families selected on the basis of defoliation scores and agronomic performance in 1991 and 1992 will be tested in the field for disease progression and resistance to both *C. arachidicola* and *Cercosporidium personatum*. The experiment will have six replications with plots isolated from each other by 3.6m of a non-host crop species to prevent interaction between adjacent plots. Plots will be inoculated with one or both pathogens to ensure disease development.

3. Selection of early-maturing large-seeded virginia lines with good storability.

   a. Populations have been developed from crosses of virginia cultivars with F435, a spanish line with an extremely high ratio of oleic to linoleic acid in the fatty acid profile of the oil. F_4-derived lines homozygous for the two recessive genes conferring the trait will be backcrossed to their respective adapted parents. F_1 hybrids will be planted in Puerto Rico. $BC_2S_{1:2}$ progenies will be evaluated for O/L ratio.

   b. 19 advanced F_5-derived selections from crosses of NC 7 with NC 9 and Florigiant will be evaluated for performance at early (September 15) and conventional (October 1-7) digging dates.

4. Recurrent selection for resistance to *Aspergillus* species. F_2 progeny of crosses among families previously identified as exhibiting one or more mechanisms of resistance to *A. parasiticus* will be grown at Lewiston in the summer of 1992. $F_{2:3}$ progeny will be evaluated for resistance to dry-seed infection and aflatoxin production. Families exhibiting one or another form of resistance will be intermated in a second cycle of recombination.

5. Incorporation of arthropod pest resistance into *A. hypogaea*.

   a. F_3 progeny will be grown of crosses between large-seeded lines and tetraploid lines derived from an interspecific cross of *A. hypogaea* PI 261942-3 with *A. cardenasii* 10017. These lines include some resistant to leafspots and some with resistance to nematodes and insect pests. Single-seed descent and single-plant selection will be performed and F_4 populations grown in 1994 as part of a program of inbred line selection.

   b. *A. hypogaea* lines selected on the basis of resistance to multiple arthropod pests (spider mite, thrips, leafhopper, corn earworm, lesser cornstalk borer, and southern corn rootworm) will be crossed with a series of large-seeded, adapted breeding lines. F_1 hybrids will be grown at Puerto Rico.

6. Recurrent selection for productivity in a population derived from elite germplasm.

   a. $S_{1:4}$ families from selected crosses of the fifth cycle (C_5) of recurrent selection will be grown and single plant selections made in the 1993 growing season at Lewiston as part of the cultivar development program.

   b. The sixth cycle of recombination (C_6) will be initiated by intermating the 40 highest-yielding families from C_5. S_0 plants will be grown at Puerto Rico.

   c. Residual genetic variance for yield, pod, and seed characters will be measured by testing four S_0- and S_1-derived families from each of 80 C_5 crosses at Lewiston and Rocky Mount. This study will partition the observed variation into components due to C_5 parents, C_5 crosses,

S_0 plants within crosses, and S_1 plants within S_0's.

7. Recurrent selection for productivity in a population derived from an interspecific cross (*A. hypogaea / A. cardenasii*).
   a. $S_{0:2}$ families from selected crosses of the fourth cycle (C_4) of recurrent selection will be grown and single plant selections made in the 1993 growing season at Lewiston as part of the cultivar development program.
   b. The fifth cycle of recombination (C_5) will be initiated by intermating the 10 highest-yielding families from C_4. S_0 plants will be grown at Puerto Rico.

B. Plant Pathology

1. *Cercospora* leafspot diseases
   a. Peanut genotypes derived from crosses of *Arachis* spp. and high-yielding cultivars will be evaluated in the field for resistance to *Cercospora arachidicola*, *Cercosporidium personatum*, and defoliation. Genotypes also will be characterized for yield and seed size. Additional field and greenhouse studies will be conducted to determine levels of resistance to *Cercosporidium personatum* in commercial virginia cultivars. This information will be used to develop recommendations for leafspot spray schedules in newer cultivars and to assess the potential for increased severity of late leafspot in these cultivars.
   b. Greenhouse studies will be conducted to determine if isolates of *Cercospora arachidicola* have specific virulence to leaf spot-resistant genotypes identified by ICRISAT. This work will be conductd by Dr. Farid Waliyar, Groundnut Pathologist from ICRISAT's Sahelian center at Niamey, Niger. Dr. Waliyar is on sabbatical leave and associated with Dr. Beute's project.
2. *Aspergillus* and aflatoxin: Studies to identify preharvest resistance to infection by *A. parasiticus* and subsequent toxin accumulation will be conducted in field microplots. Test genotypes will be grown under conditions necessary for infection and toxin accumulation. Seedling resistance to infection by *A. niger* will be studied in greenhouse experiments. Soil temperature and moisture effects on infection also will be characterized.
3. Root-knot nematodes. Advanced breeding lines and wild species will be evaluated in microplots for resistance to *Meloidogyne arenaria*. Genotypes that limit reproduction and damage by the nematodes will be identified.
4. *Sclerotinia* blight, *Sclerotium* wilt, and *Cylindrocladium* black root rot.
   a. Advanced lines with resistance to Cylindrocladium black rot will be planted in disease nurseries for Sclerotinia blight and Sclerotium wilt. Similarly, lines with resistance to Sclerotinia blight will be evaluated for resistance to the other two pathogens. The goal of reciprocal screening is to develop cultivars with resistance to all three pathogens.
   b. Studies will continue to examine the effects of tillage on peanut diseases caused by soilborne pathogens. Microplots will be infested with *Sclerotium rolfsii*, *Sclerotinia minor*, or *Cylindrocladium crotalariae* in the presence or absence of surface litter (wheat straw). Surface litter may enhance or suppress disease development through several mechanisms. Additional studies will be conducted in replicated field trials with several tillage treatments ranging from completely conventional tillage to a completely no-till treatment. Incidence and progress of the three diseases will be determined in these plots.
   c. Control of Sclerotinia blight through new fungicides and manipulation of the canopy environment will be investigated in greenhouse and field experiments. Alteration of canopy environment through clipping has potential to control Sclerotium wilt in addition to Sclerotinia blight.

C. Molecular Biology

1. Bioengineering for disease control. A nematode "killer" gene for resistance to root-knot nematodes and a chitinase gene, which may confer resistance to *Aspergillus parasiticus*, should be available for the bioengineering project. These studies are being conducted in cooperation with Dr. Weissinger.
2. Our effort during the coming year will center on the development of transgenic peanut germplasm with enhanced resistance to two important viral pathogens, peanut stripe virus (PStV) and tomato spotted wilt virus (TSWV). Work with other transformed plants which carry the coat protein (CP) from various viruses suggests that such transgenic peanuts should have enhanced resistance to the viruses from which the chimeric CP gene is derived. Peanut varieties with improved resistance to PStV would have potentential application in the development of resistant cultivars for use in Thailand and the Philippines.
3. During FY93, our laboratory, in collaboration with Dr. Peggy Ozias-Akins' laboratory at the University of Georgia, succeeded in developing protocols for peanut transformation based on microprojectile bombardment of embryogenic cultures. We have recently obtained PStV CP constructs from our collaborators, and have begun to introduce these into embryogenic cultures of peanut using these transformation protocols. The initial transformations were carried out with cultures of peanut cv. Toalson, the cultivar used in development of the transformation system. Additional transformations will be carried out with cv. NC 7, Spanco and UPL Pn4, genotypes chosen on the basis of their performance in tissue culture and also on their potential utility as breeding materials for target peanut-growing regions.
4. Cultures of Toalson co-transformed with the selectable marker hygromycin phosphotransferase (HPT) and the PStV CP construct have now been recovered through hygromycin selection. The first group of these cultures are currently undergoing molecular testing for presence of the introduced gene. Those which are found to be transformed will be advanced immediately to plant regeneration.
5. Additional embryogenic peanut cultures of cv. Spanco and UPL Pn4 will be started in the near future. These cultures, along with cultures of NC 7, will be transformed with the PStV CP construct in order to generate transgenic plants from these varieties.
6. A chimeric TSWV nucleocapsid gene has been obtained from Dr. James Moyer, Department of Plant Pathology, NCSU, for use in developing transformed peanut lines with enhanced resistance to this virus. This gene is currently being re-engineered for use in the peanut transformation system. In the coming year, we will complete this project, and begin transformations with the TSWV nucleoprotein gene.
7. During the coming year, we will continue our efforts to transform embryogenic cultures derived from commercial varieties of peanut with the CP gene from PStV, and the nucleoprotein gene from TSWV, using microprojectile bombardment to deliver transforming DNA. We will identify transgenic cultures which carry the transgenes, and will use these to regenerate transgenic plants. The exact time-frame for production of these transgenic plants is difficult to predict because transformation protocols are new and we have little experience upon which to base such an estimate. It is expected, however, that we will be well into the plant regeneration phase by the end of the 1993-1994 year.
8. Regenerated plants will be screened in the greenhouse by inoculation with PStV and TSWV. Plants which exhibit increased resistance to the diseases under greenhouse conditions will be propagated for further tests in the greenhouse. In subsequent years, advanced genotypes will be tested under field conditions.

   We will complete genetic constructions required to initiate transformations with the TSWV nucleocapsid gene, and will initiate these transformations.

D. Cytogenetics

1. Evaluating germplasm for disease and insect resistances

a. *Cercospora arachidicola* resistance. Selections previously made for leafspot resistance from an interspecific *A. cardenasii* x *A. hypogaea* hybrid will be re-evaluated in the field for *C. arachidicola* resistance. Fifty-six seeds per entry will be replicated four times and compared to leafspot-resistant lines of *A. hypogaea* to evaluate the relative amount of resistance. Disease ratings will be made during mid to late August and just prior to harvest in late September or early October. Yield data will be taken under sprayed and non-sprayed conditions to determine the effects of leafspot on the populations and to prepare for germplasm releases.

b. *C. arachidicola* and *Cercosporidium personatum* resistances

1) Ten interspecific hybrids from an *A. hypogaea* x *A. cardenasii* population will be tested in the field for disease progression and resistance to both *C. arachidicola* and *C. personatum*. This is the third year of the test where disease incidence for both pathogens will be evaluated weekly from mid July to the end of the growing season. During 1992 there was very low incidence of leafspot, and this third year of evaluation is necessary to formulate valid conclusions about the resistance levels. The experiment will have six replications of 200 seeds each, and plots will be artificially inoculated as necessary. Entries with both high levels of *C. arachidicola* and moderate levels of *C. personatum* resistances will then be considered for germplasm release.

2) Second generation hybrids between 22 disease-resistant lines described above and large seeded genotypes will be grown in the field to advance generations and to conduct a preliminary evaluation of leafspot resistance. First generation hybrids of several additional crosses will also be grown to advance generations to select resistant genotypes with favorable agronomic traits.

c. Evaluating nematode resistance

1) The interspecific hybrids *A. hypogaea* x *A. cardenasii* and *A. hypogaea* x *A. chacoense* will be tested for resistance to *Meliodogyne aranaria* resistance. The hybrids will be compared to two of the best lines from the Georgia nematode program for comparisons. In North Carolina the lines will be tested in micro-plots and in Georgia the same lines will be grown in a field with high levels of nematodes. The comparison in the fields should lead to release of germplasm lines during the coming year.

2) The inheritance of *M. aranaria* resistance will be investigated by inoculating cuttings of F_1 hybrids between resistant interspecific hybrids and susceptible cultivars in the greenhouse. Selected populations of second generation hybrids will be grown in the greenhouse to determine the genetics and inheritance of nematode resistance. Remnant seeds will be increased in the field to establish populations for selection of large-seeded genotypes with nematode resistance.

d. Evaluating *Cylindrocladium* black rot resistance. *Cylindrocladium* black rot is a major soil pathogen in several production areas. Preliminary studies has shown at least one accession of the wild species *A. monticola* has some resistance to black rot. All of the available accessions of *A. monticola* will be evaluated in the greenhouse under several inoculum densities and the experiment will be replicated 20 times. The tests will better indicate the levels of resistance in this species as compared to resistant cultivated types, and indicate the potential value of *A. monticola*. Hybrids will be made between resistant accessions and large seeded

cultivars, in reciprocal, and the F_1s grown in the field during 1993.

e. Insect resistances
   1) Advanced generation interspecific hybrids will be evaluated for corn earworm, thrips, leafhopper and southern corn rootworm resistances in the field in a replicated experiment. Seed increase nurseries will be planted to anticipate release of one or more hybrids as germplasm lines. Agronomic traits will be re-evaluated to estimate stability of traits, and a test will be conducted to estimate yield potentials.
   2) A non-replicated experiment will be conducted in the field to make preliminary evaluations of F_4 progenies derived from interspecific hybrids backcrossed to insect-resistant *A. hypogaea* accessions. Plant growth habit and seed size estimates will also be made to eliminate susceptible lines to corn earworm, thrips and leafhopper and with poor agronomic potential.

2. Introgressing germplasm from wild *Arachis* species to *A. hypogaea*
   a. Triploid and hexaploid interspecific hybrids between three wild and cultivated species are available for analyses. RFLP primers have been identified which distinguish the accessions, and serve as markers to hybridization. Crossing programs between hexaploids and *A. hypogaea* have resulted in pentaploid progenies, which now must be self-pollinated to lower the chromosome number to the tetraploid level. Materials will need to be analyzed for molecular markers during the coming year to confirm hybrids and to estimate the percentage of introgressed genes into the cultivated genome. Both RFLP and RAPD markers will be used in the study.
   b. The same three *Arachis* species as described above have been used to make interspecific hybrids at the diploid level and colchicine treated to produce amphiploids. The materials will be cytologically analyzed to identify polyploid plants and then used in crossing programs with the cultivated peanut to transfer disease resistance and study favorable introgression pathways. RAPDs will be used to perform the molecular analyses. During the coming year the polyploid sectors will be identified and crossing programs initiated. DNA extractions will be made from both the parental and hybrid materials for later analyses. The results will lead to a better understanding of gene introgression to the cultivated peanut, especially after comparing results with triploid and hexaploid materials.
   c. Several cultivars were pollinated with seven species from four sections of the genus to study interspecific hybridization barriers. Embryo samples were collected and are currently being embedded in paraffin for histological analyses. During the coming year, we will continue efforts to analyze embryo development between 1 and 28 days after pollination to understand when embryo abortion occurs and then to develop methods to overcome the incompatibility.
   d. Interspecific hybrids between *A. hypogaea* and species of section *Arachis* with disease or insect resistances will be grown in the field for generation advances and to promote recombination between the wild species and cultivated genomes.
   e. Fifty lines derived from one *A. hypogaea* x *A. cardenasii* hybrid will be evaluated for disease and insect resistances in the field and greenhouse. Lines resistant to one or more pest will be backcrossed to the susceptible cultivated parent. More than 200 RAPD markers have been screened and many RAPDs are now available which separate the two species. These markers will be used to show the amount of gene introgression occurred and then to perform a bulk segregation analysis in an attempt to find linkages between the resistances and the markers.

3. Biosystematic evaluations in *Arachis*. Intraspecific hybrids among accessions of *A. duranensis* have been made and several cytologically analyzed. The project will continue until completion during the coming

year and should clarify the differentiation within the species and better define whether this species is a progenitor of the cultivated peanut.

II. Research in the Host Countries

A. Philippines

1. Optimum sunlight and pH conditions
   a. Seed production and promotion of UPLB-developed cultivars and promising materials (funded by P-CRSP project) at Laguna, Isabela, and Pampanga.
   b. On-farm trials of promising peanut entries at Isabela, Pampanga, Zambales, Aurora Province, and other peanut-growing areas.
   c. Monitoring performance of elite peanut lines entered in National Cooperative Tests across seven testing locations.
   d. General yield trials at Laguna and Isabela.
   e. Preliminary yield trials at Laguna and Isabela.
   f. Advancement of segregating materials at artificial epiphytotic conditions and extraction of resistant materials at appropriate selection pressures.
   g. Continuing germplasm evaluation and confirmation of quantitative and qualitative characters.
   h. Yield loss assessment due to peanut rust
      1) Confirmatory screening against
         a) *Puccinia arachidicola* (peanut rust)--field and greenhouse
         b) *Sclerotium rolfsii*--greenhouse
         c) *Pseudomonas solanacearum*--greenhouse
      2) Field screening for resistance to *Puccinia arachidicola*, *Sclerotium rolfsii*, viral diseases and *Aspergillus niger* wilt
      3) Dry seed resistance test against *Aspergillus flavus*
         a) Retest using new seeds of peanut cultivars and promising lines
         b) Effect of various factors on infection (incidence rate and type of infection) on the following:
            i. Resistant vs. susceptible lines
            ii. Concentration of inoculum (1, 5, and 8 x 10^5 spores/ml)
            iii. Age of seeds (fresh, 1, 2, and 3 months after storage)
            iv. Isolate source
      4) Basic study on *Aspergillus niger*
         a) Determine the following for screening in greenhouse
            i. Inoculum concentration
            ii. Method of application
            iii. Effect of drought
         b) Start screening for resistance on NCT entries and commercial varieties
      5) Pictorial guide for evaluating resistance to major peanut diseases
2. Partial shaded growing condition
   a. Advancement of segregating materials
   b. Preliminary yield tests using artificial shade and full sunlight growing conditions at UPLB
   c. General yield tests of peanut entries intercropped under coconut at Quezon, Bicol, and other cooperating stations.
   d. On-farm trials of shade-tolerant materials at various coconut testing sites such as PCA, Bago Oshiro, Davao City; Baao, Pili, Camarines Sur; Baler, Aurora Province, etc.
   e. Seed production of promising entries which are high yielding under partial shade and with extended shelf-life.
3. Highly acidic soil conditions
   a. Screening of 20 new peanut lines at UPLB and Siniloan, Laguna
   b. Greenhouse experiments to characterize acid-tolerant and intolerant lines
   c. Diallel cross for a genetic study on acid tolerance
4. Drought conditions
   a. Screening breeding lines/accessions and confirmatory tests on

drought tolerance at MMSU, Batac, Ilocos Norte on January to April 1993.

B. Thailand
   1. Department of Agriculture
      a. Peanut germplasm will be introduced from ICRISAT for evaluation and selection.
      b. New crosses will be made among high yielding adapted lines and sources of desirable traits.
      c. Segregating material of all breeding objectives will be advanced and screened for the desirable traits appropriated to breeding objectives.
      d. Yield trials at different stages will be conducted to evaluate promising lines in different environments.
      e. The annual Thailand National Peanut Meeting will be held as usual.
   2. Khon Kaen University
      a. New crosses will be made among high yielding adapted lines and identified sources of desirable traits.
      b. Segregating material of all breeding objectives will be advanced and screened for the desirable traits.
      c. Yield testing of peanut lines will be done in the before-rice, after-rice and main rainy seasons.
      d. Work on breeding for increasing nitrogen fixation and for resistance to certain insects will be continued.
      e. Improvement of pod seed and eating quality of boiling-type peanut will be emphasized.

II. Training planned
   A. US trainees
      1. G. Garcia
         a. Degree: PhD
         b. Date of expected completion: May, 1995
         c. Country - present affiliation: US
         d. Thesis / dissertation topic: Introgression pathways of wild germplasm into cultivated peanut
      2. G. Menon
         a. Degree: PhD
         b. Date of expected completion: June, 1995
         c. Country - present affiliation: US
         d. Thesis / dissertation topic: Development of transgenic peanuts with enhanced resistance to *Aspergillus* infection
      3. T.P. Shyamalrau
         a. Degree: PhD
         b. Date of expected completion: August, 1993
         c. Country - present affiliation: US
         d. Thesis / dissertation topic: Isozyme and RFLP studies in interspecific crosses of peanut
      4. C.A. Salas
         a. Degree: PhD
         b. Date of expected completion: May, 1996
         c. Country - present affiliation: US
         d. Thesis / dissertation topic: Utilization of Peruvian germplasm resistant to late leafspot and rust
   B. Host Country trainees
      1. Woothisuk Butranu
         a. Degree: None
         b. Date of expected completion: July 31, 1993
         c. Country - present affiliation: Thailand

III. Manuscripts, presentations, releases planned:
   A. Presentations
      1. Garcia et al. Identifiaction of molecular markers associated to disease and insect resistance genes in an interspecific hybrid population. APRES, Huntsville, AL.
      2. Isleib. Fixed-effect genetic analysis of diallel and factorial

mating designs in peanut. APRES, Huntsville, AL.

3. Shyamalrau et al. Restriction fragment length polymorphism (RFLP) analysis to monitor alien germplasm introgression in peanut (*Arachis hypogaea* L.). APRES, Huntsville, AL.
4. Utomo et al. Regeneration efficiency of four peanut culture methods. APRES, Huntsville, AL.

B. Manuscripts in process

1. Chappell et al. Evaluation of mechanisms of resistance to *Sclerotinia minor* in peanut genotypes. Plant Dis. (in review)
2. Clemente et al. Identification of resistant tomato spotted wilt germplasm in *Arachis*. Peanut Sci. (in review).
3. Clemente. Culture performance of embryonic leaflets from 70 cultivated genotypes of peanut. Peanut Sci. (in review).
4. Isleib and Stalker. Combining ability for agronomic traits in peanut populations derived from crosses of *Arachis hypogaea* with *A. cardenasii*. Peanut Sci. (in preparation)
5. Isleib and Wynne. Groundnut production and research in North America. Proc 2nd International Workshop on Groundnuts. 25-30 Nov. 1991. ICRISAT. Patancheru, Andhra Pradesh (in press).
6. Isleib et al. Contributions of ancestors to genetic variation for agronomic traits in a peanut population under recurrent selection for yield. Peanut Sci. (in preparation)
7. Lacks and Stalker. Isozyme analyses of *Arachis* species and interspecific hybrids. Peanut Sci. (in press).
8. Schnall and Weissinger. The culturing of peanut (*Arachis hypogaea* L.) zygotic embryos from transformantion via microprojectile bombardment. Plant Cell Rep. (in review).
9. Shew et al. Biological and biotechnological control advances in *Arachis* diseases. Chapter in APRES monograph, Advances in Peanut Science (in review).
10. Shew et al. Greenhouse and microplot evaluation of resistance to *Meloidogyne arenaria* in *Arachis hypogaea*, *A. cardenasii*, *A. chacoense*, and genotypes derived from a cross of *A. hypogaea* x *A. cardenasii*. Peanut Sci. (in review)
11. Shew et al. Peanut genotype effects on occurrence of *Cercospora arachidicola* and *Cercosporidium personatum* in North Carolina. Phytopathology (in review).
12. Shyamalrau et al. Early reproductive ontogeny in interspecific crosses of *A. hypogaea* and section *Arachis* species. Sexual Plant Repro.
13. Stalker. Utilizing *Arachis* germplasm resources. Proc 2nd International Workshop on Groundnuts. 25-30 Nov. 1991. ICRISAT. Patancheru, Andhra Pradesh (in press).
14. Stalker and Beute. Registration of four interspecific peanut germplasm lines resistant to *Cercospora arachidicola*. Crop Sci. (in press).
15. Stalker et al. Diversity of isozyme patterns in *Arachis* species. Theor. Appl. Genet. (in press)
16. Weissinger. Transformation in peanut. Chapter in monograph on plant transformation edited by Y.P.S. Bajaj.

IV. International travel planned

A. R. Abilay

1. Month(s): July, 1993
2. Destination: North Carolina State University, APRES meeting at Huntsville, Alabama
3. Duration: 2 weeks

B. T.G. Isleib

1. Month(s): January, 1994
2. Destination: Institute of Plant Breeding, University of the Philippines at Los BaÑos, Philippines, and Khon Kaen University, Khon Kaen, Thailand
3. Duration: 2 weeks

TX/MM/S,G

Mycotoxin Management in Peanut by Monitoring and Prevention of Contamination

Texas A&M University, College Station, Texas
Institut Senegalais de Recherches Agricoles, Bambey, Senegal
Institut de Technologie Alimentaire, Dakar, Senegal
University of Science and Technology, Kumasi, Ghana
Food Research Institute, Accra, Ghana

Marian N. Beremand (Principal Investigator:), Nancy P. Keller,
Timothy D. Phillips - Texas A&M University
Amadou Ba - ISRA , Amadou Kane - ITA
Richard T. Awuah - UST, Kafui Kpodo - FRI

INTRODUCTION

Mycotoxin contamination of peanut poses a serious health hazard to consumers of peanut products throughout the world. Effective mycotoxin management in peanut depends upon the implementation of multiple strategies to prevent contamination or to reduce levels of aflatoxins and other mycotoxins which may be present in peanut and peanut products. This project is designed to conduct experiments which can further identify the mycotoxins and mycotoxigenic fungi present on peanut; define compounds from peanut and other organisms that prevent mycotoxin accumulation; implement molecular biological tools to understand the biosynthesis of mycotoxins at the gene level; select peanut germplasm with resistance to aflatoxin production; improve agronomic production practices which reduce the levels of contamination within the field; improve storage practices which minimize further contamination; develop rapid, practical and economical monitoring procedures for the detection of mycotoxins; and devise cleaning, sorting, and detoxifying protocols for removal or deactivation of mycotoxins within peanut and peanut derived products.

IMPACTS

Host Countries - Reducing the levels of aflatoxin/mycotoxins in peanut will help improve the health of the local population, and improve the quality of peanut products. New methods of aflatoxin detection should aid in quantifying levels of aflatoxin present, and aid in justifying the diversion of contaminated peanut into processing for clean-up or detoxification. Development of improved marketing procedures, those which provide an incentive for producing aflatoxin-free peanut, will help encourage implementation of aflatoxin preventive measures and removal of mold-damaged seed previous to processing. Newly developed aflatoxin sorption methodologies will allow local villagers and industry to treat peanut oil to reduce aflatoxin levels to a safe level for consumption. Continued screening of peanut genotypes for resistance to penetration by the mycotoxin producing fungi will further help reduce the degree of contamination of peanut at the village level. Identification of local plants which exhibit fungistatic properties or inhibit mycotoxin production can be used in biocontrol programs. Training efforts will improve technology transfer to host countries and be instrumental in the much needed development of molecular biology programs at universities and research institutes. Finally, successful research in the above areas will be applicable to other crops affected by mycotoxins.

In the United States - Research results will lessen the impact of the mycotoxin problem to the peanut industry in the U.S. Molecular and genetic analyses of *Aspergillus* and *Fusarium* mycotoxin genes offer new approaches to preventing mycotoxin contamination and for selecting or producing mycotoxin resistant peanut cultivars. Newly developed aflatoxin resistant peanut cultivars, adapted to the peanut growing regions of the United States, could greatly reduce the amount of Segregation III peanut marketed within the country. (Peanut exceeding maximum

allowable levels of aflatoxin for direct consumption are marketed as Seg III's and go into oil market). Marketing of peanut seed with reduced levels of mold and mycotoxin damage will reduce the costs of processing peanut products. Improved mycotoxin detection techniques should increase the speed and accuracy of analyses, and reduce the costs related to the diversion of contaminated peanut lots. Newly discovered sorption techniques to bind and inactivate aflatoxins, and other mycotoxins, by blending aluminosilicates into peanut products, should increase the margin of safety to insure that these products are safe for use as food or feed components.

MAJOR ACCOMPLISHMENTS

Two Ghanaian Institutes have been officially accepted into the Mycotoxin Program: the University of Science and Technology (UST), Department of Crop Science at Kumasi and the Food Research Institute (FRI) at Accra. The respective PIs are Dr. Richard T. Awuah (plant pathologist) and Ms. Kafui Kpodo (food biochemist). Dr. Awuah will be visiting Texas A&M University in July 1993 and arrangements are being made to have Ms. Kpodo to visit in the same fiscal year. Ms. Kpodo will also be collaborating with the AAM/FT/BF/G Food Utility Project headed by Dr. Elena Castell-Perez. The complimentary interactions between the Mycotoxin and Food Utility projects should result in more efficient use of resources.

Microbial assays using colored aflatoxin mutants in *Aspergillus flavus* and *Aspergillus parasiticus* have been initiated (a) to assess peanut cultivars for relative resistance/susceptibility and *Aspergillus* infestation and/or aflatoxin contamination and (b) to assess plant extracts for their effects on this interaction. Preliminary results have identified three promising Ghanaian plants which may decrease both *Aspergillus* growth and aflatoxin production.

Co-operative studies with Dr. Thomas H. Adams (Department of Biology, Texas A&M University) have resulted in the cloning, sequencing and characterization of *verA*, a gene in the sterigmatocystin/aflatoxin pathway of *Aspergillus nidulans*. The study of this and other genes in the aflatoxin pathway will lead to a molecular understanding of what environments, peanut metabolites, and other factors result in aflatoxin production in peanuts.

Fusarium species including those species known to produce the mycotoxin fumonisin have been isolated from Texas field grown isolates. The development of simple minicolumn to detect fumonisin is in its final stages.

Dr. Julius Fajardo completed his Ph.D. degree in August 1992 from the Department of Plant Pathology and Microbiology at Texas A&M University.

Dr. Julius Fajardo and Dr. Bashir Sarr completed post-doctoral programs in the 1992-1993 fiscal year.

GOALS

The goals of the mycotoxin management project are to develop and apply techniques which reduce the severity of the mycotoxin contamination problems within Developing Countries and the United States. Prevention of mycotoxin contamination through the development of aflatoxin resistant cultivars, effective biocontrol strategies, and improved production, harvest, storage, and processing procedures will help reduce the costs of excessive processing to remove the mycotoxins. For peanut which still contains mycotoxins, the goal is to develop improved inspection and diversion procedures, and clean-up and detoxification procedures, which will reduce the levels of mycotoxins present within peanut and peanut products to assist in meeting governmental health and safety standards.

OBJECTIVES

1. Screen peanut cultivars and genotypes under laboratory and field conditions in Texas for tolerance to aflatoxin producing fungi and aflatoxin elaboration.
2. Investigate the relationship between drought and irrigated conditions in field grown peanuts in newly developed irrigated plots in Senegal.
3. Investigate the genetic and molecular mechanisms that control mycotoxin biosynthesis in *Aspergillus* and *Fusarium* spp.
4. Develop new assays and studies to assess the importance of other mycotoxins and mycotoxigenic fungi in peanut.
5. Initiate the transfer of clay chemi-sorption technologies at a village level in Senegal.
6. Institute the use of minicolumn technology for detection of aflatoxin in Senegal.
7. Assess Ghanaian plants and plant extracts for their ability to decrease *Aspergillus* growth and aflatoxin production.
8. Develop safe, economical and effective methods for the detoxification of aflatoxin-contaminated peanut products.
9. Maintain the training programs for students, technicians and senior scientists.

ORGANIZATION AND PERSONNEL

U.S. Lead Institution: Texas A&M University (TAMU)

Principal Investigator	Dr. Marian N. Beremand, Department of Plant Pathology and Microbiology (PPM), TAES, TAMU, CS
Co-Principal Investigators	Dr. Nancy P. Keller, Department of Plant Pathology and Microbiology, TAES, TAMU, CS
	Dr. Timothy D. Phillips, Department of Veterinary Public Health (VPH), TAMU, CS
Cooperators	Dr. Olin D. Smith, Department of Soil and Crop Sciences, TAMU, CS
	Dr. Thomas H. Adams, Department of Biology, TAMU, CS
	Dr. Charles Simpson, Department of Soil and Crop Sciences, TAMU, CS
Technician	Mr. Robert Butchko, Department of PPM, TAES, TAMU, CS
	Ms. Della Olvera, Department of PPM, TAES, TAMU, CS
Graduate Student	Ms. Rudeina Baasiri, Department of PPM, TAES, TAMU, CS
Post-Doctoral	Dr. Julius Fajardo, Department of PPM TAES, TAMU, CS
	Dr. Bashir Sarr, Department of VPH, TAMU, CS
Budge Analyst	Ms. Marcia Walker and Mr. Lee Boozer, TAMU Research Foundation
Institutional Representatives	Dr. Dudley T. Smith, Associate Director, TAES, TAMU, CS
	Dr. Neal Van Alfen, Head, Dept. of PPM, TAES, TAMU, CS

Senegal: Institut Senegalais de Recherches Agricoles (ISRA)

Principal Investigator	Dr. Amadou Ba, Secteur Centre-Sud, ISRA, Bambey, Senegal
Directeur	Dr. Amadou Ba, Department Des Productions Vegetales, CRNA, ISRA, Dakar, Senegal

Director General — Dr. Mohamadouh Ly, ISRA, Dakar, Senegal, B.P. 3120

Senegal: Institut de Technologie Alimentaire (ITA)

Principal Investigator — Dr. Amadou Kane, Mycotoxin Laborastoire, ITA, Dakar-Hann, Senegal, B.P. 2765

Directeur General — Dr. Mouhamadou Diop, ITA, Dakar-Hann, Senegal, B.P. 2765

Ghana: University of Science and Technology (UST)

Principal Investigator — Dr. Richard T. Awuah, Department of Crop Science, UST, Kumasi, Ghana

Ghana: Food Research Institute (FRI)
Ms. Kafui Kpodo, FRI, Accra, Ghana

APPROACH

Field screen and test selected cultivars and genotypes for detection and verification of tolerance to colonization by aflatoxin producing fungi or to aflatoxin production.

Determine the molecular mechanisms that control mycotoxin production by utilizing the techniques of molecular biology and genetics to identify and clone the structural and regulatory genes required for toxin biosynthesis in *Aspergillus* and *Fusarium* species.

Evaluate and further develop mycotoxin detection systems and detoxification methodologies for mycotoxin contaminated peanut and peanut products.

Assess the efficacy of phyllosilicate clays in preventing aflatoxicosis in farm animals and the accumulation of aflatoxins and related compounds in milk.

Further assist, train and encourage host country scientists in conducting, developing and establishing their own mycotoxin research programs and in attaining project goals, including the transfer and adaptation of technologies developed in conjunction with the research project.

RESEARCH ACCOMPLISHMENTS

Texas

Use of microbial assays

Studies were initiated to develop and evaluate a new microbiological assay to assess factors which regulate aflatoxin production and to test peanut cultivars for relative resistance/susceptibility to *Aspergillus* infestation or aflatoxin contamination. This assay utilizes *Aspergillus* aflatoxin mutants which accumulate colored intermediates in the aflatoxin pathway. To date, four intermediates in the aflatoxin pathway have been isolated (norsorolinic acid - red color; averantin - golden color; averufin - golden color; and versicolorin A - lemon color). These semi-purified compounds will serve as standards for measuring production of these intermediates in different peanut cultivars. Studies have been completed which allow spectrophotometric quantitation of norsorolinic acid (NOR) production as an indicator of aflatoxin pathway function in agar grown *Aspergillus* cultures. Spectrophotometer and HPLC methodologies for quantitating NOR will be compared in future experiments. Tests are in progress to determine how these procedures can be applied to peanut grown cultures.

Preliminary results indicate that the assays may help to identify peanut genotypes which reduce fungal growth and aflatoxin biosynthesis.

Evaluation of peanut cultivars and genotypes for Aspergillus colonization and aflatoxin production

Field and laboratory studies were conducted to test new germplasm for novel sources of aflatoxin resistance and to determine if they could be effectively screened for increased resistance using the *A. parasiticus* NOR-accumulating strain described above. Forty-four landraces originating from Beni, Bolivia and several selected cultivars were grown under rain-fed field conditions. Aflatoxin assays were conducted on harvested, forced-air dried samples and the new laboratory microbial assay was assessed using seeds from three different developmental stages: immature seed during pod filling and mature seed, before and after forced-air drying.

Aflatoxins were not present in any of the varieties tested, including the susceptible checks (detection limit = 5ppb). This, and additional data, indicated that the field conditions were not favorable for *Aspergillus* infestation or aflatoxin production. Analysis of the 44 landraces with the NOR microbial assay indicated that all of the lines were susceptible to *Aspergillus* infestation and aflatoxin production at maturity but that immature seed from some of the lines (P1540839, P1540852, P1540855 and P154C856) may harbor some increased resistance. These studies are being repeated and new studies have been initiated to both evaluate the above landraces for potential increased resistance to aflatoxin contamination and to determine how the NOR strain can most effectively be utilized in peanut breeding programs to assist in the development of more aflatoxin resistant cultivars.

Inducing and Inhibitory Environments for Aflatoxin Production

Studies have been initiated to explore the nature of aflatoxin induction in *Aspergillus* spp. One goal is to look for global regulatory stimuli which induce polyketide production in *Aspergillus* spp., towards this end norsoralinic acid (NOR), aflatoxin (AF) and sterigmatocystin (ST) production is being monitored in the three producing species, *A. parasiticus*, *A. flavus*, and *A. nidulans* with special regard to *A. parasiticus* and *A. flavus*. These three polyketide mycotoxins are in the same biosynthetic pathway: polyketide precursor >NOR> ca. 6-8 biosynthetic steps > ST > 1 biosynthetic step >AF. *In vivo*, these polyketide mycotoxins are produced in high oil seed crops (e.g. peanut) subjected to environmental stress and our preliminary results have pointed out significant similarities and differences in AF production *in vitro*. Studies are underway to use *in vitro* models which will dissect and assess the peanut metabolites involved in regulation of ST/NOR/AF biosynthesis. Our studies have shown that NOR/ST/AF are similarly regulated *in vitro*: They are (i) consistently produced in sucrose-based media; (ii) inconsistently produced in lipid-based media and (iii) either not (NOR/AF) or negligibly (ST) produced in peptone-based media. The fact that NOR and ST are regulated in a manner similar to AF, argues for conserved regulatory mechanisms for production of these mycotoxins which should allow for a systematic search for such regulatory molecules (e.g., the inhibition of AF in one *Aspergillus* spp. can be applicable for inhibiting AF/ST in other *Aspergillus* spp.). This knowledge supports the use of *A. nidulans*, a genetically and molecularly well-characterized fungus, as a model to study aflatoxin gene regulation at a molecular level.

Studies have shown that AF and ST production are limited to certain developmental stages of *Aspergillus* and that aflatoxin/sterigmatocystin biosynthesis appears to be limited to substrate mycelium (e.g. the part of the fungus which grows in peanut tissue) not in the aerial mycelium (e.g. the part of the fungus which grows above the peanut tissue and produces spores). Experiments will be designed to further explore this relationship between fungal development and aflatoxin biosynthesis.

Molecular biology and genetics of mycotoxin production

In a collaborative project, Dr. Keller and Dr. Adams are cloning genes in the aflatoxin biosynthetic pathway using the fungus *A. nidulans* (which produces the mycotoxin sterigmatocystin). Progress in this molecular project significantly contributes to the Peanut CRSP project; eventually any inhibitors/inducers of aflatoxin will be assessed for their effect on specific genes in the aflatoxin pathway. We continued with characterization of the *Aspergillus nidulans verA* gene: subcloning, restriction mapping and sequence analysis. The gene encodes for a reductase activity thought to be active in the aflatoxin pathway between versicolorin A and sterigmatocystin. Predicted amino acid sequence of the *A. nidulans* gene product shows 85% homology to the *A. parasiticus verl* gene product.

Phyllosilicates and Clays

Clay mixtures were also designed to speed up the sedimentation of these materials when added to liquid samples. Clay mixtures with effective sedimentation coefficients are being tested to facilitate the removal of aflatoxins and other mycotoxins in liquid samples.

Various mycotoxins possessing an enolized form of the b-diketone of aflatoxins are being tested for binding with HSCAS and other clays. Chemisorption indices and *in vitro* tests using the Hydra model show a significant interaction between these toxins and HSCAS.

Mycotoxin detection assays

A minicolumn method for the detection of fumonisins was developed and tested with corn. Several target interfaces were assayed for a better visualization of derivatized fumonisins. A column was successfully constructed. Various extraction procedures are being optimized to limit the effects of interfering compounds. A new HPLC method was developed to allow the detection of compounds viewed on TLC but not with the published HPLC methods. Preliminary results indicate that most of the so called interfering compounds are possible fumonisins. This may explain the discrepancy observed between previous minicolumn and HPLC results. Experiments are underway to separate these compounds from fumonisin B_1, the fumonisin of interest. Future work will be conducted to chemically characterize these fumonisins and determine their toxicity.

Other mycotoxin producing fungi on peanuts

Fusarium species have been isolated from field grown peanuts and are being further characterized as to species and for mycotoxin production. A primary goal of these studies has been to determine if fumonisin-producing species are present on field grown peanuts. Fumonisin production has now been documented in several of the above isolates. Subsequent tests showed that these same strains synthesize fumonisins when grown in peanut cultures under laboratory conditions. The significance of these findings are being further tested.

Senegal ISRA

Continuation of evaluation of groundnut cultivars with resistance to A. flavus.

Cultivar 77-33 appeared to be more infected than cultivars 55-437 and 73-30 under spray-inoculation conditions; cultivar susceptibility may influence the soil content of *A. flavus* propagules. Spraying plants at pegging resulted in most infection. This could be associated with millipede damage which suggests the need for IPM systems in preventing peanut preharvest contamination with aflatoxin.

Continuation of collaboration with ICRISAT Shelian Center.

Percent of peanuts contaminated from fields inoculated in 1990 - 1992 showed that there was variability in *Aspergillus* infection between years, contamination was lower in 1992 probably due to favorable rainfall, advanced lines from resistant parents ICGV 87084, ICGV 87094 and ICGV 87110 showed variable contamination levels and the cultivar JL 24, TS 32-1, Var 27 and ICGV 87101 appeared to be the most susceptible to contamination.

The multilocational test proposed by ICRISAT (Senegal, Niger and Burkina Faso) is an occasion to test the performances of groundnut genotypes for several growing conditions and could help improve exchange material between western african research institutions.

Ghana UST and FRI

A formal MOU was signed with the Ghanaian counterparts of the Mycotoxin CRSP. This includes Dr. Richard Awuah (UST) and Ms. Kafui Kpodo (FRI). Both Dr. Awuah and Ms. Kpodo have received some starting funds for initial work in Ghana. Several of the *Aspergillus* colored aflatoxin mutants have been sent to Dr. Richard T. Awuah along with pertinent aflatoxin literature. Dr. Awuah has initiated his own research work by looking at the effects of plant extracts on *Aspergillus* infestation and aflatoxin production. Dr. Awuah has worked out some promising conditions for analyzing aflatoxin/NOR production under inducing and inhibiting environments in preparation for screening local flora for their inhibitory effect on aflatoxin/NOR production or on *Aspergillus* growth. Dr. Awuah and Ms. Kpodo are collaborating on aflatoxin/NOR quantitation using chromotographical methods. Dr. Awuah has initiated a preliminary screen of peanuts in the Kumasi market place and has found several fungal species including *A. flavus/A. parasiticus* isolates. So far he has not isolated any *Fusarium spp.* from the market peanuts. Dr. Awuah will be attending the upcoming APRES meeting in Huntsville, AL in order to meet with other participants in the Peanut CRSP and to share his preliminary data and ideas.

Mrs. Kafui Kpodo has been sent pertinent literature on extraction and identification of aflatoxin, sterigmatocystin and other mycotoxins from food stuffs.

PUBLICATION AND PRESENTATIONS

Abstracts

Butchko, R. A. E., N. P. Keller. March 1993. Polyketide biosynthesis in *Aspergillus* spp. as a developmental response to lipid substrata. Asilomar Fungal Genetics Conference.

Fajardo, J.E., M. N. Beremand, N. P. Keller. December 1992. Development of microbial assay for resistance to aflatoxin production in peanuts. Texas Plant Protection Conference.

Keller, N.P., T. H. Adams. March 1993. Isolation of an *Aspergillus* gene, *verA*, encoding a putative reductase activity in the sterigmatocystin/aflatoxin biosynthetic pathway. Asilomar Fungal Genetics Conference.

Sarr, A. B., T. D. Phillips, Z. G. Hwang, A. L. Fisher, M. R. Dwyer, S. M. Williams, B. A. Clements. March 1993. A rapid method for the detection of fumonisin B_1 in corn. Toxicologist 32nd annual Meeting.

White, P., A. B. Sarr, K. Mayura, B. Spainhour, T. D. Phillips. March 1993. Binding of secalonic acid B to hydrated sodium calcium aluminosilicate. Toxicologist 32nd Annual Meeting.

Thesis

Fajardo J, Ph.D. Thesis: "Phenolic Compounds in Peanut: Studies on Pod Maturity, Ellagic Acid, Elicitors, Growth and Aflatoxin Production by *Aspergillus flavus*, Seed Protein Profiles, and Isozymes"

Presentations

Dr. Phillips and Dr. Sarr attended the Symposium on the Impact of Technology on Agricultural Transformation in Africa held in Washington D.C. from Oct. 14-16, 1992. Dr. Phillips gave a seminar on the impact of HSCASD utilization on aflatoxin management, and Dr. Sarr reported on minicolumn assays.

Dr. Phillips, Cummins, and Sarr met with the Ambassador of Senegal in Washington D.C., and discussed with him about the transfer of HSCAS and minicolumn technology to Senegal. The Ambassador, His Excellency Ibra Ka, expressed enthusiasm and reiterated his willingness to help achieve the goals.

Dr. Keller attended the USDA Aflatoxin Elimination Workshop held at Fresno, Calif. 1-3 November, 1992. Dr. Keller presented a poster co-authored by Dr. Adams on their complimentary molecular project aimed at identify *Aspergillus* genes involved in the aflatoxin biosynthetic pathway.

Drs. Keller, Beremand and Fajardo attended the Texas Plant Protection Conference in November at College Station, TX 1992. Three posters were presented.

Dr. Keller attended the Asilomar Fungal Genetics Meeting held at Asilomar, Calif. 23-28 March, 1993. Dr. Keller was invited to give presentation in a polyketide workshop and in the biochemistry session on aflatoxin production in *Aspergillus* spp.

Drs. Beremand and Keller attended the American Society for Microbiology Annual meeting in Atlanta, GA, May 16-20, 1993. Dr. Keller chaired a symposium entitled "Molecular Plant/Microbe Interactions" and presented a seminar on host induction of polyketide mycotoxins in *Aspergillus* spp. Dr. Beremand presented an invited paper on *Fusarium* trichothecene mycotoxins.

TRAINING: DEGREE AND SHORT-TERM

Dr. Julius Fajardo received his Ph.D. degree in August 1992 from the Department of Plant Pathology and Microbiology at Texas A&M University. In September Dr. Fajardo accepted a four month post-doctoral position with Drs. Beremand and Keller to conduct research towards the development of a microbial assay, based on *Aspergillus* aflatoxin pathway mutants, to assess aflatoxin resistance in peanuts. He is currently employed as a post-doctoral fellow with the Canadian Grain Commission, Winnipeg, Manitoba where he is working on a *Fusarium* mycotoxin project.

Mr. Robert Butchko was hired as a technician by Dr. Keller and has been trained in *Aspergillus* microbiological skills and mycotoxin extraction procedures. Mr. Butchko has applied for and been accepted as a graduate student into the Department of Plant Pathology and Microbiology, Texas A&M University where he will work under the guidance of Dr. Keller, He will continue his work on elucidating the compound(s) responsible for induction and inhibition of aflatoxin biosynthesis and the relationship of these compound(s) to the peanut plant.

Ms. Della Olvera was hired as a technician by Dr. Beremand and has received training in *Fusarium* culture techniques and mycotoxin detection assays.

Ms. Rudeina Baasiri, a Ph.D. student in Dr. Beremand's laboratory, has recently joined the project. Ms. Baasiri will evaluate *Fusarium* mycotoxin production in peanuts and determine how *Fusarium* trichothecene mycotoxins effect fungal developmental stages related to the disease cycle of these organisms.

PLANS FOR 1993-1994

1. Have Dr. Awuah (UST, Ghana) and Dr. Ba (ISRA, Senegal) visit scientists in the Peanut CRSP Programs at Texas A&M and attend the APRES meeting.
2. Have Ms. Kpodo (FRI, Ghana) and Dr. Kane (ITA, Senegal) receive training at Dr. Phillips laboratory (TAMU) during the 1993-1994 fiscal year.
3. Continue exploring use of rapid, inexpensive laboratory assays to identify compounds from peanuts and from other organisms which specifically block aflatoxin production and/or accumulation.
4. Explore the nature of aflatoxin (and the related mycotoxins norsorolinic acid and sterigmatocystin) production as a response of the fungus to stressful environments. Initiate search for global regulatory signals for polyketide production which may lead to logical control strategies through recombinant DNA methodologies.
5. Screen peanut cultivars and genotypes for compounds which inhibit aflatoxin biosynthesis or accumulation.
6. Continue to evaluate Fusarium mycotoxin production peanuts.
7. Identify new genetic and molecular controls that regulate Fusarium mycotoxin production.
8. Survey peanut cultivars for the presence of associated fungi and mycotoxins in collaboration with scientists at UST and FRI.
9. Develop innovative field-practical methods for the rapid detection and detoxification of aflatoxin-contaminated peanuts and peanut products.
10. Continue to characterize the molecular and biological mechanisms involved in the binding interaction NovaSil™ (HSCAS) and other phyllosilicate clays with aflatoxins.
11. Collaborate with scientists at ITA and SONACOS (*Societe Nationale pour la Commercialisation des Oleagineux du Senegal*) to develop a commercial model for the clarification of peanut oil and the detoxification of peanut meal.
12. Collaborate with scientists at ISRA to develop a viable small-scale model for the addition of NovaSil at the village level for the detoxification of peanut meal (destined for animal consumption) and peanut oil.
13. Develop innovative field-practical methods for the rapid detection of *Fusarium* mycotoxins.
14. Utilize microbial assays developed at Texas A&M University to test

Ghanaian plant extracts for presence of potential fungicidal properties or aflatoxin inhibition properties.

15. Identify mycotoxins produced in Ghanaian peanuts, peanut foods (especially infant formula) and peanut paste at FRI in cooperation with the Food Technology project (Dr. Elena Castell-Perez).
16. Work towards development of a forecasting method for aflatoxin contamination at ISRA.

GA/IM/BF

IPM Strategies for Peanut Insects in Semi Arid Tropical Africa

University of Georgia
University of Ouagadougou, Institut Development Rurale

R. E. Lynch, Principal Investigator, USDA/UGA, Tifton, GA
A. P. Ouedraogo and I. O. Dicko, Burkina Faso, West Africa

INTRODUCTION

Food production in the developing countries of the world continues as one of the most crucial problems. In the Sahel of West Africa, peasant farmers use primitive production practices and unimproved land races of food crops. Such production techniques, along with inadequate rainfall, poor distribution of rainfall during the growing season, and losses from plant pests, result in tremendous fluctuations in the quantity/quality of food produced and subsistence farming. During years with adequate rainfall, farmers increase crop production as the food produced may have to suffice for several years. Successive years with inadequate rainfall or major losses due to plant pests leads to famine, similar to what has occurred recently in Ethiopia and Somalia. Thus, the major goal for the developing countries of West Africa is stable, sustainable food production. Attainment of this goal will require cooperative research aimed at improving cropping procedures, developing better crop varieties, and improving methods for control of insects and diseases.

Arthropod pests are a major detriment to stable food production in the developing nations and have been estimated to reduce yield or destroy over 30% of the food produced. Equally important to direct losses caused by arthropod injury are the plant pathogens that they transmit or exacerbate. Rosette transmitted by the groundnut aphid and enhanced contamination of peanut seed with Aspergillus flavus and aflatoxin as a result of termite injury are two of the most important insect-pathogen relationships in West Africa.

A coordinated, interdisciplinary approach to research integrating entomology, plant pathology, agronomy, and plant breeding will be required to attain the goal of stabilized food production in West Africa. The research must develop systems of food production that are compatible with the socioeconomic frame of the developing nations and are sustainable. In entomology, plant resistance to insect pests such as termites and aphid-transmitted rosette, control of pests with indigenous products, and reduction of aflatoxin contamination of groundnut through cultural practices and plant resistance are compatible with these guidelines.

IMPACTS

The peanut aphid, Aphis craccivora, jassids, Empoasca dolichi and E. facialis, a termite, Microtermes thoracialis, lepidopterous larvae, Helicoverpa armigera and Spodoptera littoralis, the peanut bruchid, Caryedon serratus, and millipedes, Peridontopyge spp., have been identified as potential economic threats to peanut production in the Sahel of West Africa (Lynch et al. 1986). Germplasm with resistance to a number of these insects, closely related species, or the diseases that insects transmit has been identified (see Lynch 1990 for a list of resistant Arachis germplasm). Research in Burkina Faso has shown that preharvest damage to peanut pods by termites exacerbates aflatoxin contamination of peanut seed. Germplasm with resistance to termites has been identified in Burkina Faso, and cooperative research with the Texas A&M Breeding project in the Peanut CRSP has been initiated to evaluate crosses with the resistant germplasm for termite and aflatoxin resistance. Development of aflatoxin resistant peanut germplasm would be of tremendous benefit to the people and livestock of this region.

MAJOR ACCOMPLISHMENTS

Research Results

In 1992, research in Burkina Faso was conducted at Gampala and Farakoba. Four major objectives were addressed in this research to: 1) evaluate the influence of peanut plant population on insect damage, rosette, yield and aflatoxin contamination; 2) determine the effect of harvest date on termite damage to plants and pods, yield and aflatoxin; 3) evaluate peanut lines from ICRISAT with reported resistance to termites for resistance to this insect and aflatoxin contamination in Burkina Faso, and 4) evaluate the effect of preplant tillage depth on termite damage to pods, yield, and aflatoxin contamination.

At Gampala, thrips damage and defoliation by lepidopterous larvae to peanut declined with increase in plant population. No meaningful differences were detected in aphid abundance or incidence of rosette that could be attributed to plant population. Conversely, a trend was evident for an increase in both plant and pod damaged by termites as plant population increased. No differences in yield due to plant population were noted. However, control of insects with insecticides increased yield by 900 - 1550 kg/ha.

At Farakoba, foliar insect damage was variable in relation to plant population. The incidence of rosette was greater in the highest plant population, significantly higher than the incidence at the lowest plant population. Termite damage to pods increased as plant population increased. Likewise, peanut yield also increased with plant population.

Termite damage to peanut pods increased with an increase in days to harvest at both Gampala and Farakoba. Evaluation of the influence of soil moisture on termite damage showed that the percentage of externally damaged pods and penetrated pods increased as soil moisture decreased.

Evaluation of peanut cultivars for termite resistance at Gampala produced significant differences in pod damage and yield as a result of both peanut variety and harvest date. A significant cultivar x harvest date interaction was noted for the percentage undamaged, scarified, and penetrated pods at both Gampala and Farakoba, and for number of termite damaged plants and yield at Farakoba. At Gampala, NCAc 2243 and NCAc 2240 sustained the least termite damage with the delayed harvest. Yield of NCAc 343 at Gampala was significantly greater than for all other cultivars evaluated. At Farakoba, NCAc 343, NCAc 2240, NCAc 2243, and RMP 40 produced greater than 90% undamaged pods with a delayed harvest. Yield at Farakoba was also significantly greater for NCAc 343 than for all other cultivars evaluated.

Tillage depth did not affect the percentage of undamaged pods, scarified pods or penetrated pods. The number of termite damaged plants decreased with increase in tillage depth. Pod and plant damage due to termites was increased with a delay in harvest. Neither tillage depth nor harvest date affected peanut yield.

In the U.S., Lorsban applied for lesser cornstalk borer control at planting, at pegging, or at planting + at pegging did not affect the pod weight, pod moisture or aflatoxin in undamaged, scarified, or penetrated peanut pods under drought conditions. Dry pod weight for scarified and penetrated pods increased with an increase in the period of drought while soil moisture of the pods declined with an increase in the duration of the drought. Overall, aflatoxin was significantly greater in externally damaged pods than in undamaged pods, and significantly greater in penetrated pods than in externally damaged pods. A significant days x damage category interaction was noted as a result of a more rapid accumulation of aflatoxin in the seed of damaged pods, both externally damaged and penetrated, than in the seed from undamaged pods.

Lorsban applied as granules or pressure injected for lesser cornstalk borer control resulted in a higher percentage of undamaged peanut pods than was recorded for untreated peanuts. However, only Lorsban 15G significantly increased yield over that recorded for the untreated control.

Thrips damage among recommended peanut varieties in Georgia was significantly lower on Georgia Runner, GK-7, Southern Runner, and Sunrunner than on Florigiant. Leafhopper damage was significantly greater for Georgia Runner and NC 9 than on Southern Runner. Yield and value were greater on Georgia Runner, GK-7, and Sunrunner than for NC 7.

Laboratory evaluations of peanut germplasm for resistance or susceptibility to the corn earworm, fall armyworm, and velvetbean caterpillar resulted in highly significant differences in larval weight at 10 days and pupal weights when larvae were fed terminals or young leaves of the different lines.

GOALS

Major goals for the research are:

1. Identify peanut germplasm with resistance to termites, lesser cornstalk borer, aflatoxin formation, and rosette that can be utilized in breeding programs in West Africa and the U.S.

2. Identify the major mechanisms and interrelationships between insect damage to peanut pods, A. flavus invasion, and aflatoxin formation in seed.

3. Develop IPM strategies utilizing host plant resistance to insects, cultural practices, and indigenous plant products for insect control to reduce peanut losses to arthropods and aflatoxin.

4. Provide training for host country collaborators.

OBJECTIVES

A. Identify the major economic pests of peanut in Burkina Faso.

B. Determine the relationships between level and type of arthropod injury to peanut pods and aflatoxin contamination of preharvest and postharvest peanut.

C. Develop economic injury levels for the major arthropods by quantifying pest density or injury level with losses in peanut yield.

D. Develop reliable sampling procedures to estimate population densities of the major pests.

E. Determine arthropod abundance in relation to plant phenology and growing season in Burkina Faso.

F. Provide training for scientists and students from Burkina Faso.

G. Evaluate promising peanut lines from ICRISAT or lines developed by the Breeding CRSP for resistance or susceptibility to major arthropod pests.

H. Cooperate with the Texas A&M Breeding CRSP in the evaluation of germplasm for resistance to termite damage and aflatoxin contamination.

ORGANIZATION AND PERSONNEL

University of Georgia:

Dr. Robert E. Lynch, Principal Investigator, Insect Biology and Population Management Research Laboratory, USDA-ARS, Tifton, Georgia.

University of Ouagadougou, Institute Development Rurale:

Dr. Albert Patoin Ouedraogo, Collaborating Principal Investigator, University of Ouagadougou, IDR, Ouagadougou, Burkina Faso.

Dr. Idrissa Dicko, Collaborating Principal Investigator, University of Ouagadougou, IDR, Ouagadougou, Burkina Faso.

Cooperators:

International Crops Research Institute for the Semi-Arid Tropics, Sahelian Center, Sadore, Niger, and India Center, Andhra Pradesh, India.

Dr. Olin Smith, Principal Investigator, Peanut Breeding CRSP, Crop Science Department, Texas A&M University, College Station, Texas.

Dr. Philippe Sankara, Plant Pathologist, University of Ouagadougou, Ouagadougou, Burkina Faso.

Graduate Student, Research Project, Status:

Served on the graduate committee for Solibo J. A. Some: "Effect of Intercropping and Residue Management on Plant Water and Nutrient Use Efficiency, and Soil Properties." Solibo completed all requirements for his Ph.D. in June 1993.

APPROACH

During the initial stages of the project, research was conducted to define the major arthropod pests of peanut in Burkina Faso, to determine their abundance in relation to plant phenology in the different growing regions, and to evaluate local peanut cultivars for arthropod injury using two different cultural practices commonly used in Burkina Faso. The second phase of the research has been directed toward the following objectives:

A. Determine the economics of arthropod injury by using Temik to control thrips and jassids during the early portion of the growing season, and Lorsban to control soil arthropods during the latter portion of the growing season.

B. Determine the relationship between peanut harvest date and the extent of termite injury to pods and aflatoxin contamination of seeds.

C. Evaluate peanut lines, reported resistant to termites in India, for resistance to these insects and to aflatoxin contamination in Burkina Faso.

D. Determine the interrelation between soil moisture and pod injury by termites during the latter portion of the growing season.

E. Evaluate neem preparations for control of peanut insects in the field.

F. Determine the effect of peanut plant population and preplant tillage depth on insect damage to peanuts.

G. Cooperate with the Texas A&M Breeding project of the Peanut CRSP in the evaluation of crosses with termite resistant germplasm for extent of termite damage in Burkina Faso.

RESEARCH ACCOMPLISHMENTS

Burkina Faso

Effect of Plant Populations on Insects

Gampala

Significant differences were recorded in thrips, jassid, Lepidoptera, and termite damage in relation to peanut plant populations (Table 1). Thrips damage was significantly greater in plots with 120,000 and 180,000 plants/ha than damage in plots with 220,000 or 330,000 plants/ha. Jassid damage was significantly greater in plots with 330,000 plants/ha than damage in plots with 180,000 plants/ha or plots treated with insecticides, but was not significantly different than damage in plots with 120,000 or 220,000 plants/ha. Lepidopteran defoliation was significantly higher with plant populations of 120,000 and 180,000/ha than defoliation with 330,000 plants/ha, but did not differ from that at 220,000 plants/ha. Termite damage to plants was significantly greater in plots with 330,000 plants/ha than damage when plots were treated with insecticides.

The percentage of undamaged pods and scarified pods was not affected by peanut plant population (Table 2). Other than the insecticide treatment, which significantly increased the percentage of undamaged pods and decreased the percentage of scarified pods and penetrated pods, and increased yield compared with other treatments, differences among treatments were only noted in the percentage of penetrated pods. Although a significant greater percentage of penetrated pods was only noted at a plant population of 330,000 plants/ha compared with other plant populations, a trend for an increase in the percentage of penetrated pods with increased plant population was evident.

Farakoba

At Farakoba, no differences were observed in thrips damage, aphid abundance, or termite damage among plant populations (Table 3). Significant differences were noted in jassid damage and defoliation due to lepidopterous larvae, but differences were not directly related to plant population.

A significant treatment x harvest date interaction in the number of plants at harvest was noted (Table 4) and resulted from a greater decline in the number of plants for the 330,000 plants/ha on the second harvest compared with the decline noted among other treatments. Pod damage due to termites was low and differences were primarily in response to control of insects with insecticides rather than a response to plant population. Damage to pods significantly increased with a delay in harvest. A significant trend for increase in yield with increase in plant population was noted at Farakoba.

Effect of Harvest Date on Termite Damage

Gampala

At Gampala, peanut was harvested at 90, 100, 115, and 120 days after planting. Plots treated with Temik and Lorsban versus untreated plots were included for each harvest interval. Termite damage to plants was relatively low among all treatments with no consistent trend that could be related to harvest time (Table 5). However, plant damage in plots treated with Temik and Lorsban was significantly lower than plant damage in untreated plots for each harvest age. Conversely, pod damage by termites was substantial and pod scarification increased with plant age at harvest. Significant differences in post harvest pod

scarification between untreated and insecticide-treated plots was evident only at 110 days. The efficacy of the insecticide declined rapidly so that by 120 days no differences were noted in the percent pod scarification between treated and untreated plots.

Soil moisture at Gampala was low at all harvest ages and no consistent trend was noted that could be related to termite damage. However, analysis of results over several years showed that both pod scarification and pod penetration increased as soil moisture declined (Figure 1).

Peanut yield increased with age at harvest (Table 5). Yields from plots treated with insecticides were significantly greater than that from untreated plots at 110 and 120 days. Insecticides increased peanut yield by 17.2% at 110 days and 18.1% at 120 days.

Farakoba

At Farakoba, the percentage of undamaged pods declined and the percentage scarified and penetrated pods increased in untreated plots with each increase in plant age at harvest (Table 6). After 90 days, plots treated with insecticides had a significantly higher percentage of undamaged pods than their counterpart in untreated plots. Termite damage to plants also increased with age at harvest and insecticides reduced the damage at 110 and 120 days. Soil moisture declined at 110 days to approximately 2 percent, but increased at 120 days as a result of a late season rain. Yield was highly variable at Farakoba and no significant differences were detected with regard to either age at harvest or application of insecticides. However, insecticides increased yield by 35.6% over that for untreated plots at 120 days.

Termite Resistant Peanut Lines

Gampala

Seven peanut cultivars were selected from previous studies for continued evaluation for termite resistance. TMV-2 was selected because it is susceptible to termite damage. The NCAc lines and RMP 40 have shown promising resistance to plant or pod damage in previous studies. TS 32-1 is a recommended cultivar for the region and was included as a check. All cultivars were planted at equal populations, but significant differences in number of plants/row were recorded at harvest (Table 7). Plant population was significantly higher for TMV-2 and TS 32-1 at harvest than for all other cultivars, and significantly higher for NCAc 2242 than for NCAc 343 and NCAc 2243.

A significant cultivar x harvest date interaction was noted for the percent undamaged, scarified, and penetrated pods. These interactions resulted from the differences in damage among cultivars between the two harvest dates; although significant, differences among cultivars were only slight when they were harvested October 16, while differences among cultivars increased substantially when the harvest was delayed to October 31. For the delayed harvest, TMV-2 and TS 32-1 had a significantly lower percentage of undamaged pods than all other cultivars. NCAc 2240 and NCAc 2243 had the highest percentage of undamaged pods with greater than 90% undamaged even with a delayed harvest. At the first harvest, NCAc 343 had a significantly higher percentage of scarified pods than any other cultivar. However, by the later harvest, scarification and pod penetration for NCAc 343 was significantly lower than they were for the susceptible check, TMV-2. Pod scarification was significantly lower for all cultivars than for TMV-2 on the second harvest date, with the exception of TS 32-1. Scarification was least for NCAc 2240 and NCAc 2243. Pod penetration with the delayed harvest was significantly lower on all cultivars than for TMV-2.

Termites may also damage peanut plants by tunneling in the tap root which results in plant wilting and death. The number of plants killed by termites was affected both by peanut cultivar and by harvest date (Table 7). Damage to plants was highest for TMV-2 and RMP 40, significantly higher than for NCAc 2243 and NCAc 343.

Peanut yield was substantially greater for NCAc 343 than for any of the other cultivars evaluated. NCAc 343 yielded more than twice that of its nearest competitor even with the lowest plant population of all cultivars evaluated. Yields were least for NCAc 2240, 2242, and 2243.

Farakoba

At Farakoba, the number of plants/row at harvest was significantly higher for RMP 40 than for all other cultivars (Table 8). Plant numbers were not affected by harvest date.

Significant cultivar x harvest date interactions were noted in the number of termite-damaged plants, percentage of externally damaged, penetrated, and undamaged pods and yield (Table 8). Analysis by harvest date showed that all cultivars had a higher percentage of undamaged pods than TMV-2 for the first harvest, but that pod damage had increased by 25% for TS 32-1 while only increasing 2 to 4% on some of the more resistant cultivars for the delayed harvest. NCAc 343, 2240, 2243 and RMP 40 had over 90% undamaged pods on the second harvest, while TMV-2 had only 35% undamaged pods. Similarly, the percentage of scarified pods, penetrated pods and termite damaged plants increased much more for TMV-2 and TS 32-1 between the two harvests than for the more resistant cultivars.

Analysis of yield by harvest date showed that the yield for NCAc 343 did not differ from the yield of TMV-2 for the first harvest, but, by the second harvest, yield for NCAc 343 had increased and was significantly greater than that for all cultivars except TS 32-1. Between the two harvests, yields increased for NCAc 343, 2240, 2243, TS 32-1, and RMP 40 while declining for TMV-2 and NCAc 2243.

Effect of Preplant Tillage Depth on Termite Damage

Gampala

Tillage prior to planting may destroy termite tunnels which may in turn affect termite damage to peanut plants and pods. This concept was evaluated at Gampala by tillage to a depth of approximately 0, 25, or 50 cm before planting. Tillage depth did not affect plant populations at harvest or the percentage of undamaged, scarified, or penetrated pods (Table 9). However, the number of plants killed by termites declined with increase in tillage depth. Yield of peanuts also was not affected by tillage depth.

Harvest date did not influence number of plants at harvest or yield. However, the percentage of undamaged pods declined while the percentage of scarified pods, penetrated pods, and damaged plants increased with a delay in harvest.

Aflatoxin

ELISA analyses for aflatoxin in the above tests are being conducted in Burkina Faso by Mr. Ollé Kam, who was trained in the Mycotoxin Laboratory, Coastal Plain Experiment Station, University of Georgia, Tifton, GA, during the last year. However, the data have not been received for inclusion in the annual report.

Georgia

Lesser Cornstalk Borer Damage to Peanut Pods and Aflatoxin

The lesser cornstalk borer is a major pest of peanut in the southeastern U.S. and damages peanut pods in a similar manner to that produced by termites in Africa, i.e., both scarify and penetrate pods. The interaction of pod damage was studied at Tifton, GA, with the aid of moveable greenhouses to induce drought during the latter part of the growing season and to confine lesser cornstalk borers. Plots were treated with Lorsban at planting, at pegging, at planting and at pegging, or untreated. Peanut was grown under normal field conditions until 85 days after planting. At 85 days, the moveable greenhouses were pulled over the plots so that they excluded rain and the cages were infested with lesser cornstalk borer moths. Moths laid eggs among peanut plants to initiate an infestation that resulted in substantial damage to the peanut pods. A 3-m plot from each plot was sampled at 14, 28, 42, 56, and 70 days after initiating the drought, and the pods from each plot were separated into undamaged, externally damaged (scarified), and penetrated categories. Pods from each damage category were weighed fresh, dried in an oven and reweighed, analyzed for Aspergillus flavus infection in pods and seed, and the seed were analyzed for aflatoxin. The experiment was designed and analyzed as a split-split plot with insecticide treatment as the main plot, days of drought as the subplot, and pod damage category as the sub-subplot.

The portable greenhouses and artificial infestation technique with lesser cornstalk borer adults produced excellent results, both from the standpoint of inducing drought stress and severe pod damage due to the feeding of lesser cornstalk borer larvae. Insecticides applied at planting and at pegging reduced lesser cornstalk borer only slightly, probably due to rapid dissipation of insecticide activity during severe drought. Therefore, application of insecticides did not affect aflatoxin in peanut seeds (Table 10). No differences were noted for the insecticide treatments among the pod damage categories for pod weight, or aflatoxin concentration in seed.

A significant insecticide treatment x damage category interaction was noted for pod moisture content (Table 10). Analysis by treatment showed that the moisture content in undamaged pods was significantly higher than the moisture in scarified or penetrated pods. Thus, either external damage or pod penetration by the lesser cornstalk borer results in a more rapid water loss from pods and enhances A. flavus contamination and aflatoxin formation.

A significant insecticide treatment x age of peanut at harvest was also noted in aflatoxin. Analysis of this interaction within a harvest age showed that at 99 days, no differences among treatments were noted in aflatoxin contamination (Figure 2). At 113, aflatoxin concentration was significantly higher in seed when Lorsban was applied at planting + at pegging than that for all other treatments. At 127 days, no differences in aflatoxin concentration were noted again. At 141 days, aflatoxin in seed from untreated peanuts was significantly lower than aflatoxin in seed where Lorsban was applied at planting. At 155 days, aflatoxin in seed from plots treated with Lorsban at planting + at pegging was significantly higher than aflatoxin in seed from plots treated with Lorsban only at pegging. Thus, no consistent trend was evident in the contamination of peanut seed with aflatoxin could be detected with regard to insecticide application to control the lesser cornstalk borer and age at which the peanuts were harvested.

A significant age at harvest x damage category interaction was also noted for aflatoxin contamination. This interaction occurred as a result of the rate of aflatoxin accumulation in peanut pods damaged by the lesser cornstalk borer (Figure 3). At 99 days, aflatoxin concentration in seed from externally damaged pods was intermediate between that found in seed from undamaged and penetrated peanut pods. By 113 days, aflatoxin concentration in seed was significantly different among all three damage classes of pods. However, at 127 days through 155 days, aflatoxin accumulation in seed from scarified pods was equivalent to

that in seed from penetrated pods, and aflatoxin concentration in seed from both damage categories was significantly higher than that found in seed from undamaged pods. Thus, aflatoxin accumulated significantly in seed from pods that are only externally damaged by the lesser cornstalk borer than in undamaged peanut pods.

Efficacy of Lorsban Applied as Granules, Spray, or Pressure Injected

Application of granular insecticides for insect control in agricultural crops is under severe scrutiny by EPA. Thus, alternate application methods are needed to control soil insects such as the lesser cornstalk borer in peanut. Cooperative research has been conducted over the last few years with Cross Equipment Corp. to evaluate the efficacy of pressure injecting liquid Lorsban in peanut for insect control. Commercial equipment is currently available for pressure injecting insecticides below the soil surface in turf. This equipment was modified to inject Lorsban on both sides of a peanut row at pegging. Six injection nozzles were spaced 4 inches apart, three on each side of the row. Lorsban was applied at 2.24 kg/ha as a spray (4EC), granules (15G), or pressure injected (4EC-PI) at approximately 40 days after planting. In 1992, an additional treatment of pressure injecting Lorsban mixed with SM-9, a surfactant, (4EC+-PI) was included.

Lorsban applied as granules or pressure injected resulted in a significantly higher percentage of undamaged peanut pods than was recorded for the untreated control (Figure 4). This reduction in pod damage was primarily due to the effect of the insecticide in reducing pod scarification by the lesser cornstalk borer. Plots treated with Lorsban granules and both pressure injection treatments had significantly fewer externally damaged peanut pods than did the untreated control. However, only Lorsban applied as a granule significantly increased peanut above that for the untreated control.

Insect Damage on Recommended Cultivars

Nine peanut cultivars that are recommended for production in Georgia were evaluated in the field and laboratory for differences in their susceptibility to insect damage. Thrips damage in the field was significantly higher for Florigiant than damage for GK-7, Southern Runner, Georgia Runner, Florunner, and NC 9 (Table 11). Thrips damage was also significantly lower on GK-7, Southern Runner, and Georgia Runner than damage on GK-3 and NC 7.

Potato leafhopper damage ratings were highest on Georgia Runner and NC 9, significantly higher than those recorded for Florunner, Southern Runner, Sunrunner, and GK-3. Leafhopper damage rating was lowest for Southern Runner, significantly lower than the rating for Georgia Runner, NC 9, and Sunrunner.

Peanut yield was significantly greater for Georgia Runner than for NC 7 and Southern Runner, but not significantly greater than the yield for Florunner, GK-7, Florigiant, Sunrunner, GK-3, or NC 9. Grade evaluations showed that Georgia Runner also had a significantly higher percentage of sound mature kernels (SMK) than for any of the other cultivars (Table 11). Florunner and GK-7 also had significantly higher SMK's than the other cultivars. These higher SMK's combined with their yield resulted in a significantly higher value for Georgia Runner, GK-7, and Sunrunner than value for NC 7. Value for the other cultivars were intermediate between those for Georgia Runner and NC 7.

Evaluation of Plant Introductions for Resistance to Insects

Forty-six peanut lines were evaluated in the field and laboratory for resistance or susceptibility to insects. Laboratory assays were conducted by removing terminals, flowers, or both from plants in the field and feeding them to larvae in the laboratory. Data were recorded on survival of larvae at 6 days, larval weight at 10 days, days to pupation, pupal weight, survival to pupation, days to adults, survival to adults, and sex. Assays were conducted for the corn earworm,

Helicoverpa zea, the fall armyworm, Spodoptera frugiperda, and the velvetbean caterpillar, Anticarsia gemmitalis.

Significant differences were noted among peanut lines in several of the biological parameters measured for each insect (Table 12). However, differences in host suitability index, a measure of the combined resistance on different biological parameters, were only noted among varieties for the velvetbean caterpillar. The failure to detect differences among peanut lines for the corn earworm and fall armyworm was due to more variability within a line for these insects. Interestingly, a number of the crosses with NCAc 343 or NCAc 302 as one parent, especially NC 7 x NC 343 (29), were rated among the most resistant lines affecting one or more of the biological parameters for all 3 insects. NCAc 343 has been reported to have moderate resistance to thrips, leafhoppers, corn earworm, and southern corn rootworm.

PUBLICATIONS AND PRESENTATIONS

Publications:

Dicko, O., R. E. Lynch, and H. Batchomo. 1992. Evaluation of some groundnut varieties for resistance against termite (Isoptera: Termitidae) and julid (Myriapods: Diplopods) damaged pods in Burkina Faso. Intern. Arachis Newsltr. 11: 29-30.

Mack, T. P., D. P. Davis, and R. E. Lynch. 1993. Development of a system to time scouting for the lesser cornstalk borer (Lepidoptera: Pyralidae) attacking peanut in the Southeastern U.S. J. Econ. Entomol. 86: 164-173.

Lynch, R. E., and G. K. Douce. 1992. Implementation of integrated pest management program in peanut: Current status and future direction. Pages 267-278 in Groundnut - a global perspective. Proc. Second International Groundnut Workshop, 25-29 Nov. 1991, ICRISAT Center, Patancheru, A.P., India.

Presentations:

Lynch, R. E., I. O. Dicko, and A. P. Ouedraogo. 1992. Termite damage to groundnut: Interaction with soil moisture and Aspergillus flavus, and evaluation of cultivars for resistance to pod damage. Fourth Regional Groundnut Workshop for West Africa, Ouagadougou, Burkina Faso, November 7-9, 1992.

Lynch, R. E., and J. R. Chamberlin. 1992. Sweetpotato whitefly populations on Florunner and Southern Runner peanuts. Entomol. Soc. Amer., Baltimore, MD, December 5-9, 1992.

Lynch, R. E., and J. R. Chamberlin. 1993. Sweetpotato whitefly: Distribution, sampling, and potential for damage on peanut. Ga. Entomol. Soc., Athens, GA, March 24-26, 1993.

Chamberlin, J. R., W. G. Hudson, and R. E. Lynch. 1993. Winter ecology of sweetpotato whitefly in southwest Georgia. Southeastern Branch, Entomological Society of America, Little Rock, AR, March 7-10, 1993.

Lynch, R. E., D. M. Wilson, A. P. Ouedraogo, and I. O. Dicko. 1993. Aflatoxin in peanuts: The role of insects in enhancing contamination. Am. Peanut Res. Educ. Soc., Huntsville, AL, July 13-16,1993.

Lynch, R. E. 1992. Distribution of sweetpotato whitefly, Bemisia tabaci (Gennadius), larvae on peanut. Southeastern Branch, Entomological Society of America, Savannah, GA, March 8-11, 1992.

TRAINING

The following students at the University of Ouagadougou work on research conducted by the Peanut CRSP in Burkina Faso and utilize the data for papers as required by their curriculum for graduation:

Hubert Bathomo	-	5th cycle
Hamado Tapsoba	-	5th cycle
Karim Traore	-	5th cycle
Hamado Sawadago	-	5th cycle
Sanou A. Ntoine	-	3rd cycle
Issoufou Ouedraogo	-	3rd cycle

Mr. Solibo Somé, former assistant collaborator on the Peanut CRSP Entomology Project, has been attending the University of Georgia to obtain his Ph.D. in agronomy working under the direction of Dr. Bill Hargrove. Dr. Lynch served on the graduate committee for Mr. Somé. All requirements for his Ph.D. were completed in June 1993.

Mr. Ollé Kam, assistant in the Peanut CRSP Entomology Project in Burkina Faso, spent 2 weeks in the Mycotoxin Laboratory, University of Georgia, Coastal Plain Experiment Station, Tifton, GA receiving training in aflatoxin analysis using the Vicam Elisa aflatoxin analysis system.

INTERNATIONAL TRAVEL

U.S. Participants

Dr. Robert E. Lynch was invited to make a presentation and participated in the Fourth Regional Groundnut Workshop In Ouagadougou, Burkina Faso, September 14-17, 1992.

Host Country Participants

Drs. Idrissa Dicko and Albert Ouedraogo attended the Fourth Regional Groundnut Workshop In Ouagadougou, Burkina Faso.

Mr. Ollé Kam, assistant in the Peanut CRSP Entomology Project in Burkina Faso, traveled to Tifton, GA to receive training in aflatoxin analysis at the Mycotoxin Laboratory, University of Georgia, Coastal Plain Experiment Station.

PLANS FOR 1993/94

Burkina Faso

1. Determine the effect of peanut plant population on insect populations, incidence of rosette, and yield.

2. Evaluate the interactions of peanut harvest date, soil insect control, and pod injury on aflatoxin formation in peanut with primary emphasis on soil moisture and termite injury to peanut pods.

3. Evaluate termite-resistant peanut lines from ICRISAT, India, for resistance to termite injury and aflatoxin formation in Burkina Faso.

4. Evaluate the effects of preplant tillage depth on termite damage to peanut plants and pods.

Georgia

1. Determine the mechanism for increased aflatoxin contamination in peanut pods externally injured by insect feeding.

2. Determine rates of water loss for uninjured peanut pods and externally scarified pods due to lesser corn borer feeding.

3. Continue to evaluate peanut genotypes for resistance to insects in Georgia.

4. Evaluate a Peanut Core Collection for resistance or susceptibility to insects.

5. Determine the efficacy and longevity of Lorsban using pressure-injection and granular application techniques for control of the LCB.

6. Evaluate peanut cultivars and genotypes for resistance or susceptibility to the sweetpotato whitefly.

7. Evaluate peanut germplasm with resistance to termites in West Africa for resistance to lesser cornstalk borer damage and aflatoxin contamination in Georgia.

Table 1. Effect of peanut plant population on insect damage to peanut plants at Gampala, Burkina Faso (1992).[1]

Plant Population (No./ha)	No. Plants Sampled	Insect Ratings[2]				No. Plants with Rosette	No. Termite Damaged Plants
		Thrips Damage	Jassids Damage	Lep. Defol.[3]	Aphid Abun.[4]		
120,000	4.7 b	6.2 a	0.5 ab	2.5 a	0.5 ab	0 a	1.0 ab
180,000	4.6 b	6.0 a	0.3 b	3.0 a	0.3 b	0 a	1.4 ab
220,000	8.9 a	4.0 b	0.5 ab	1.7 ab	0.5 ab	0 a	2.8 ab
330,000	9.4 a	3.3 b	0.9 a	0.8 b	0.9 a	0 a	4.0 a
Treated[5]	9.1 a	2.4 b	0.3 b	1.0 b	0.3 b	0 a	0.4 b

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan.

[2] Insect damage rated on a 0-10 scale, where 0 = no damage and 10 = 100% damage.

[3] Defoliation due to feeding by Lepidoptera.

[4] Aphid abundance rated on a 0-3 scale, where 0 = no aphids, 1 = 1-10 aphids, 2 = 11-100 aphids, 3 = > 100 aphids present.

[5] Planted at 220,000 plants/ha and treated with aldicarb (5.6 kg/ha) at planting, aldicarb (7.5 kg/ha) at 40 days after planting, and chlorpyrifos (7.5 kg/ha) at 40 and 90 days after planting.

Table 2. Effect of peanut plant population and harvest date on termite damage to pods and yield at Gampala, Burkina Faso (1992).[1]

Plant Population (No./ha)	No. Plants at Harvest	Pod Damage (%)			Yield (kg/ha)
		Undamaged	Scarified	Penetrated	
120,000	92.9 b	75.2 b	20.8 a	4.0 bc	2134.0 b
180,000	91.0 b	74.5 b	20.3 a	5.1 b	1951.0 b
220,000	139.3 a	64.2 b	29.9 a	5.9 b	2709.6 b
330,000	156.1 a	64.5 b	25.6 a	10.0 a	2015.2 b
Treated[2]	147.5 a	93.5 a	5.5 b	1.2 c	3615.7 a
Harvest Date					
October 18	123.2 a		14.6 b	5.3 a	2634.3 a
November 2	127.5 a		26.2 a	5.2 a	2335.9 b

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan for plant population means or LSD for harvest date means.

[2] Planted at 220,000 plants/ha and treated with aldicarb (5.6 kg/ha) at planting, aldicarb (7.5 kg/ha) at 40 days after planting, and chlorpyrifos (7.5 kg/ha) at 40 and 90 days after planting.

Table 3. Effect of peanut plant population on insect damage to peanut plants at Farakoba, Burkina Faso (1992).[1]

Plant Population (No./ha)	Insect Ratings[2]				No. Plants with Rosette	No. Termite Damaged Plants
	Thrips Damage	Jassids Damage	Lepidoptera Defoliation[3]	Aphid Abundance[4]		
120,000	5.6 b	4.0 ab	5.0 ab	0.4 a	2.0 b	8.4 a
180,000	5.2 b	3.4 bc	4.6 b	0.8 a	3.8 ab	7.2 a
220,000	5.4 b	4.2 a	5.2 ab	0.2 a	3.0 ab	7.4 a
330,000	5.6 b	3.8 ab	5.4 a	0.6 a	4.4 a	10.2 a
Treated[5]	3.8 a	2.8 c	3.4 c	0.2 a	3.0 ab	5.0 a

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan.

[2] Insect damage rated on a 0-10 scale, where 0 = no damage and 10 = 100% damage.

[3] Defoliation due to feeding by Lepidoptera.

[4] Aphid abundance rated on a 0-3 scale, where 0 = no aphids, 1 = 1-10 aphids, 2 = 11-100 aphids, 3 = > 100 aphids present.

[5] Planted at 220,000 plants/ha and treated with aldicarb (5.6 kg/ha) at planting, aldicarb (7.5 kg/ha) at 40 days after planting, and chlorpyrifos (7.5 kg/ha) at 40 and 90 days after planting.

Table 4. Effect of peanut plant population and harvest date on termite damage to pods and yield at Farakoba, Burkina Faso (1992).[1]

Plant Population (No./ha)	No. Plants at Harvest*		Pod Damage (%)			Yield (kg/ha)
	Oct. 13	Oct. 28	Undamaged	Scarified	Penetrated	
120,000	89.4 b	82.2 c	93.9 ab	3.2 ab	1.8 a	2358.3 c
180,000	89.0 b	82.4 c	93.7 ab	3.4 ab	1.8 a	2645.0 bc
220,000	163.6 a	149.0 a	93.0 ab	3.6 ab	2.2 a	2961.8 b
330,000	155.8 a	127.0 b	91.4 b	5.3 a	2.4 a	3602.7 a
Treated[2]	156.4 a	156.6 a	95.5 a	2.7 b	1.7 a	4101.5 a
Harvest Date						
October 18	-	-	95.7 a	2.0 b	2.3 b	3075.1 a
October 28	-	-	91.2 b	5.2 a	3.5 a	3192.6 a

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan for plant population means or LSD for harvest date means.

[2] Planted at 220,000 plants/ha and treated with aldicarb (5.6 kg/ha) at planting, aldicarb (7.5 kg/ha) at 40 days after planting, and chlorpyrifos (7.5 kg/ha) at 40 and 90 days after planting.

* Significant plant population x harvest date interaction.

Table 5. Effect of peanut harvest date on termite damage to plants and pods at Gampala, Burkina Faso (1992).[1]

Plant Age at Harvest	No. Plants at Harvest	Postharvest Pod Damage (%)			No. Termite Damaged Plants	Soil Moisture (%)	Yield (kg/ha)
		Undamaged	Scarified	Penetrated			
90 Days	317.0 a	94.8 a	3.6 b	1.6 a	3.4 bc	1.46 a	1703.7 c
90-Treated[2]	310.8 a	97.0 a	2.3 b	0.8 a	0.8 e	1.37 a	1854.3 abc
100 Days	318.2 a	91.1 a	7.4 b	1.6 a	2.8 c	0.95 b	1836.1 abc
100-Treated[2]	285.0 a	93.9 a	4.7 b	1.0 a	1.2 e	0.88 b	2093.5 a
110 Days	310.8 a	74.8 bc	22.5 a	2.7 a	4.4 ab	1.35 a	1686.4 c
110-Treated[2]	293.8 a	87.5 ab	7.2 b	5.3 a	1.6 de	1.47 a	2036.7 ab
120 Days	296.8 a	65.3 c	30.4 a	4.4 a	5.2 a	0.91 b	1729.4 bc
120-Treated[2]	303.0 a	75.9 bc	22.5 a	2.1 a	2.6 cd	1.01 b	2110.6 a

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan.

[2] Aldicarb app ied at planting at 5.6 kg/ha and 40 days after planting at 7.5 kg/ha. Chlorpyrifos applied at 40 and at 90 days after planting at 7.5 kg/ha.

Table 6. Effect of peanut harvest date on termite damage to plants and pods at Farakoba, Burkina Faso (1992).[1]

Plant Age at Harvest	No. Plants at Harvest	Postharvest Pod Damage (%)			No. Termite Damaged Plants	Soil Moisture (%)	Yield (kg/ha)
		Undamaged	Scarified	Penetrated			
90 Days	276.6 a	94.7 ab	2.9 bc	2.5 c	1.6 c	5.0 b	1368.6 a
90-Treated[2]	277.4 a	95.9 a	2.0 c	2.2 c	0.4 c	5.0 b	2059.0 a
100 Days	279.8 a	91.3 b	6.2 b	2.6 c	3.0 c	9.5 a	1583.6 a
100-Treated[2]	271.8 a	96.0 a	2.4 bc	1.7 c	1.2 c	9.2 a	1657.6 a
110 Days	262.6 a	84.7 c	10.2 a	5.6 b	18.4 a	2.4 c	1985.2 a
110-Treated[2]	268.8 a	93.8 ab	3.8 bc	2.5 c	10.0 b	2.1 c	2564.1 a
120 Days	257.3 a	80.1 d	13.1 a	7.9 a	21.3 a	4.2 b	1475.8 a
120-Treated[2]	260.2 a	92.7 ab	4.2 bc	3.1 c	11.0 b	4.4 b	2237.1 a

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan.

[2] Aldicarb applied at planting at 5.6 kg/ha and 40 days after planting at 7.5 kg/ha. Chlorpyrifos applied at 40 and at 90 days after planting at 7.5 kg/ha.

Table 7. Evaluation of termite-resistant peanut cultivars for resistance to termite damage at Gampala, Burkina Faso (1992).[1]

Cultivar	No. Plants at Harvest	Pod Damage (%)						No. Termite Damaged Plants	Yield (kg/ha)
		Undamaged		Scarified *		Penetrated *			
		Oct. 16	Oct. 31	Oct. 16	Oct. 31	Oct. 16	Oct. 31		
THV-2	155.5 a	92.9 d	64.7 d	4.6 b	22.0 b	2.6 ab	13.4 a	8.4 a	1164.4 b
NCAc 343	98.1 c	91.0 e	78.1 c	6.5 a	16.5 c	2.6 ab	5.4 c	3.6 bc	3362.8 a
NCAc 2240	110.2 bc	97.3 a	92.8 a	1.3 d	3.9 e	1.5 b	3.4 d	5.3 abc	701.0 c
NCAc 2242	123.1 b	96.7 ab	85.5 b	1.0 d	8.7 d	2.3 ab	5.9 c	6.5 ab	614.5 c
NCAc 2243	102.0 c	96.6 ab	93.1 a	1.2 d	2.1 e	2.4 ab	4.8 cd	2.4 c	637.9 c
TS 32-1	149.3 a	94.2 c	62.7 d	3.6 c	28.6 a	2.2 ab	8.7 b	7.2 ab	1240.0 b
RMP 40	113.0 bc	95.6 b	87.7 b	1.4 d	7.9 d	3.1 a	4.3 cd	8.3 a	1486.6 b
Harvest Date									
October 16	123.7 a	-	-	-	-	-	-	4.9 b	1231.6 a
October 31	119.5 a	-	-	-	-	-	-	7.1 a	1406.5 a

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan for cultivar means or LSD for harvest date means.

* Significant Cultivar x Harvest Date interaction.

Table 8. Evaluation of termite-resistant peanut cultivars for resistance to termite damage at Farakoba, Burkina Faso (1992).[1]

Cultivar	No. Plants at Harvest	Pod Damage (%)						No. Termite Damaged Plants *		Yield (kg/ha) *	
		Undamaged *		Scarified *		Penetrated *					
		Oct. 18	Nov. 2	Oct. 18	Nov. 2	Oct. 18	Nov. 2	Oct. 18	Nov. 2	Oct. 18	Nov. 2
THV-2	107.8 bc	71.1 d	35.1 d	21.2 a	33.3 a	7.8 a	31.7 a	28.0 a	74.3 a	2137.6 a	1732.4 bcd
ICAc 343	112.9 b	93.4 b	91.3 ab	2.2 cd	3.2 c	4.4 b	5.5 c	0.5 b	3.3 c	2503.9 a	3008.9 a
ICAc 2240	89.6 cd	95.7 a	91.6 ab	1.3 d	4.3 c	3.1 bc	4.1 c	2.3 b	3.8 c	985.2 cd	1155.9 de
ICAc 2242	105.9 bc	93.4 b	89.1 b	3.0 c	3.9 c	3.6 bc	6.6 c	1.3 b	3.3 c	1140.4 cd	1304.2 cde
ICAc 2243	83.8 d	96.3 a	92.6 a	1.2 d	2.9 c	2.6 c	4.9 c	0.8 b	3.3 c	761.0 d	656.0 e
TS 32-1	123.9 b	83.9 c	58.3 c	11.4 b	25.1 b	4.8 b	16.9 b	20.5 a	49.3 b	2204.3 ab	2295.5 ab
RHP 40	151.3 a	95.1 ab	91.1 ab	2.4 cd	4.0 c	2.5 c	4.9 c	2.5 b	2.5 c	1576.4 bc	2134.4 bc
Harvest Date											
October 16	112.7 a	-	-	-	-	-	-	-	-	-	-
October 31	108.7 a	-	-	-	-	-	-	-	-	-	-

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan for cultivar mean or LSD for harvest date means.

* Significant Cultivar x Harvest Date interaction.

Table 9. Effect of preplant tillage depth and harvest date on termite damage to pods and yield of peanut at Gampala, Burkina Faso (1992).[1]

Tillage Depth (cm)	No. Plants at Harvest	Pod Damage (%)			No. Termite Damaged Plants	Yield (kg/ha)
		Undamaged	Scarified	Penetrated		
0	200.5 a	71.8 a	21.2 a	6.7 a	14.2 a	1020.6 a
25	165.7 a	76.7 a	17.8 a	5.7 a	5.5 ab	1552.5 a
50	220.1 a	73.2 a	19.5 a	7.1 a	2.8 b	1060.2 a
Harvest Date						
October 28	196.2 a	82.4 a	11.5 b	5.9 b	7.0 b	1257.4 a
November 12	194.7 a	65.4 b	27.6 a	7.0 a	8.0 a	1164.9 a

[1] Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan for tillage depth means or LSD for harvest date means.

Table 10. Effect of insecticide, lesser cornstalk borer damage, and length of drought period on pod weight, pod moisture, and aflatoxin in 'Florunner' peanut, Tifton, GA, 1992.

Treatment	Dry Pod Weight (g)[1]			Pod Moisture (%)[1]			Log Aflatoxin (PPB)[1]		
	Undamaged	Scarified	Penetrated	Undamaged	Scarified	Penetrated	Undamaged	Scarified	Penetrated
Untreated	91.0 a	68.3 a	36.7 a	23.6 A	19.1 B	19.3 B	3.16 a	3.99 a	4.77 a
Lorsban-AP[2]	99.9 a	79.2 a	30.8 a	22.8 A	19.1 B	18.9 B	3.52 a	4.01 a	4.20 a
Lorsban-P[2]	106.7 a	67.4 a	32.2 a	25.2 A	19.5 B	19.1 B	2.73 a	4.01 a	4.30 a
Lorsban-AP+P[2]	108.7 a	50.2 a	29.0 a	27.3 A	20.5 B	20.8 B	3.32 a	4.18 a	4.68 a
Days									
14	254.8 a	22.0 c	15.7 c	50.1 a	44.9 a	48.2 a	1.10 B	1.54 AB	2.23 A
28	112.9 b	60.2 b	32.1 b	32.3 b	24.0 b	23.6 b	3.19 C	4.41 B	4.82 A
42	57.9 c	73.2 ab	35.8 ab	16.9 c	12.4 c	11.0 c	3.46 B	4.50 A	5.13 A
56	37.3 d	81.8 a	41.2 a	13.9 d	7.4 d	6.7 d	3.82 B	4.85 A	5.02 A
70	55.0 c	81.7 a	40.0 a	12.9 d	8.8 d	9.0 d	4.08 B	5.00 A	5.23 A
Mean	103.6	63.8	33.0	25.2	19.5	19.7	3.13 C	4.06 B	4.49 A

[1] Means within a column for each treatment or age followed by the same lower case letter are not significantly different ($P \leq 0.05$) using LSD. Means within a row followed by the same upper case letter are not significantly different ($P \leq 0.05$) using LSD.

[2] AP = At planting; P = At pegging; AP + P = At planting and at pegging.

Table 11. Evaluation of peanut varieties recommended in Georgia for resistance/susceptibility to insects, Tifton, GA, 1992.[1]

Cultivar	Thrips Damage Rating	Leafhopper Damage Rating	Yield (lb/A)	Total Sound Mature Kernels (%)	Value ($/A)
Florunner	4.2 bc	5.8 bc	2418 a-c	77.4 b	1038.70 ab
Georgia Runner	4.0 c	6.8 a	2934 a	78.9 a	1171.80 a
GK-7	4.0 c	6.4 a-c	2908 a	77.3 b	1105.70 a
Southern Runner	4.0 c	5.7 c	2248 bc	75.8 c	1013.20 ab
Florigiant	4.8 a	6.2 a-c	2681 ab	73.1 d	1052.70 ab
Sunrunner	4.0 c	6.5 ab	2829 ab	75.5 c	1141.30 a
GK-3	4.6 ab	5.8 bc	2797 ab	72.2 d	1038.00 ab
NC 7	4.6 ab	6.0 a-c	1961 c	70.3 e	800.50 b
NC 9	4.2 bc	6.8 a	2586 ab	73.4 d	1064.60 ab

[1] Means within a column for an insect followed by the same letter are not significantly different ($P \leq 0.05$) using Waller-Duncan.

Table 12. Evaluation of peanut lines for resistance/susceptibility to insects, Tifton, GA, 1992.

Rating	Larval Wt. @ 10 Days		Days to Pupation		Host Suitability Index	
	Variety	Wt. (g)[1]	Variety	Days[1]	Variety	Index[1]
Corn Earworm						
Sus[2] 1	GAT 2741	200.3 a	279627	17.9 j	197702	12.3 a
Sus 2	GAT 2847	172.9 ab	179630	18.0 ij	259829	12.2 a
Sus 3	279627	168.6 a-c	GAT 2845	18.1 h-j	NC7xNC10247 (36)	11.5 a
Sus 4	196725	154.4 a-d	298867	18.4 g-j	GAT 2736	11.5 a
Sus 5	298867	154.3 a-d	GAT 2847	18.4 f-g	279625	11.5 a
Res[3] 1	442605	53.3 m	NC6	21.1 a	179630	5.2 a
Res 2	NC7xNC343 (29)	55.3 lm	GAT 2844	20.8 ab	196638	5.6 a
Res 3	NC6	61.0 k-m	GAT 2843	20.7 a-c	NC7xNC343 (29)	5.7 a
Res 4	Florunner	66.7 j-m	442605	20.5 a-d	203397	6.2 a
Res 5	259789	67.3 i-m	Florunner	20.4 a-e	378165	6.4 a
Fall Armyworm						
Sus 1	GAT 2845	367.7 a	GAT 2845	14.1 d	NC7xNC343 (32)	10.7 a
Sus 2	183916	338.1 ab	GAT 2846	14.2 cd	Florunner	9.9 a
Sus 3	196612	331.4 a-c	378165	14.3 b-d	298867	9.6 a
Sus 4	GAT 2847	330.7 a-c	GAT 2847	14.3 b-d	NC7xNC343 (30)	9.6 a
Sus 5	GAT 2846	328.4 a-d	GAT 2736	14.4 a-d	306230	9.1 a
Res 1	NC7xNC302 (33)	199.6 l	NC7xNC343 (29)	15.5 a	203397	4.5 a
Res 2	442605	209.5 kl	NC7xNC302 (33)	15.4 ab	442605	4.5 a
Res 3	NC7xNC343 (32)	217.4 j-l	196617	15.3 a-c	196627	4.7 a
Res 4	NC7xNC343 (29)	217.6 j-l	279627	15.3 a-c	259739	5.1 a
Res 5	306230	219.5 j-l	Florunner	15.3 a-d	NC7xNC10247 (35)	5.1 a

Table 12. (Continued)

Rating	Larval Wt. @ 10 Days		Days to Pupation		Host Suitability Index	
	Variety	Wt. (g)[1]	Variety	Days[1]	Variety	Index[1]
Velvetbean Caterpillar						
Sus 1	GAT 2845	177.1 a	GAT 2845	17.9a	NC7xNC10247 (36)	9.4 a
Sus 2	GAT 2847	150.3 ab	298867	17.9 a	196702	9.2 ab
Sus 3	196612	144.4 a-c	GAT 2846	18.0 a	203397	8.9 a-c
Sus 4	GAT2736	134.2 a-d	196612	18.1 a	259633	8.8 a-d
Sus 5	298867	134.2 a-d	GAT 2844	18.1 a	279627	8.7 a-d
Res 1	NC7xNC343 (29)	58.3 e	NC7xNC343 (29)	21.4 a	NC6	5.0 e
Res 2	NC7xNC343 (31)	75.2 de	GAT 2742	21.2 a	196612	5.9 de
Res 3	203397	77.2 de	NC7xNC302 (34)	20.6 a	NC343	6.0 c-e
Res 4	NC6	78.6 de	NC6	20.2 a	GAT 2742	6.1 c-e
Res 5	442605	83.0 de	NC7xNC343 (30)	20.1 a	GAT2844	6.2 b-e

[1] Means within a column for an insect followed by the same letter are not significantly different ($P \leq 0.05$) using Waller-Duncan.

[2] Sus = Susceptible.

[3] Res = Resistant.

Figure 1. Interrelationship between soil moisture and termite damage to peanut pods in Burkina Faso.

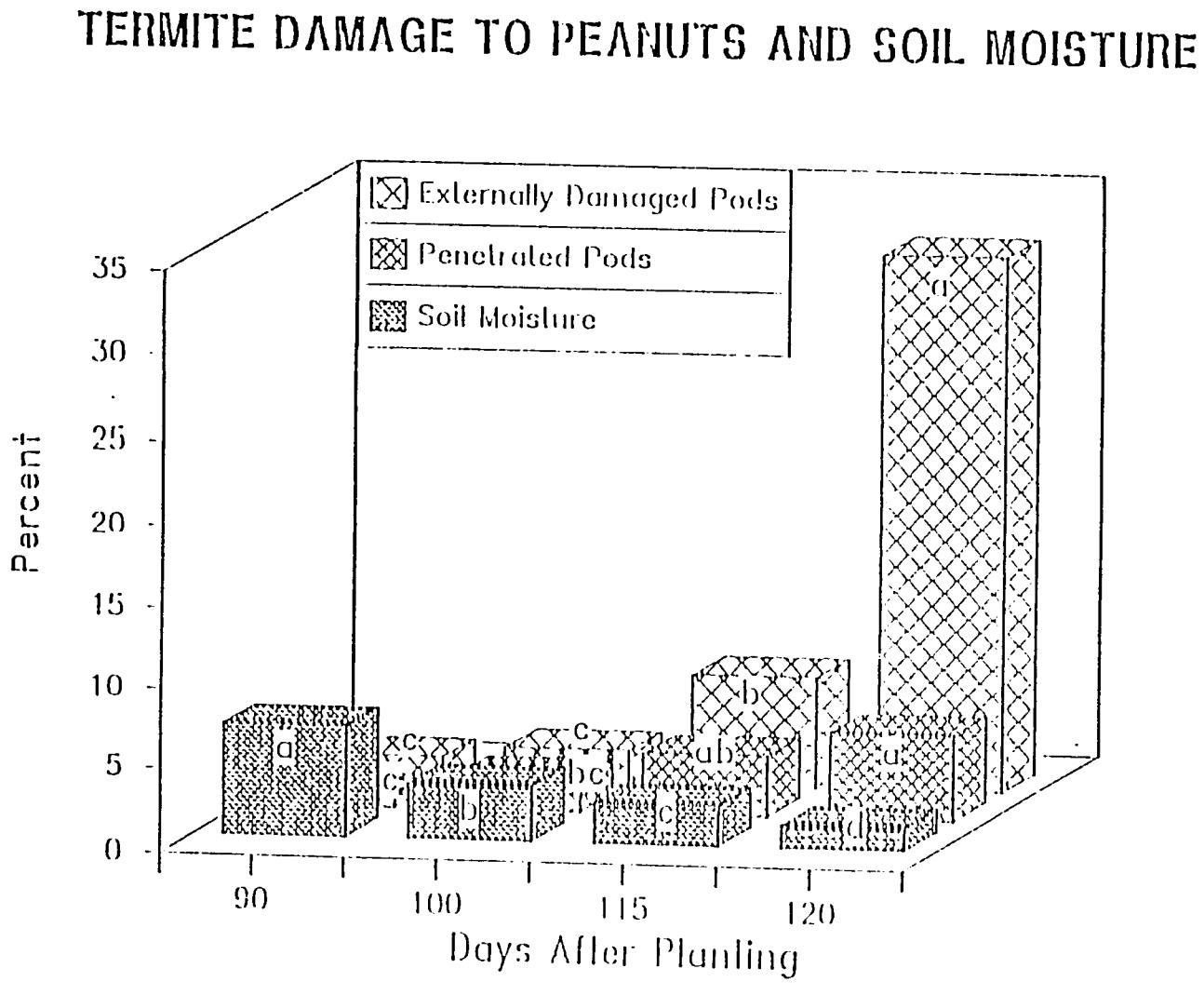


Figure 2. Interaction between treatment and age of plants on aflatoxin in peanut seed, Tifton, GA, 1992.

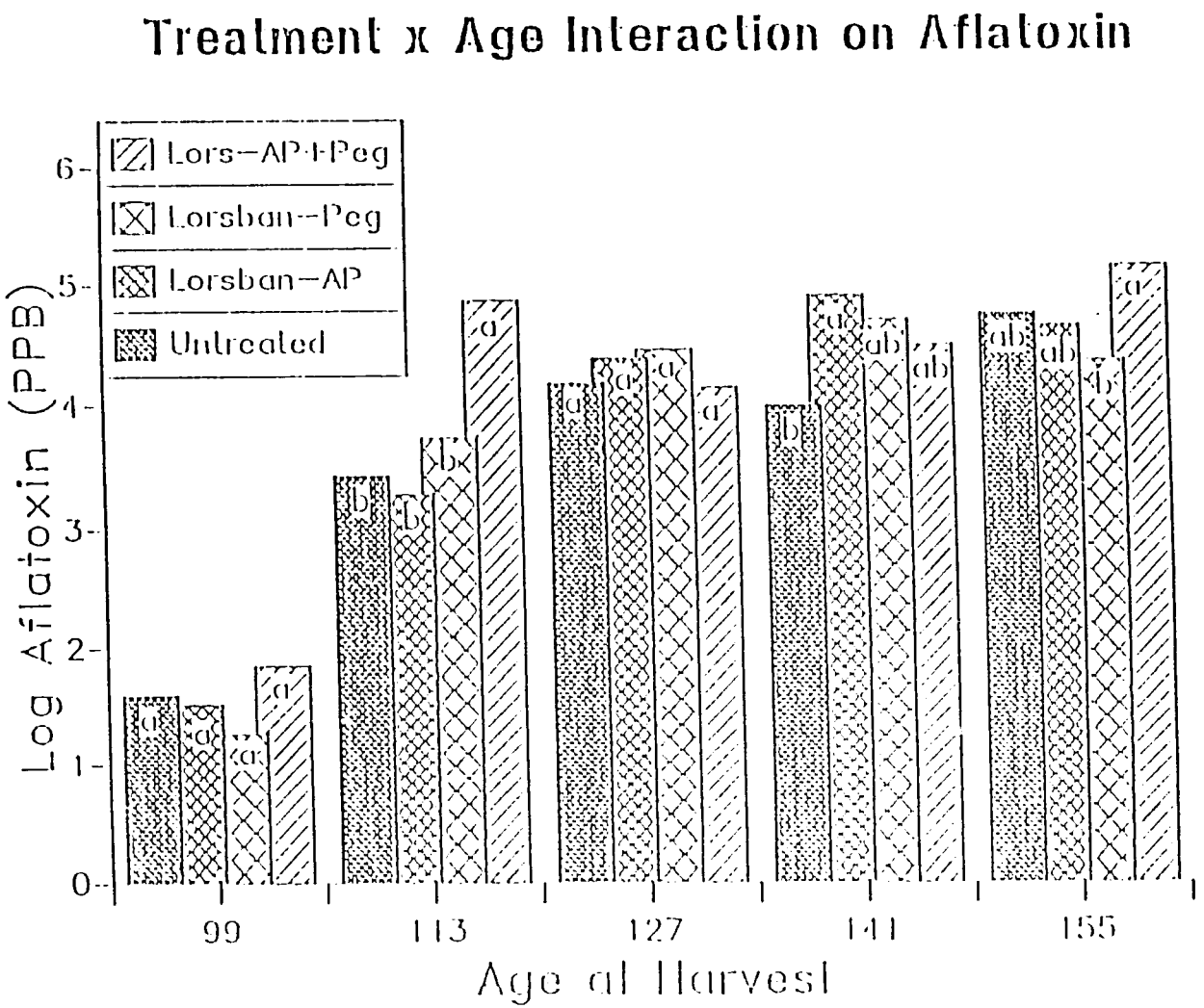


Figure 3. Interaction between age of plants and extent of pod damage on aflatoxin in peanut seed, Tifton, GA, 1992.

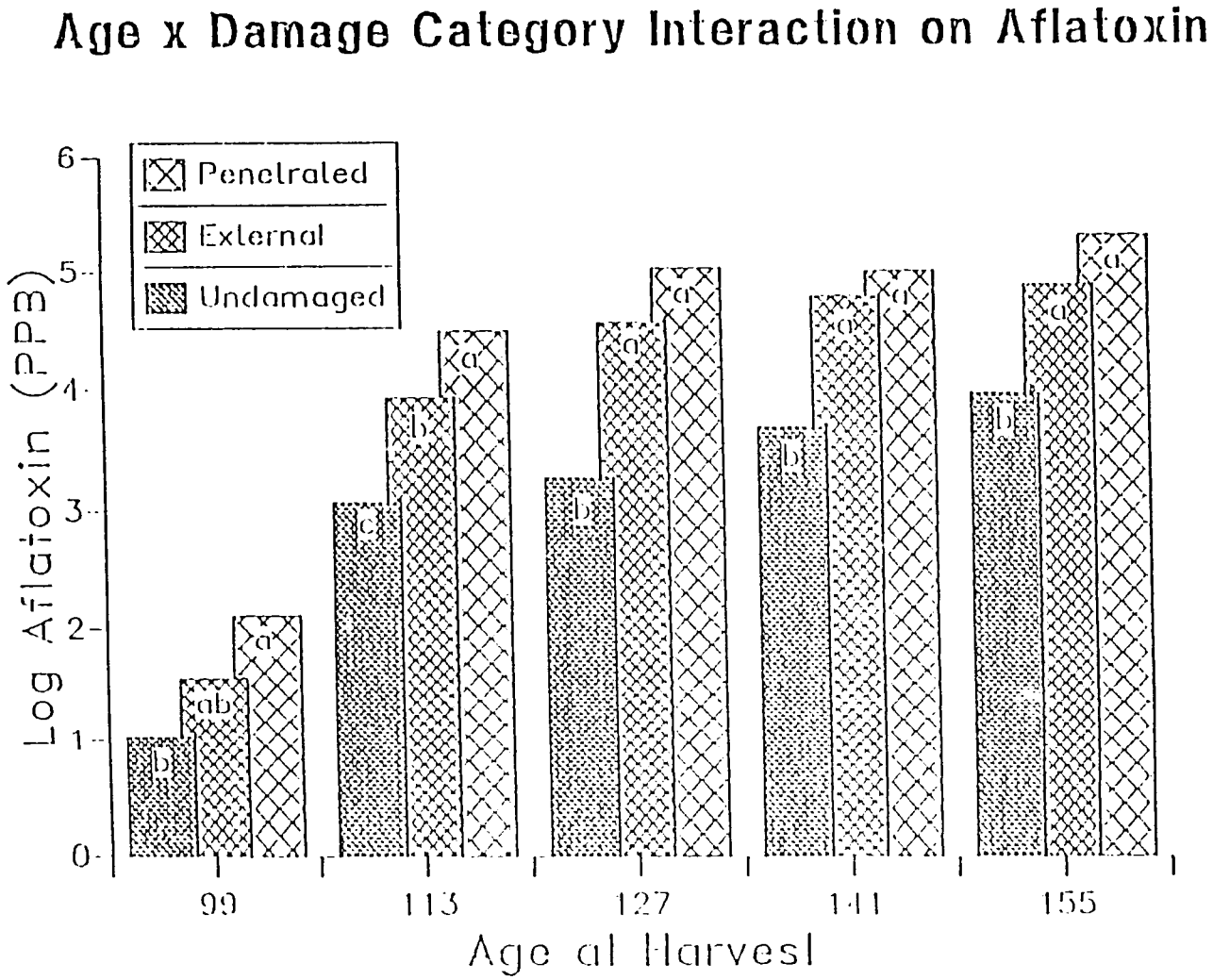
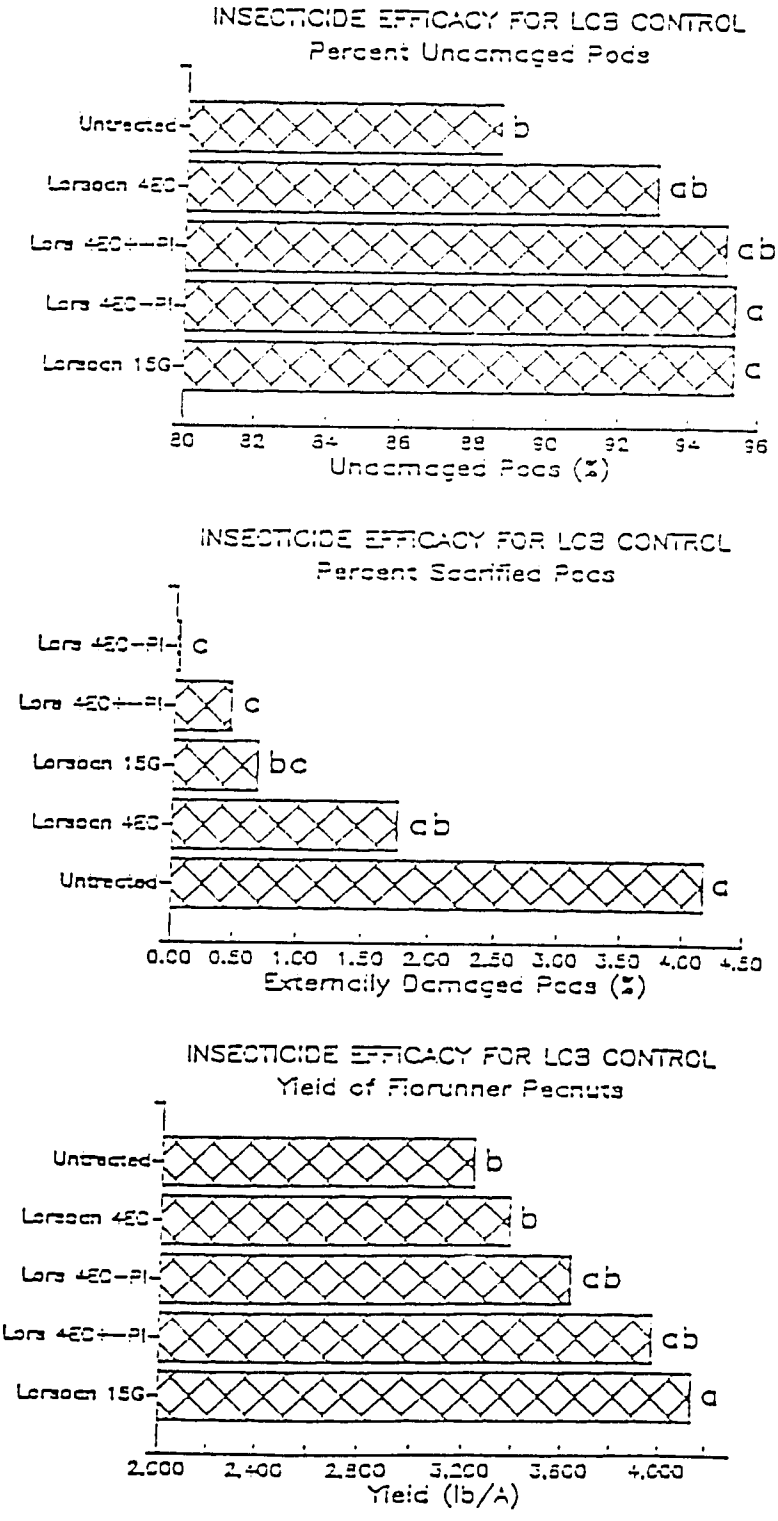


Figure 4. Comparison of Lorsban applied as granules (15G), sprays (4EC), or pressure injected (PI) for lesser cornstalk borer control, Tifton, GA, 1992.



NCS/IM/TP

MANAGEMENT OF ARTHROPODS ON PEANUT IN SOUTHEAST ASIA

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INTRODUCTION

Current emphasis on the use of sustainable agricultural practices in peanut production in concert with the principles of integrated pest management requires a strong basic and applied research component for insect management. A strong understanding of the biological, economic, and social factors involved is also necessary. Peanut production in the Philippines and Thailand is a complex agroecosystem subject to a wide variety of plant stresses as well as certain cultural and economic restrictions. In general, two crops are grown annually. Continuous cropping and the warm climate make insect pest management a significant challenge for peanut producers as economic damage by insect pests frequently occurs. All parts of the plant are susceptible to attack, and the plant is exposed to insect feeding virtually the whole growing season. To effectively manage these pests in an economically and environmentally-sound approach lending itself toward sustainable agriculture, a sound biological base must be established. Ecological studies, surveys of pest problems, damage assessments and thresholds, population monitoring and scouting techniques, off-target impacts of pesticide use and potential interactions, as well as the development and implementation of alternative control strategies including host-plant resistance, cultural and biological control, are all critical in maintaining this goal. This broad-spectrum research program is directed toward building effective integrated pest management programs and progressing toward the goal of a sustainable production system for peanut production in all countries.

IMPACTS

Since pesticides continue to be a major tool used for managing insect pests in peanuts, improving grower decision making for insecticide use is being effected through research in both the Philippines and Thailand. Studies have documented fewer well-timed treatments improve yield, are less disruptive to the ecosystem, and are more profitable to the grower. Growers in both countries who have observed these trials are rapidly adapting the use of thresholds (where available) and prescription pesticide use rather than calendar-type sprays.

Both the Philippines and Thailand have spent considerable time evaluating varietal tolerance and resistance of new genotype entries and currently recommended varieties. Cultivars with improved tolerance or resistance are then evaluated in IPM programs for their overall role when integrated into a complete management system.

North Carolina peanut growers have improved their ability to use prescription applications of pesticides for southern corn rootworm. These improve control, reduce pesticide use, and reduce costs. Work with cultural practices, in conjunction with studies in Thailand, has demonstrated that tillage can reduce pest population levels and consequently the need for insecticide treatments. Agronomic studies are nearing completion to begin educating growers on the

benefits of reduced tillage production.

Thresholds developed for thrips and leafhoppers have been fully incorporated into North Carolina peanut IPM programs. These allow growers to make more intelligent decisions in light of the potential threat of tomato spotted wilt virus vectored by thrips. The use of alternate, less toxic products for thrips management has been demonstrated to have economic and environmental advantages.

MAJOR ACCOMPLISHMENTS

PHILIPPINES - The host plant resistance work has developed an excellent data base for a large number of entries under Filipino production systems. Many cultivars have also been investigated in farmers' programs to document their integration into a "real world" setting. These data indicate several entries have some level of resistance that may provide opportunity to utilize these plant characteristics more fully in a host plant resistance package. Studies evaluating these entries have been expanded to numerous locations in the Philippines. Some additional studies have looked at current Seed Board recommended varieties and promising cultivars used in conjunction with classical biological control programs.

Studies to improve the use of insecticides since, in many instances, pest management must rely upon this control method. These studies to evaluate insecticide timing, off-target effects, and incorporation into an IPM system, as well as the economic benefits, have improved our understanding of the use of pesticides. In addition, the effect of cropping patterns on the arthropod complex, its composition and abundance are being studied at UPLB and other locations. The impact of peanut production under multi-crop systems, such as production under banana, is being investigated for its impact on pests and pest control strategies.

Biological control using *Trichogramma* sp. and a microbial insecticide *Bacillus thuringiensis* has been successful. New biological control studies have revealed a significant improvement in farmer profitability using an integrated program in IPM evaluation trials. Other trials evaluate the thresholds and efficacy of alternate control strategies in a realistic farm setting. These studies provide an excellent opportunity for the demonstration of research to local peanut farmers and evaluation of new techniques under different farming conditions.

THAILAND - The effort to evaluate entries for insect resistance continued at both DOA and KKU with multiple site studies. Other studies continued development of a sound data base for refinement of the IPM program. This included basic insecticide evaluations to improve the timing of application to increase pod fill and total integrated program using host plant resistance as well as cultural and biological control methodologies. Insecticides are relied upon heavily in certain areas. Studies to develop a better timetable for insecticides application have been successful. Such schedules will reduce insecticide use while improving control, until more integrated approaches can be developed and implemented. Studies using sticky boards continue to investigate the migration and dispersal of thrips and the possible relationship to virus transmission. These studies have provided important insight into the ecology of this pest which will eventually lead to improved management of the disease by effective management of the vector.

NORTH CAROLINA - Research efforts continued to emphasize the development of an adequate data base to further refine the development of a sustainable agricultural system for peanut. Our current management approach to insect control is still dependent upon insecticides, sometimes including preventive insecticide application. Efforts to integrate biological and cultural control practices as well as to predict pest outbreaks to avoid preventive applications have been expanded. Extensive studies evaluating the impact of tillage practices on insect populations are yielding promising results. This study complements a

similar study in Thailand. Evaluations of pesticide interactions are revealing new approaches to reduce pesticide dependency while maintaining yields and potentially reducing costs.

Studies using floral and feeding attractants provide information that supports rootworm treatment decisions. The use of pheromone traps alone has limited the decision process to those fields averaging less than 45 beetles per week and this must be improved. While this may prove cost effective for growers, the savings are so minimal that most growers are not willing to accept the slightly increased risk associated with this system. Additional studies to improve trap efficiency in combination with soil drainage studies will hopefully enhance this decision-making process.

Wide-area studies investigating thrips overwintering, migration, and within the field dispersal continued into the third year of investigation. These were conducted to isolate relationships with the increasing threat from tomato spotted wilt virus in peanut which is vectored by these thrips. Only limited biological and ecological information is available on this pest, but current studies have improved our understanding of the vector to help to manage this disease. This study complements similar studies in Thailand.

Biological insecticides for pest control are under investigation for at least two pests in peanut. Initial evaluations indicate some potential with distinct ramifications for reduced secondary pest outbreaks. These studies closely correlate similar studies in the Philippines.

GOALS

The major goal of this project is the effective management of those arthropod pests that limit peanut production through an effective pest management program based on sound principles of IPM and sustainable agriculture.

OBJECTIVES

1. To continue the evaluation of a wide variety of genetic material for possible insect tolerance or resistance to single species and arthropod complexes. This work will be conducted in cooperation with Dr. Tom Isleib in North Carolina and through collaborators in Thailand and the Philippines.

2. To develop damage assessment data for the arthropod complex and relate to host plant phenology. This information will be incorporated into economic thresholds for use in IPM programs.

3. Study the biology and ecology of the important arthropod pests. Conduct surveys to determine abundance and pest status of arthropods.

4. Determine the effect of cultural practices (i.e., tillage) on insect populations and host plant damage.

5. Utilize monitoring devices to gain a better understanding of insect biology and use as a predictive tool for insect occurrence and pest abundance.

6. Develop an effective IPM program and demonstrate the benefits through research findings and on-site demonstrations utilizing information developed from the Peanut CRSP in North Carolina, Thailand, and the Philippines.

7. Evaluate the potential for biological control as a realistic approach to arthropod management in peanut.

ORGANIZATION

A.	U. S. Lead Institution:	North Carolina State University
	Principal Investigator:	Dr. Rick L. Brandenburg, Dept. of Entomology
	Cooperator:	Dr. Mary Barbercheck, Dept. of Entomology
	Post-Doctoral Assistant:	Dr. Jim Barbour, Dept. of Entomology
	Technicians:	Mr. Peter T. Hertl, Dept. of Entomology
		Mr. Brian Royals, Dept. of Entomology
		Ms. Brenda Watson, Dept. of Entomology
	Cooperators:	Dr. Tom Isleib, Dept. of Crop Science
		Dr. Jack Bailey, Dept. of Plant Pathology
B.	Counterpart Institution:	Khon Kaen University, Khon Kaen, Thailand
	Principal Investigator:	Dr. Manochai Keerati-Kasikorn, Dept. of Entomology
	Technician:	Mr. Preecha Singha, Dept. of Entomology
C.	Counterpart Institution:	Department of Agriculture, Field Crops, Bangkok, Thailand
	Principal Investigator:	Dr. Turnjit Satayavirut, Entomology & Zoology Division
	Cooperators:	Ms. Srisamorn Pitak, Entomology & Zoology Division
		Mr. Pisit Sepswasdi, Entomology & Zoology Division
	Technician:	Mr. Punya Pooksoon, Entomology & Zoology Division
D.	Counterpart Institution:	University of the Philippines at Los Banos, Philippines
	Principal Investigator:	Dr. Virginia Ocampo, Dept. of Entomology
		Dr. Eliseo Cadapan, Dept. of Entomology
	Cooperators:	Dr. Edwin Benigno, National Crop Protection Center
		Mr. R. V. Ebora, National Inst. of Biotechnology
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	Research Associates:	Ms. Evelyn Bergonia, Dept. of Entomology
		Mr. Octavius Caesar P. Ebron, Dept. of Entomology
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	Technicians:	Mr. M. V. Navasero, Dept. of Entomology
		Mr. Ramir Batumalake, Dept. of Entomology
E.	USAID Project Officers:	K. A. Rushing/Manila, Philippines
		T. Hiranraks/Bangkok, Thailand

APPROACH

Various peanut genotypes will be tested in Thailand and the Philippines. These seeds are being grown in numerous locations to provide data under a range of agronomic, environmental, and insect pest conditions. Because of the multiple species attack peanut faces in these countries, the search for resistance to insect guilds rather than a single species is emphasized. Broad resistance would probably result in a more sound release for growers. Promising entries will continue to be selected and plot size expanded to ensure true tolerance or resistance exists and damage is not simply a reflection of preference. Such entries are evaluated in more advance IPM trials to determine the "best fit" into such systems for the most integrated overall approach.

Some effort to continue surveys of all arthropod pests, especially subterranean ants and other soil pests, will continue. Additional research on sampling and traditional management approaches is critical for soil pests and will continue. Continued work on monitoring and predicting southern corn rootworm in North Carolina will include a new array of trapping approaches.

Insect abundance and plant damage relationships will be conducted with more

emphasis on host plant phenology. The development of economic thresholds for varying stages of plant growth in Southeast Asia will be developed for incorporation into an IPM program.

Studies on vectors and virus relationships will be evaluated in Thailand and North Carolina. Sticky boards to monitor migration, as well as studies of feral host plants, insect abundance in field, and disease incidence, will be monitored.

In North Carolina, studies will focus exclusively on thrips, while in Thailand, studies will include aphids and jassids as well.

Studies looking at the release and use of biological control agents will be investigated in the Philippines and North Carolina. These studies will include the release of egg parasites, *Bacillus thuringiensis*, and entomogenous nematodes, with the ultimate goal of incorporating these into a totally integrated control system. In addition, studies looking at the off-target effects of pesticides will be investigated at all locations to determine the detrimental effects and the potential to induce secondary pest problems. The use of alternate spray timing will be monitored to study the effect on beneficial arthropods.

Control philosophies oriented to reduce such secondary pest problems will be devised. Finally, IPM programs will be evaluated in the field to determine the potential benefit to growers. These programs will vary significantly in scope, varying from simple changes in spray application calendars to complex integration of thresholds, cultural, and biological control agent releases. These will vary with the area, pest problems, and the farmers' abilities. Programs will be continually evaluated for areas requiring upgrading or additional data bases.

ACCOMPLISHMENTS IN DETAIL

PHILIPPINES - The evaluation of peanut genotypes was expanded with excellent coordination between Dr. Ocampo and Dr. Abilay. However, seed storage remains a problem and some genotypes are still in short seed supply. Dr. Ocampo has developed a large data base on many genotypes through this cooperative work at IPB and UPLB. Dr. Cadapan has focused more on insect tolerance and resistance of the Seed Board recommended varieties and their fit into IPM programs. Dr. Ocampo has also focused on insecticide management and intercropping with several years' results now available. Additional studies looked at the effect of the cropping pattern on the species composition and abundance of arthropods in the peanut system.

Work is conducted by Dr. Ocampo both at UPLB and in the north at Cabagan, Isabela and San Marcos, Quirino. The host plant resistance studies show great promise for the eventual incorporation of some levels of insect resistance into peanut production. The studies during the past year were quite extensive, and data collected is far too voluminous to present in tables within this report. A rather wide range of insect preference or resistance exists among the various entries and examples of this are illustrated in data from the Uniform Insect Nursery trial (Tables 1, 2 and 3). Results from tests of peanut genotypes for the UIN, UIN(LHT), IGT, and IC as well as INT-F, and Philippine Seedboard recommended varieties show promise for incorporation of some entries into an IPM program. In general, a five year review of trials has shown that two entries, Robut 33-1 X NC 2214 and J11 X (M13 X NC 3083) have shown excellent resistance to leafhoppers. Yield over the five years has not always been associated with levels of resistance. However, Robut 33-1 X NC 2214 has been a consistent high yielding entry and has shown good resistance to leafhoppers. However, most all leafhopper resistance was inadequate to protect the plants during severe insect pressure such at that occurring during the 1990-1991 dry season.

The resistance trial in the International Germination Test was relatively unsuccessful due to low insect pressure. Other problems in this test have been poor germination and seed production indicating poor adaptation of these entries

to the Philippines. Many of the Seed Board recommended varieties still provide among the highest yields and some show differences in insect abundance. UPL Pn8 has shown some of the highest yields and relatively lower insect abundance, especially for leafhoppers (Table 4).

The survey of arthropods in the peanut system has determined that leafhoppers are more abundant in drier conditions when rainfall is less abundant. Defoliators do not seem to be affected by rainfall patterns.

Continued work in Quirino to evaluate the intercropping of peanut and banana is providing information for a balanced pest management program. Results of screening trials are significantly different from trials conducted at UPLB. These emphasize the need for local evaluations.

The evaluation of an IPM package in Cebu against major insect pests of peanut indicates the use of biological control may be practical under moderate pest infestations. Studies were run in the southern Philippines to conduct IPM verification trials at Mandaue City. Dr. Cadapan continued work with *Trichogramma* sp. and with *Bacillus thuringiensis* in peanut with encouraging results. These studies are focused primarily on the Lepidopterous pests found in peanut and offer promise to play an integral role in developing a more sustainable system. Studies continued to look at these treatments and their incorporation into spray regimes. Results have shown that a combination treatments may be best. Results also indicate that this approach can not only reduce grower reliance on pesticides, but can also increase farmer profits (Table 5). The use of released parasites and *B.t.* has proven very effective and acceptable in this region when using previously tested thresholds (Table 6).

Dr. Cadapan continued his evaluations of Philippine Seed Board varieties at UPLB to determine any insect resistance or preference. The value of this work derives from the fact that these are the varieties most commonly grown by farmers in the Philippines. Significant differences were found among the varieties for certain insect pests but were not always consistent with those found by Dr. Cadapan. It also appears that while Pn8 has shown some resistance to leafhoppers, it exhibits more serious bronzing from thrips.

Additional work on the subterranean ant is beginning to reveal important biological and ecological information about this serious, but poorly understood soil pest. This study has demonstrated that poor crop stands are often directly related to this pest. Chemical control is the only option available for this pest and has been found to be effective. Currently, studies are evaluating techniques to monitor ant distribution and the need to treat with chemicals for control.

THAILAND - The evaluation of peanut germplasm for resistance continued at Khon Kaen and Prabuddhabat Experiment Station. Tests were conducted during both the rainy and dry seasons using over 100 entries from the Uniform Insect Nursery, the International Test F6, and ICRISAT lines at Khon Kaen. In general, pod damage was low, but some relatively heavy pressure occurred from leafhoppers, thrips, and leafminers. Although the data are too large to present in tabular form in this report, several entries did outperform Tainan 9, the most common farmer planted variety. An example of such data is presented from the Uniform Insect Resistance Nursery Test at Khon Kaen during the rainy season (Table 7). The dry season trial consisted of 57 entries.

An additional experiment was conducted to determine the best calendar spray approach for insecticide use at a farmer's field near Cholnabot. This study illustrated that pod yield can be significantly affected by thrips feeding and that the optimal time for calendar applications is 30 days after planting. While such practices are not recommended, farmers use them and it is important to provide some guidelines for such practices.

Two supplementary tests were established at Khon Kaen looking at the timing and frequency of later season sprays on plots of Tainan 9, KK60-3, and S.K. 38. Earlier sprays increased later season problems with *Heliothis*. This resulted in earlier treated plots for thrips and leafhoppers requiring a later spray to maintain yield. These interactions are important to understand and develop an optimum management strategy.

At Prabuddhabat Experiment Station, 143 lines were evaluated for resistance to thrips, leafhoppers, aphids, and defoliating insects under natural field infestations. In general, insect populations were quite low with meaningful readings available only for leafhoppers for the 41 lines in the Leafhopper Test (data not shown).

Studies during the rainy season of 1992 at Prabuddhabat again confirmed the correlation between thrips density and incidence of peanut yellow spot virus (PYSV)(Table 8). Effective control of thrips and leafhoppers reduced the incidence of the disease but, once again, defoliators were more abundant later in the season. Of the entries used in this test, the Tainan 9 and KK 60-1 had higher insect damage than KK 60-3 but did not yield as well.

Studies of insect migration and the relationship of insect abundance to disease incidence (peanut yellow spot virus and peanut mottle virus) at Khon Kaen Experiment Station revealed a weak relationship among vectors captured on traps and disease incidence. Surrounding crops also have some interactive role. The number of insects captured on sticky traps was relatively low, making it difficult to develop sound conclusions.

Studies to determine optimum sampling size and pattern for a variety of insect pests on peanut were conducted at Prabuddhabat Experiment Station. These studies are critical in developing time-efficient sampling programs for growers. Over 1,080 peanut plants were sampled (Table 9). Three distribution patterns, binomial, poisson, and negative binomial were evaluated and will be further refined with an additional year's data.

Studies to incorporate new technology into IPM practices were conducted at several locations. These in turn were used for demonstrations and farmer education to assist technology transfer. These studies included the use of different insecticides and spray timing regimes. These have shown some rather significant differences in control and yield, thereby providing improved guidelines for insecticide use.

NORTH CAROLINA - The use of feeding attractants in combination with pheromone-baited traps has improved our ability to relate trap catches to subsequent outbreaks of southern corn rootworm. Additional work on trap design, placement, and abundance is being completed and will enable us to begin promoting such monitoring in the near future. The use of trap crops continues to demonstrate potential for enhancing a more integrated approach to rootworm management. While trap crops may not be practical as a cultural practice at this time, they also function as an indicator of future rootworm problems. These studies all focus on improving the predictive capabilities initially established with the pheromone trap studies from 1985-1990.

The management of early season thrips as a means of reducing the threat of tomato spotted wilt virus was further investigated. Studies of tillage effects were concluded with some conflicting results (Table 10). Theses studies complement similar studies in Thailand that are investigating different farmer land preparation scenarios.

Studies of thrips overwintering and migration into peanut fields have produced a significant amount of new information, especially for *Frankliniella fusca*, the primary vector of tomato spotted wilt virus. Thrips do not overwinter in the peanut field soil and few appear to migrate from small grains, but rather come

in from corn. Migration into the field occurs, the number of thrips in the air is quite large and much of this migration occurs before peanut emerges. There is continued movement in the field all season long and some changes in species abundance as the season progresses (Table 11). This overwintering and movement have direct implications to the management of the tomato spotted wilt virus.

The use of biological control in the form of entomogenous nematodes has demonstrated some potential, but much more research is necessary to refine application techniques, timing, and rates. This control method may have an integral role in future IPM programs directed closely by sustainable agriculture guidelines.

Research on pesticide interactions is reducing those current control practices that are most disruptive. The timing of preventive rootworm insecticide applications can have a significant impact on the beneficial arthropod fauna as shown by current studies and as demonstrated by studies in Thailand for early season pests. This impact exacerbates secondary problems such as corn earworm and spider mites later in the season. In such scenarios where there are no alternatives to the use of synthetic insecticides, the modification of application technology may be of benefit.

TRAINING OUTPUTS

Dr. Eliseo Cadapan, UPLB, to spend one week in North Carolina visiting research sites with Dr. Brandenburg and then proceeding to Huntsville, AL, to present a paper at the APRES meeting.

Two students are working on advanced degree programs at UPLB under the direction of Drs. Cadapan and Ocampo in Entomology funded by Peanut CRSP.

PUBLICATIONS AND PRESENTATIONS

Brandenburg, R. L., and J. D. Barbour. 1992. Thrips overwintering in relation to peanut emergence in North Carolina. American Peanut Research and Education Society Annual Meeting. Norfolk, VA.

Brandenburg, R. L., D. A. Herbert, and J. B. Barbour. 1992. Pheromone trapping for predicting southern corn rootworm damage in peanuts. Peanut Science. Peanut Science 19:37-40.

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Funderburk, J. E., and R. L. Brandenburg. 1992. Peanut insect management. In Peanut Plant Health. American Phytopathological Society (in press).

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Barbour, J. D. and R. L. Brandenburg. 1993. A survey of thrips in North Carolina peanuts. Peanut Sci. (in prep.)

Barbour, J. D., and R. L. Brandenburg. 1993. Thrips movement into peanuts in North Carolina. Environ. Entomol. (submitted).

Barbour, J. D., and R. L. Brandenburg. 1993. Thrips overwintering in relation to peanuts in North Carolina. Peanut Sci. (submitted).

Brandenburg, R. L., J. D. Barbour, and L. Garcia. 1993. Alternative strategies for thrips management in North Carolina peanuts. Southeastern Branch, Entomological Society of America meeting, Little Rock, AR.

Heagle, A. E., and R. L. Brandenburg. 1933. The effect of ozone on spider mite populations on clover and peanut. Environ. Entomol. (in prep.)

RESEARCH PLANS FOR 1993-1994

1. Research thrusts/endeavors planned

U.S.

A. Enhanced understanding of thrips (*Frankliniella fusca*) ecology and the development of management strategies through biological studies and management trials.

   1. Studies to determine overwintering will be conducted throughout peanut production area with detailed studies at the Peanut Belt Research Station, Lewiston, NC.

   2. Evaluation of thrips dispersal and migration into peanuts as they relate to thrips overwintering will be studied using sticky traps, exclusion cages, and foliage sampling.

   3. Key parameters used by thrips for host finding will be studied in early season trials at Lewiston.

   4. Effect of tillage will be studied as a cultural practice to reduce the abundance of pest species.

   5. An improved understanding of the life history of thrips on Virginia-type peanut will be elucidated.

B. Improved southern corn rootworm management through predictive modeling, trap cropping and cultural practices (primary study site: Peanut Belt Research Station, Lewiston, NC)

   1. Use feeding attractant traps to monitor presence of ovipositing female beetles in peanut and relate to subsequent rootworm infestations.

   2. Develop model of soil types and drainage potential to improve predictability of rootworm infestation.

   3. Study the potential for the trap crop use to limit the amount of rootworm oviposition in peanut.

   4. Study effects of tillage on pests and natural enemies.

   5. Conduct studies on biological control through preservation of endemic species and the use of exotic biological control agents.

C. Other endeavors

   1. Interact in plant breeding program for resistance selection.

   2. Evaluate "non-chemical" control strategies for specific peanut pests in extended areas of peanut production. These will include plant growth modifications and actual vine clipping.

PHILIPPINES

A. Wet season (July-October 1993)

1. Germplasm Evaluation for Resistance against Peanut Insect Pest Complex. Seed multiplication also underway.

   The genotypes evaluated will be based upon seed availability.

   Potential Seed Candidates

UIN Test I	- 22 genotypes
UIN Test II (LHT)	- 56 genotypes
IGT	- 60 genotypes
IC	- 21 genotypes
INT-F_7	- 21 genotypes

   Some of these studies are coordinated and done in cooperation with Dr. R. Abilay, IPB. Plots will be in single rows, 5 meters long, replicated 4 times.

2. Insect Pest Damage Assessment of Philippine Seedboard Recommended Peanut Varieties

   Seven varieties, namely UPL Pn-2, Pn-4, PN-6, Pn-8, BPI P9 and P2 and JL-24 will be sown each on a 100 m^2 plot replicated 4 times. Superimposed on this experiment is data collection for the PNUTGRO Model being evaluated by Engr. Andrew Buendia of PCARRD.

   Insect pest damage rating and insect counts will be done regularly throughout the crop's growth stage. Sticky and/or pheromone traps will be set up to monitor insect populations and their source around the area.

3. Evaluate biological control agents including *Trichogramma* and a newly discovered fungal pathogen for utilization into a grower pest management program.

4. Expand host plant resistance work and pest management assessment trials into areas of the southern Philippines.

5. Determine the severity of damage caused by subterranean ants during the wet and dry season peanut croppings; describe the feeding behavior, colonization pattern and distribution of subterranean ants in the field; and evaluate the preference of the adult ants for the different feed materials including different major crop seeds.

6. Begin development of economic threshold for leafhopper (*Empoasca ricei*). Evaluate the degree of damage and yield relationship of selected peanut cultivars and determine what stage of the crop is most susceptible to leafhopper infestation.

7. Evaluate different sampling equipment and techniques in monitoring the abundance and diversity of peanut insect pests and their natural enemies.

8. Evaluate the effect of selected trap crops on the population density of major peanut insect pests in Philippine seedboard recommended varieties.

B. Dry season (December 1993-March 1994)

1. Arthropod Diversity Studies in Peanut under Different Cultural Management Practices (2nd year projects)

   Survey on peanut insect pest damage and population as well as on their natural enemies will be done on different peanut cropping patterns (banana-peanut intercrop or corn-peanut intercrop) using the recommended Philippine Seedboard peanut varieties.

   Insect pest populations and damage will also be monitored in other experimental set-ups of Mr. Billy Temanel (Study Leader at Quirino) on cultural practices such as fertilizer and/or liming trials, weeding, irrigation, tillage practices, etc.

2. Insect Pest Management Packaging and Verification Trials

   The different control tactics in the probational IPM package will be evaluated at farmer's field in Region II and will be compared to the existing farmer's crop production practices. The package includes release of *Trichogramma* parasitoids, liming, use of microbial (BT) insecticides and other insecticides found effective in our screening trials at UPLB, based on ETL's. In addition, the use of trap crops will be evaluated.

3. Germplasm Evaluation for Resistance against Peanut Insect Pest Complex

   The germplasm collection mentioned earlier will also be evaluated for insect pest resistance during the dry season at UPLB and/or Region II following the same procedures in the wet season trials.

4. Evaluate biological control agents for Lepidopterous pest control. Agents include *Trichogramma* and a newly discovered fungal pathogen for utilization into a grower pest management program.

5. Expand host plant resistance work, evaluation of seedboard varieties, and pest management assessment trials into areas of southern Philippines.

6. Determine the severity of damage caused by subterranean ants (*Solenopsis geminata*) during the wet and dry season peanut croppings; describe the feeding behavior, colonization pattern and distribution of subterranean ants in the field; and evaluate the preference of the adult ants for the different feed materials including different major crop seeds.

7. Develop an economic threshold for the leafhopper *Empoasca ricei*; evaluate the degree of damage and yield relationship of selected peanut cultivars and determine what stage of the crop is most susceptible to leafhopper infestation.

8. Determine level of natural control in peanuts against major insect pests. Evaluate different sampling equipment and techniques in monitoring the abundance and diversity of peanut insect pests and their natural enemies.

THAILAND

A. Continued Screening of Peanut Lines from North Carolina Collection for Insect Resistance. Prabudhabat Experiment Station, Khon Kaen Field Crop Research Center, and Kalasin Field Crop Research Center. Some studies have been limited due to lack of seed. Seed multiplication is slowly rectifying this situation.

B. Study on Optimum Insecticide Applications to Reduce the Unfilled Pod Problems of Peanut. Rayong Field Crop Research Center

1. Includes ecological and management studies on subterranean ants. Efforts focus on developing an improved understanding of the life history of this pest.

C. Insect Vector Studies - Migration and Alternate Hosts

1. Study on immigration of some insect vectors to peanut field by using sticky traps. A complete picture of vector movement as it relates to weather and crop phenology is being developed. Prabudhabat Exp. Station and Khon Kaen Field Crop Research Center

2. Correlation of thrips numbers and yellow spot virus and their effects on yield of selected peanut cultivars. Prabudhabat Exp. Station

D. Integrated Control of Major Peanut Insect Pests Using the Varieties Tainan 9, KK60-3 (NC7) and Sukotai 38 (S.K.38). These trials will investigate cultural, biological, as well as chemical strategies.
- Khon Kaen Field Crop Research Center
- Farmer field in N.E. part of Thailand

1. Development and refinement of economic injury levels for specific pests with special attention to plant phenology. These studies will also take into account viral transmission by vectors and the twofold damage potential.

INTERNATIONAL TRAVEL

Month: January 1994
Destination: Philippines
Duration: Two weeks
Meet with collaborators and tour research plots on several islands and conduct IPM workshops.

Table 1. Uniform Insect Nursery. Resistance to common field insects pests. May-Aug. 1992, UPLB

Original Entry No.	Identity	% Yellowing	% Defolia-tion	% Thrips Damage	Aphid Rating (0-3)
3	NC 6	1.84	0.04	0.86	0.37
4	GP-NC 343	6.55	3.46	4.98	0.45
5	NC 302	3.86	1.48	2.64	0.30
6	Florigiant	1.72	0.29	1.85	0.38
7	Florunner	3.25	1.69	1.17	0.60
8	Robut 33-1 x NC 2214	1.81	0.68	1.56	0.35
9	Robut 33-1 x NC 2214	1.98	0.64	1.00	0.40
11	Mani Pintar x (Robut 33-1 x 2232)	3.50	0.69	1.56	0.65
12	J11 x (M13 x NC 2232)	2.25	0.96	2.20	0.60
17	GP-NC 343 x NC 17367	4.83	0.21	1.50	0.20
19	GP-NC 343 x NC 7	3.25	0.74	1.30	0.60
20	GP-NC 343 x NC 5	2.92	0.73	1.69	0.28
22	PI 467307	2.92	0.40	1.37	0.60
23	NC 6 x NC 3033	2.05	0.41	1.45	0.64
24	F x (Var 2750 x PI 259747) F2-B2-B1-B2-B1	2.14	0.54	1.28	0.45
Check	BPI Pn 9	37.30	3.72	2.27	1.12

Table 2. Uniform Insect Nursery. Resistance to common field insect pests. Oct. 1992 - Jan. 1993, UPLB

Original Entry No.	Identity	% Yellowing	% Defolia-tion	% Thrips Damage
3	NC 6	2.06	1.75	0.19
4	GP-NC 343	14.74	7.31	2.96
5	NC 302	4.06	3.18	0.35
6	Florigiant	3.10	2.54	0.29
7	Florunner	8.78	2.19	0.38
8	Robut 33-1 x NC 2214	2.52	1.93	0.15
9	Robut 33-1 x NC 2214	3.70	2.32	0.50
11	Mani Pintar x (Robut 33-1 x 2232)	4.32	2.02	0.58
12	J11 x (M13 x NC 2232)	3.94	3.03	0.71
17	GP-NC 343 x NC 17367	3.82	2.83	0.67
19	GP-NC 343 x NC 7	3.87	2.42	0.11
20	GP-NC 343 x NC 5	2.66	1.98	0.29
22	PI 467307	4.24	2.94	0.12
23	NC 6 x NC 3033	3.85	2.17	0.28
24	F x (Var 2750 x PI 259747) F2-B2-B1-B2-B1	4.66	2.31	1.43
Check	BPI Pn 9	28.00	8.67	3.37

Table 3. Yield of Uniform Insect Nursery (UIN Test I). May 1992 to January 1993, UPLB

Original Entry No.	Identity	Wet Season (May-Aug. 1992)	Dry Season (Oct. 1992-Jan. 1993)
3	NC 6	11	41
4	GP-NC 343	18	43
5	NC 302	9	39
6	Florigiant	28	23
7	Florunner	11	53
8	Robut 33-1 x NC 2214	17	30
9	Robut 33-1 x NC 2214	18	32
11	Mani Pintar x (Robut 33-1 x 2232)	30	--
12	J11 x (M13 x NC 2232)	46	36
17	GP-NC 343 x NC 17367	34	13
19	GP-NC 343 x NC 7	18	10
20	GP-NC 343 x NC 5	18	--
22	PI 467307	23	16
23	NC 6 x NC 3033	36	54
24	F x (Var 2750 x PI 259747) F2-B2-B1-B2-B1	50	24

Table 4. Leafhopper damage at critical stages of peanut during wet season (May-Aug. 1992) and dry season (Oct. 1992-Jan. 1993), UPLB*

Variety	% Leaf Yellowing			
	9 WAP		11 WAP	
	W.S.	D.S.	W.S.	D.S.
UPL Pn2	16	10	10	17
UPL Pn4	13	17	17	20
UPL Pn6	8	11	11	26
UPL PN8	4	13	13	16
UPL Pn10	9	16	16	18
BPI P9 (Check)	16	19	19	28
Quirino Native (Check)	13	18	18	19

*No significant differences among varieties.

Table 5. Costs and returns of peanut (BPI P9) per hectare under different pest management practices, Mandaue City, Cebu

	IPM plot	Farmer's practice	Control plot
A. Costs			
Cost for pest control practices	1,150.00	2,100.00	0.00
Other production practices	32,000.00	32,000.00	32.000.00
TOTAL PRODUCTION EXPENSES =	33,150.00	34,100.00	32,000.00
B. Returns			
Seed yield (kg/ha)	2,521.20	1,784.90	1,587.20
GROSS INCOME (pesos) =	63,030.00	44,622.50	39,680.00
C. NET INCOME (pesos)	29,880.00	10,522.00	7,680.00

Price per kg of peanut seeds = P 25.00

IPM pest control costs/ha

DIPEL = P 310.00
Trichogramma = P 40.00
Labor costs = P 300.00

Farmer's pest control cost/ha

Insecticides = P 600.00
Labor costs = P 1,500.00

Table 6. List of pest control measures used in the IPM package evaluation during Phase II

A. PEST	ETL	TREATMENT
1. Aphids	-When leaf begins to curl	handpicking/crashing
2. Thrips	-40% leaflet bronzing	none
3. Leafhoppers	-50% leaflet yellowing	carbaryl
	-75% leaflet yellowing	carbaryl
4. Defoliators	-40% defoliation	*B.t.*(Dipel or Bactospeine) *Trichogramma*
5. Leafminers	-50% damage early or late season	none
6. Pod Borers	-3.85% pod damage	*Trichogramma* carbofuran (Furadan 3G)
B. PEST COMPLEX	**ETL**	**TREATMENT**
1. Aphids Thrips Leafhoppers	-when any single pest reaches ETL	carbaryl
2. Defoliators Leafminers	-when any single pest reaches ETL	*B.t.*(Dipel or Bactospeine) *Trichogramma*
3. Aphids Thrips Leafhoppers Defoliators Leafminers	-when any single pest reaches ETL	monocrotophos *Trichogramma*

Table 7. Leaf and pod damage and yields of some peanut lines evaluated for their resistances to an insect complex at Khon Kaen, rainy season, 1992

Entry No.	Identity	No. of average damaged leaves/row			Damaged pod (%)	Yield Kg/rai
		LM	LH	T		
	Int. Test-F6 Lines					
1	NC7 x GP-NC 343	3.2	38.3	6.9	3.8	145.6
2	NC7 x NC 302	2.4	40.7	6.9	9.6	145.6
3	NC7 x 15745	3.6	57.4	9.0	8.7	151.3
4	NC7 x 10272	3.4	30.4	13.0	9.9	121.6
5	SK38 x NC 15729	4.4	36.7	12.9	7.5	52.3
6	SK38 x NC 10272	2.6	55.0	13.6	22.4	11.5
7	Lampang x GP-NC 343	5.9	28.5	11.0	1.2	64.5
8	NC 6	3.3	30.1	7.4	2.0	100.1
9	Lampang x NC 15729	2.3	40.2	9.9	4.1	113.6
10	Lampang x NC 10247	3.3	29.5	17.9	7.0	55.3
11	Tainan 9 x NC 342	3.1	37.5	11.2	3.9	108.1
12	Tainan 9 x NC 10247	3.3	20.0	14.7	5.4	57.9
13	CES 101 x NC 342	3.5	21.4	10.3	2.5	109.1
14	CES 101 x NC 301	2.0	28.4	10.0	3.9	117.1
15	CES 101 x NC 15729	3.0	45.8	9.9	0.9	136.5
16	CES 101 x NC 10272	4.2	27.6	12.4	6.2	110.7
17	UPL Pn4 x NC 15749	5.1	22.7	9.6	3.1	107.2
18	UPL Pn4 x NC10247	3.6	18.9	7.1	7.4	40.5
19	NC 7	3.7	44.2	12.3	4.9	111.3
20	SK 38	4.8	39.4	13.8	5.1	34.7
21	Lampang	4.2	25.0	8.5	2.4	93.7
22	Tainan 9 x NC 302	3.5	27.4	17.8	4.8	241.1
23	UPL Pn4	4.4	11.3	6.5	0.0	14.4
24	GP-NC 343	4.0	49.6	5.9	5.4	170.4
25	NC 302	3.9	39.8	11.2	4.5	217.1
26	Tainan 9 x NC 10272	3.4	28.1	10.5	1.0	143.3
27	Tainan 9	5.0	44.0	22.1	2.8	137.1
28	KK 60-1	3.7	38.6	17.2	11.2	108.1

Table 8. Thrips density, number of peanut yellow spot virus (PYSV) leaflets, leafhopper (LH) hopperburn (HB) and defoliator damaged leaflets of three peanut cultivars, Tainan 9, S.K.38 and K.K.60-3 at different levels of application, Khon Kaen FCRC, January-April 1992.

	Thrips	PYSV	LH	HB	PRED	AP	LM	HE	LD
A. Cultivar									
1. Tainan 9	28.7	18.3	3.9	27.5	7.9	4.7	15.6	7.9	131.6
2. S.K. 38	21.9	23.7	3.8	31.9	7.1	4.5	12.0	6.8	140.5
3. K.K.60-3	17.6	17.0	3.3	19.5	8.1	2.1	23.1	5.1	133.9
	*	NS	NS	*	NS	NS	NS	NS	NS
B. Treatment (wk after planting)									
1. 8,10,12,14	14.3	18.0	3.7	23.7	1.9	3.6	3.4	10.9	141.5
2. 8,10,12	14.8	17.9	2.8	22.4	1.4	2.8	3.3	7.6	125.9
3. 10,12,14	25.4	19.7	3.4	25.8	10.2	4.6	27.3	3.7	131.2
4. 8,10	19.4	19.1	3.7	27.7	3.6	1.8	8.9	11.0	144.4
5. 10,12	31.1	18.4	3.9	26.2	4.3	4.3	17.7	5.6	142.5
6. 12,14	25.8	19.2	4.1	27.2	10.7	4.4	23.8	3.7	129.9
7. Control	28.2	25.3	3.9	30.2	12.1	5.1	34.0	3.9	125.9
	NS	NS	NS	NS	*	NS	**	*	NS

Note: No. insects per 10 plants, 3-5 counts.

(RPED - predator, *Menochilus sexmaculatus*; AP = *Aphis craccivora*; LM = leafminer, *Aproaerema modicella*; HE = *Heliothis* sp.; LD = defoliator damaged leaflets).

Table 9. Distribution patterns and optimum sample size of *Spodoptera exigua* (Hubner), *Empoasca* sp. and *Menochilus sexmaculatus* (Frabricious) on the Tainan 9 peanut, Prabuddhabat Exp. Sta., 1992.

Date	No. of insects per 1,080 plts.	No. of insects per plt. ($\bar{x}$)	Variance	Probability distributions: binomial	poisson	neg. binomial	Sample size (n)
8 Apr.	624	0.58	0.9615	*	*	*	165
15 Apr.	903	0.84	1.0528	*	*	*	93
21 Apr.	498	0.46	0.5583	*	0.1170	*	152
29 Apr.	219	0.20	0.2341	*	*	0.9745	284
6 May	384	0.36	0.3350	0.9632	0.2556	0.9920	154
B. Empoasca sp.							
13 May	1664	1.54	2.0762	*	*	*	56
21 May	1948	1.80	1.9503	*	*	*	39
27 May	3922	2.80	3.3086	*	*	*	28
5 Jun	2946	2.73	5.2048	*	*	*	45
10 Jun	2745	2.54	4.2930	*	*	*	43
17 Jun	1336	1.24	1.5953	*	*	0.4518	66
24 Jun	1662	1.54	1.6630	*	*	*	46
2 Jul	1526	1.41	1.2621	0.3326	*	0.3194	41
C. Menochilus sexmaculatus							
6 May	253	0.23	0.3797	*	*	0.5836	327
13 May	325	0.30	0.3551	*	*	*	213

*Reject hypothesis at p = 0.05.

Table 10. Thrips populations and different tillage regimes in peanuts. Bertie County, NC, 1992

Tillage	% leaflet damage		No. of thrips/10 leaflets
	June 11	June 18	June 11
Fluted Coulter planter (no-till)	48.0a	67.0ab	88.00a
Rip - no-till	75.0b	83.0ab	109.75a
Moldboard plow + disc + rototill bed	56.0ab	76.0ab	119.75a
Moldboard plow + rip + rototill bed	66.0ab	85.0b	116.00a
Moldboard plow + disc + rototill bed plus Temik	62.0ab	63.0a	99.25a

Means followed by the same letter are not significantly different (DNMRT, P = 0.05). Mean separation vertical.

Table 11. Total number of thrips collected from flowers and foliage over all fields and sample dates

Thrips	Sex	Wing-form	Flowers	Foliage	Sum	% of total
F. fusca	Female	Brach.	183	37	220	3.2
		Macr.	1076	586	1662	24.2
	Male	Brach.	336	13	349	5.1
		Macr.	486	27	513	7.5
Larvae			687	3249	3936	57.4
F. tritici[1]	Female	Both	133	7	140	2.0
	Male	Both	10	0	10	0.2
Others[2]	Both	Both	16	16	32	0.4
Total					6862	100.0

[1]Not a vector of TSWV.

[2]*Limothrips* spp. and *Neohydadothrips* spp. Not TSWV vectors.

GA/PV/N, TP

Peanut Viruses: Etiology, Epidemiology, and Nature of Resistance

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Institute for Agricultural Research,
Ahmadu Bello University, Nigeria
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P. Olorunju (Nigeria); S. Wongkaew (Thailand)

INTRODUCTION

Groundnut (peanut) rosette (GR) is a major constraint in the production of peanut in Africa, and along with other viruses causes significant yield losses. In addition to actual yield losses, the periodic occurrences of rosette epidemics, causing total local crop loss, induces farmers to plant other more dependable crops. Before control measures can be implemented, the source of the rosette virus must be found, the nature of resistance elucidated, and resistance incorporated into drought-resistant, short season peanut.

Peanut stripe virus (PStV) was first discovered naturally infecting peanuts in the U.S. in 1982. After PStV was characterized and methods of identity developed, data from surveys in different countries of the world indicated that PStV is the most prevalent virus infecting peanut in S.E. Asia (Indonesia, Malaysia and the Philippines) and China. Recent reports documented the occurrence of PStV in India. Thus PStV is prevalent in areas where a large majority of peanut production occurs. Even though PStV may induce only low yield losses in the U.S., preliminary data suggest much higher losses in S.E. Asia and China. The virus infects a sufficient number of plants to have an economic impact on the total peanut production.

The incidence of tomato spotted wilt virus (TSWV) infecting peanut has increased in the U.S. in the past decade and has threatened production in a three county area of Texas. Increased incidence in the south eastern states has been noted in 1987, 1988, 1989, 1990 and more dramatically in 1993. The high yield loss by this virus could pose a new constraint for peanut production.

Peanut mottle virus (PMV) infects peanut on every continent where peanut is grown. Because it is seed and aphid transmitted, it infects more peanut plants on a global basis than any other virus.

IMPACT

Resistance to GR in peanut lines that are acceptable to growers will permit greater production of peanut in Africa. This production will be by the subsistence farmers and provide a more reliable food crop that will enhance their diet. In general it will increase food production across the whole of Africa where peanut is grown.

Identifying and transferring plant resistance to viruses in peanut and transforming peanut with virus coat protein genes are two systems that have the greatest potential to reduce peanut virus diseases and thus provide a more sustainable crop which will increase the world food supply.

ACCOMPLISHMENTS

The breeding project in Nigeria, to move GR resistance into acceptable lines, continues to evaluate crosses and is making good progress. Two medium maturing plus one short season variety have been identified for release. The medium maturing varieties are rosette resistant while the short season variety is

rosette susceptible but high yielding under Sudan Savannah ecological region. A document for the release of these lines has been submitted to the Institute for Agricultural Research.

A survey of virus diseases of peanut in Thailand has been completed. The most prevalent and economically important virus disease was bud necrosis (BN). BN and TSWV are members of the Tospovirus group. The incidence of PStV was spotty and not considered a major problem in Thailand. Yellow spot also was found periodically with high incidence but because of non systemic movement in peanut, it may not be of economic importance. PMV and cowpea mild mottle virus (CMMV) was detected in Thailand this past year.

Twelve plant introductions -- 262794, 262817, 421707, 468141, 468144, 468170, 468174, 468345, 468363, 468366, 468370, and 468371 -- were resistant to mechanical infection with PMV, PStV and TSWV. When three scions, each infected with one of the viruses, were grafted on the same plant, only PI 262817 remained virus free.

An efficient system for plant regeneration has been developed using the diazuron. Over 200 shoots develop from a single seed through organogenesis. Plantlets can be obtained in less than three months. This system virtually by-passes a callus stage and is considered a major advance in peanut regeneration.

GOALS

The overall goal of this coordinated research program is to develop strategies and control measures to minimize incidence of the major peanut virus diseases, to foster interdisciplinary studies between countries and to develop linkages between supporting food production agencies. This will primarily be accomplished by strengthening peanut production programs in the host countries and the US through training and active research projects.

OBJECTIVES

Host Country - Nigeria

Phindile Olorunju completed her Ph.D. degree at the University of Georgia in virology/breeding. She is carrying on a program of breeding for resistance to GR. Currently most African growers would like different resistant lines (RMP-12 has a mottled seed coat, RG-1 is not proper size, etc). Other studies (objectives) are to get GR resistance into a range of season lengths, develop state trials and demonstration plots to assess disease and agronomic performance at a range of sites in Sudan and Guineas Savanna regions and to show farmers that resistant lines prevent epidemics of GR. Other objectives are to multiply seed of resistant released lines so they are readily available to farmers; interact with other Peanut CRSP programs such as the breeding project in Burkina Faso and the ICRISAT Sahelian Center for dissemination of ideas, information and breeding material.

Host Country - Thailand

Techniques for identification and manipulation of the peanut viruses have been established. As the virus surveys are completed, the major emphasis is being placed in various avenues that may lead to disease suppression or control. Some peanut cultivars have been identified with low rates of seed transmission to PStV and PMV. Studies are directed to determine if this trait is genetically controlled, and if so, to work with plant breeders to incorporate this resistance into acceptable peanut cultivars. A US peanut cultivar, Southern Runner, has resistance to TSWV. This will be tested for resistance to BN and yellow spot, diseases of peanut in S.E. Asia caused by an apparent relative of TSWV. As resistant lines or transformed peanut plants become available from the US project they will be tested for effectiveness in S.E. Asia.

United States

Studies are being completed on the nature of the TSWV epidemics in peanut such as effects on yield, thrips as vectors, virus spread and field screening of commercial cultivars for resistance. This research project will also involve the transformation of peanut (Arachis hypogaea) with the DNA sequence coding for the coat protein of several peanut viruses to which a GUS marker gene will be attached.

Organization/Personnel:

A. U.S. Lead Institution:	University of Georgia (UGA)
Principal Investigator	Dr. James W. Demski Georgia Experiment Station, Griffin, GA 30223
Co-Principal Investigator	Dr. Mike Deom Plant Pathology University of Georgia Athens, GA 30602
B. Nigerian Counterpart Inst:	Institute of Agricultural Research (IAR) Ahmadu Bello University, Samaru, PMB 1044 Nigeria
Principal Investigator:	Dr. Phindile Olorunju
Collaborative Investigator	Dr. Steve Misari
C. Thailand Counterpart Inst:	Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand
Principal Investigator:	Dr. Sopone Wongkaew
Collaborative Investigator:	Dr. Duangchai Choopanya
D. Informal Cooperation:	ICRISAT, Patancheru P.O., A.P., 502324, India
Principal Investigator:	Dr. D.V.R. Reddy

APPROACH

Host Country - Nigeria

1. Inheritance of resistance studies will be conducted in a diallel test with eight peanut genotypes (28 crosses). The studies are designed to determine the nature of resistance to GR, the number of host genes involved in resistance, individual early-maturing F_3 plants with resistance to GR, and F_2 and F_3 plants with acceptable agronomic characteristics. Selection of F_2 and F_3 plants will provide the basis for a 5-10 yr. breeding program which will seek improvement in yield performance and incorporation of new traits such as drought resistance associated with resistance to GR. Screening for resistance to GR in all breeding generations will include both field and laboratory/screenhouse studies. Field screening will be done by providing virus inoculum pressure by planting aphid-infected plants in alternate rows with test genotypes. The field inoculum will include both GRV and GRAV. Mechanical inoculation with GRV only will be done in the laboratory/screenhouse tests. The two methods should be useful in

identifying interactions between the two viruses that might affect certain agronomic characteristics. Principal investigators (host country and U.S.) will maintain communication with Peanut CRSP personnel having breeding programs (Tx/BCP/WA) in other W. Africa countries. Site visits to the breeding plots for selection of virus resistance will be made when appropriate.

2. Resistant (example-RMP-12) and susceptible (example-MK374) peanut lines will be increased and given to farmers in diversified areas. These seed are to be planted as demonstration plots to convince growers of the value of using resistant lines to prevent GR epidemics.

Host Country - Thailand:

3. More emphasis will be placed on bud necrosis virus (BNV) since it has been identified as the prominent virus disease in Thailand. These studies will include improved diagnostic studies, identification of vectors, virus isolate characterization and epidemiological studies.

4. Since PStV is so important in other S.E. Asia countries, a geographical area with no PStV incidence the previous year will be selected. Plots of approx. 10 m^2 with 20 m spacing between plots will be established. Maize will be grown as a barrier crop between plots. Spacing within and between rows will be approx. 30 cm. Randomly spaced plants (100 in each plot) will be inoculated at the 1st true leaf stage with PStV. The infected plants will be tagged. Yield data from the mechanically infected plants and the same number of healthy plants will be compared in each plot.

5. A second year of virus survey will be completed. To determine virus incidence, a single green leaf will be taken from each of 10 plants per acre, at random throughout the field. Incidence per county, state or specified areas will be obtained by dividing the total number of plants infected by the total number of plants sampled. Surveys should be done in at least two different years. To detect other viruses, additional samples will be taken from plants with virus like symptoms.

6. Seed from the U.S. Plant Introduction Unit or the ICRISAT collection will be screened for virus resistance in greenhouse and field tests. Field tests will be conducted with infected source plants placed in the edge rows and internal plot rows separating test plants. Greenhouse tests will be by mechanical inoculation. Non-seed transmission of PMV has been identified in some peanut lines and these lines will be tested for non-seed transmissibility with PStV.

United States:

7. *Arachis hypogaea* types and 'wild' peanut types will be acquired from the U.S. Plant Introduction Station. Seedlings, rooted cuttings and other progeny will be mechanically and vector inoculated (separately with TSWV, PStV and PMV) using general virology procedures. Lines showing promise of resistance will be field planted and subjected to inoculum pressure from infected source plants. Interspecific lines will also be tested by mechanical and vector inoculation.

8. Primary source of virus will be sought by serological tests of weeds and other plants growing in areas where TSWV epidemics have occurred in prior years. Thrips vectors will be trapped as they emerge from the soil and serologically tested for TSWV. Plots will be devised to test for internal virus spread as opposed to continual virus source from outside the plots. TSWV infected peanut seedlings will be transplanted into some plots but not others and comparative incidence in each plot analyzed. Known TSWV source plants (peanut, datura, tomato or tobacco) will be placed in and near healthy peanut and spread will be carefully monitored.

9. Four approaches for transformation will be attempted. The first approach will involve electroporation of peanut protoplasts in a solution containing the coat protein sequence for peanut stripe virus. Electroporated protoplasts will be plated onto a GUS selection medium and those protoplasts showing incorporation of the coat protein sequence into their genomes, as determined by the GUS assay, will be regenerated into complete plants. The second approach will involve the direct bombardment of cultured peanut shoot tips or meristems utilizing the particle gun. In this procedure the coat protein sequence is bound to microscopic tungsten or gold particles that are forcibly "shot" into the cells or tissues. Incorporation of the coat protein sequence into the peanut genome is determined by the GUS assay. The third approach will be placing the coat protein gene in solution with protoplasts and polyethlene glycol to induce protoplast penetration by this gene. The fourth will use Agrobacterium to carry the genes into the peanut tissue.

ACCOMPLISHMENTS IN DETAIL

Nigeria

In addition to the breeding lines already established at the Institute for Agricultural Research, ICRISAT, Hyderabad, India supplied the Samaru station with 15 aflatoxin-resistant, advanced breeding lines, 25 early-maturing lines (IV IEGVT), 16 drought-tolerant lines (IDRGVT), and 15 medium and late-maturing lines (IV IMLGVT) (VB). ICRISAT Sahelian Centre (ISC) sent three lines (ICGV-SM 88709; ICGV-SM 88710 and ICGV-SM88711) for yield testing and 15 lines for groundnut rosette screening. These were included in our yield trials and screening nursery.

Two breeding nurseries were executed, namely Breeding Nursery I (which involved screening of advanced breeding lines for groundnut rosette resistance), and Breeding Nursery II (in which early generation lines) were screened for disease and other agronomic characteristics.

Breeding Nursery I: Fifty lines, selected earlier from 260 lines on the basis of less than 10% rosette infection were planted in 1992 for the second successive year to confirm their resistance to rosette. Four of the lines had 80-100% of infection, 20 had infection ranging from 1-9% while the rest were free from rosette. Little leaf (a possible variant of rosette) was observed on two of the lines. A detailed report of the screening for rosette resistance is presented in Table 1.

Table 1. Reaction of Advanced lines to groundnut rosette virus infection at Samaru, Nigeria 1991 and 1992

Breeding Line	Pods per stand	% rosetted
K 20. 84	45.2	16.6
K 21. 84	25.0	13.2
K 22. 84	30.3	5.9
K 23. 84	50.0	9.5
K 38. 84	40.0	6.4
K 48. 84	35.0	9.5
K 5. 85	30.0	7.1
K 9. 85	27.0	100.0
K 17. 85	27.0	4.3
K 18. 85	27.0	100.0
K 20. 85	50.0	9.8
K 21. 85	31.0	37.2
K 26. 85	25.0	11.5
K 27. 85B	25.0	43.5
K 30. 85	26.0	20.3
K 31. 85	28.0	13.4
K 33. 85	28.3	9.4
K 34. 85	45.3	8.0
K 36. 85	33.0	7.8
K 43. 85	23.3	8.8
K 46. 85	33.5	1.4
K 47. 85	36.0	2.7
K 50. 85	27.7	1.9
K 51. 85	29.3	0.0
K 52. 85	30.1	9.3
K 58. 85	29.0	16.1
K 59. 85	29.6	1.5
K 60. 85	32.3	12.9
K 62. 85	37.7	11.3
K 81. 85	38.2	1.5
K 94. 85	36.7	13.5
K 99. 85	36.7	7.4
K 101. 85	32.4	10.5
K 106. 85	32.4	5.1
K 107. 85	32.4	5.0
K 116. 85	47.0	11.9
K 117. 85	44.0	10.2
K 118. 85	37.7	21.9
K 130. 85	34.0	3.6
K 198. 85	40.0	6.2

The 15 lines for rosette resistance screening from ISC, Niamey (Niger) were screened in the field according to the Bock and Nigam method. There were no rosette symptoms on these lines in the first 2 weeks of planting. Symptoms appeared on a few plants of some lines 4 weeks after planting. On the whole, the symptoms were not severe and appeared mostly late in the season. The total number of infected plants were 33 out of 413 (about 8%).

Breeding Nursery II: Twenty F_1 and F_2 progenies derived from crosses involving two rosette resistant and three rosette susceptible lines were planted together with their parents and some backcrosses. These were inoculated in the field with viruliferous aphids. Disease incidence and severity were high with 100% infection of susceptible parents, F_1s, and infector rows (Table 2). Rosette symptoms were also observed on some F_2s, backcrosses and resistance parents. Symptoms on resistant parents were, however, mild and appeared very late in the season on a few branches. Surviving F_2s, parents and backcrosses have been harvested and will be used in future for generation advance.

Table 2. Reaction of Parents, F_1 and F_2 generation Crosses to infection by groundnut rosette virus

Resistant Parents	H/D[1]	Susceptible Parents	H/D
RG 1	137/12	M1204.78I	0/135
RMP 12	105/11	ICGS 56(E)	0/ 70
		JL 24	0/188

F_1 Crosses		F^2 Crosses	H/D
RG 1 x RMP 12	25/ 4		53/ 21
RMP 12 x RG 1	25/ 2		69/ 20
RMP 12 x M1204.78I	0/27		12/ 76
M1204.78I x RMP 12	0/22		13/ 71
RMP 12 x ICGS-56(E)	0/28		7/ 99
ICGS-56(E) x RMP 12	0/30		4/ 84
RMP 12 x JL 24	0/28		6/ 89
JL 24 x RMP 12	0/17		5/104
RG 1 x M1204.78I	0/30		18/ 71
M1204.78I x RG 1	0/28		12/ 78
RG 1 x ICGS-56(E)	0/29		5/ 83
ICGS-56(E) x RG 1	0/27		3/108
RG 1 x JL 24	0/28		4/ 88
JL 24 x RG 1	0/14		7/ 90

[1] H/D=healthy vs diseased

Variety Testing

The two trials conducted under this subproject were: Selection Trial and Main Variety Trial (MVT). A total of 78 lines were tested in replicated trials.

(i). Selection Trial: A total of 30 breeding lines were planted on 4 June 1992. These included the selections made from last year's breeding Nursery II (Georgia Crosses) Table 3. The selection trial is a preliminary trial in selection for yield potential, resistance to foliar diseases and other agronomic characteristics. Lines selected from this trial go to the main variety for further testing before being tested in the States of the Federation.

No major foliar diseases were observed. None of the new selections showed rosette symptoms and only three of the IAR lines showed rosette symptoms despite the high aphid population in the field.

Timely planting resulted in a good harvest. Pod yields averaged 2807.9 kg/ha with a range of 1,580.9 - 3577.4 kg/ha. Twenty-three of the 30 lines yielded above 2.5 tons/ha, while 14 lines produced up to 3.0 t/ha. The two check varieties, M554.76 and RMP 12, yielded 2492.9 and 2958.9 kg/ha, respectively. The highest yielder was M516.78 with a yield of 3.6 t/ha.

Table 3. Performance of 13 lines developed from Rosette resistant (R) x Susceptible (S) crosses.

Genotype	Pedigree	Pod Yield kg/ha	100 Seed wt (g)
UGA 1	RMP 12 x RG 1	2274.99	46
UGA 2	RMP 12 x ICGS	3129.73	46
UGA 3	RMP 12 x 55-437	2612.90	48
UGA 4	RMP 12 x M1204.78I	2895.65	47
UGA 5	RMP 12 x JL 24	2783.60	44
UGA 6	RMP 12 x MK 374	3371.42	44
UGA 7	RMP 12 x RRB	2176.12	46
UGA 8	RG 1 x ICGS	1461.53	39
UGA 9	RG 1 x 55-437	2666.66	46
UGA 10	RG 1 x M 1204.78I	2542.37	44
UGA 11	RG 1 x JL 24	1800.00	45
UGA 12	RG 1 x MK 374	2332.39	47
UGA 13	RG 1 x RRB	3099.99	51
Control			
RMP 12		2958.90	39
M554.76		2492.95	43

(ii). Main Variety Trial: A total of 48 advanced elite lines were planted on 4 June, 1992. Fifteen of these lines were from 1991 selection trial. Varieties that performed well (i.e., with yield of up to 3000 kg/ha) in 1991 MVT were also included for a second year before they could be advanced to State Trials Observations included reaction to diseases (rosette, leafspots and rust) as well as yield and its components.

No significant foliar diseases were observed. However, 12 lines showed rosette symptoms, the incidence varying from 1% to 16%.

Pod yields ranged from 676.1 to 4153.8 kg/ha, with a mean of 2863.65 kg/ha. about 44% of the lines yielded above 3 tons/ha, while 10% produced more than 3.5 tons/ha. Three check varieties were used namely 48-115B for the early lines M554.76 for medium duration lines and RMP 12 for late maturing lines and these yielded 676.1 kg/ha, 3442.6 and 2845.5 kg/ha, respectively. The best yielders among early lines were M359.79 (2114.8 kg/ha) and 1691.79 (2453.2 kg/ha). Best yielders among the medium and late maturing lines were: M343.81 (3814.3 kg/ha); K2701.80 (3636 kg/ha); M364.80I (3632.7 kg/ha); M354.81 (4153.8 kg/ha); and M554.79I (3698.4 kg/ha).

Seed Multiplication

Four peanut varieties (SAMNUT 10, 11, 14, 16) were grown in the 1992 cropping season as breeder's seed and also foundation seed. A total of 4.89 tons of foundation seed and 100 kg breeders seed were realized this past year. Breeders seed and foundation seed are in great demand as they supplement the production by National Seed Service.

State Trials: 28 yield trials were conducted in 14 states of the federation. It is from these trials that high yielding resistant varieties are identified for release for the different ecological zones.

International Impact

Screening for Rosette resistance: 15 lines from ICRISAT, Niamey were screened for resistance to rosette.

Training: Mr. Lassane Belem from Burkina Faso came for three weeks training on Rosette screening and aphid manipulation.

Seed Testing: A total of 30 rosette resistant advanced lines were sent to ICRISAT, Niamey in May 1993 for yield and selection trials.

Variety Release: 2 medium-maturing plus 1 short-season varieties have been identified for release. The medium maturing are rosette resistant while the short season is rosette susceptible but high yielding under Sudan Savannah ecological region. A document pertaining to the release has been submitted to the Institute for consideration.

Thailand

During December 1992 to April 1993, major peanut producing area of 16 provinces had been surveyed for viral diseases. The areas were representatives of main production region, the Northeast, North, East, and Central. Field symptoms and serological tests were used as diagnostic procedures for incidence assessment. Details of sites, varieties, and planting dates were gathered by interviewing farmers (Table 4).

Table 4. Details of peanut planting sites surveyed for virus during the dry season of 1992/93 in Thailand.

Site	Surveyed area[1]/ (rai)	Production objective	Area specification (Irrigation/ spacing/other)
Northeast	16	General	Furrow/20 x 40
Khon Kaen 1	8	Research	Sprinkle/20 x 30
Khon Kaen 2	15	Certified seed	Furrow/20 x 40
Mahasarakam	12	General	Furrow/20 x 40
Nong-Kai	3	General	River bank/20 x 30 early planting
Roi-et	18	Certified seed	Furrow/10 x 40
Sakon-Nakorn	12	General	Rurrow/20 x 40
Surin	16	General	Residual/20 x 30
Ubon-Ratchathani	10	General	River bank/20 x 30/early planting
North			
Lampang 1	12	General	Furrow/10 x 15 on 2 x 5 m row
Lampang 2	10	General	Flooded/10 x 15
Lampoon	2	General	Furrow/10 x 20
Prae	5	General	Furrow/10 x 15
Utra radit 1	12	General	Flooded/10 x 15/ early planting
Utra radit 2	8	General	Furrow/10 x 15/ Medium-late planting
East			
Prachinburi 1	8	General	Residual/20 x 30
Prachinburi 2	10	General	Residual/20 x 30
Chantraburi	8	General	Residual/20 x 30
Rayong	5	General	Residual/20 x 30
Central			
Singha buri	10	Boiled	Residual/20 x 30/ local variety

[1]/ Disease incidence was assessed from 10% of the surveyed area. (6.25 rai=1 hectare).

Bud necrosis caused by peanut bud necrosis virus was the most prevalent especially in the Northeastern and Eastern areas. The incidences in some locations were as high as 80%. The affected crops normally bear no pods resulting in a total loss. The disease is less prevalent in the North and Central regions where the plant density is higher than that of the Northeast and Eastern areas. Early planting as observed in Ubon Ratchathani and Nong-Kai appeared to have an effect in reducing the disease incidence. PStV was a problem only in research stations. Spotty incidence

was noted in only some areas grown by farmers. Yellow spot had a similar pattern, spotty, but an exceptionally high incidence was observed in the central region where an indigenous cultivar is grown. From this survey, none of the samples collected gave positive results when being indexed with anti serum to PMV and CMMV. This indicates the low or lack of incidence of mottle and leaf roll during the past dry season. Results are tabulated in Table 5.

Table 5. Virus disease incidence observed in peanut during the dry season of 1992/93 in Thailand.

Site	Disease incidence [1/] (%)			
	Bud necrosis	Stripe	Yellow spot	Others
Northeast				
Kalasi	15-30	0	2-5	0
Khon Kaen 1	5-15	80-100	1-2	0
Khon Kaen 2	4-40	0	0	0
Mahasarakam	5-15	0	0	0
Nong-Kai	5	1	1	0
Roi-et	30-80	1	1	0
Sakon-Nakorn	30	0	0	0
Surin	0-15	0	2	0
Ubon-Ratchathani	0	0	1	0
North				
Lampang 1	1	0	10	0
Lampang 2	0.8	0	0.5	0
Lampoon	0.5	0.5	0	0
Prae	0	0	0	0
Utra radit 1	0	0	0	0
Utra radit 2	1-6	0-5	0	0
East				
Prachinburi 1	30	2	1	0
Prachinburi 2	70-90	0	0	0
Chantraburi	2	0.5-1	0	0
Rayong	5	0	0	0
Central				
Singhaburi	0.5	0	60-70	0

[1/] Field results were confirmed by DAC ELISA

Bud necrosis disease has become a major threat for peanut production in dry season in the recent years but little is known concerning the virus identity and detailed characteristics.

Although 145 diseased plant samples were collected from major peanut growing areas of 16 provinces (Table 6). The samples were mostly peanut but some other crop species as well as indigenous weeds were also collected. After the virus identity had been proved by DAC-ELISA to be bud necrosis virus (BNV), it was further single-lesion isolated in either cowpea or petunia for detailed studies. Symptomatology, thermal inactivation point (TIP), and seed transmission frequency were the 3 main characters studied during the past season.

Table 6. Plants showing symptoms of possible bud necrosis virus infection collected for detailed studies during 1992-93.

Species	Symptom	Location (Sample number)
Achyranthes aspera	Severe mottling, malformed leaves	KK (2)
Ageratum conyzoides	Chlorotic-necrotic rings	UD (1), KK (1)
Alternantherades sessilis	Chlorotic-necrotic rings	KK (2)
Arachis hypogaea	Mild-severe stunting with chlorotic or necrotic rings or spots or patches on leaves which may or may not malform. Necrosis may appear on stipule, shoot tips or stem.	CB (3), KK(12), KS(8),LPG(6), NK(4),NKR(3), LP(4),MS(5) P (4), PC (5), RE (6), RY (1), SB (4), SK (4) SR (6), UD (6).
Borreria laevis	Necrotic rings	UD (2)
Capsicum frutescens	Chlorotic rings with malformed fruits	SK (8)
Cucumis sativus	Chlorotic-necrotic rings, stunting	KK (2), SK (2) CB (3)
Cucumis melo	Necrotic angular spots, malformed leaves.	KK (2)
Citrullus vulgaris	Necrotic angular spots malformed and spotted fruits	KK (3)
Cleome viscosa	Severe mosaic-necrotic rings	SB (2)
Commelina benghalensis	Chlorotic rings.	KK (1)
Eupatorium odoratum	Chlorotic-necrotic rings.	KK (2)
Heliotropium indicum	Chlorotic rings-mosaic	KK (2), SR (2)
Lycopersicon esculentum	Chlorotic-necrotic rings,anthocyanosis golden mosaic with mild stunting, necrosis may appear on stem petiole and malformed fruits	NK (3) NK (3)
Nicotiana tabacum	Faint necrotic oak-leaf pattern	MS (2), NK (2)
Physalis minima	Chlorotic-necrotic rings on malformed leaves.	KK (3), KS (2)
Polygonum nepalense	Chlorotic-necrotic rings.	UD (1), KK (1)
Solanum toruum	Mild mottling.	NK (2)
Soja max	Foliar basal chlorosis	UD (2)
Synedrella nodiflora	Chlorotic-necrotic rings	KK (3)
Targetes patula	Bronzing, malformed leaves	NK (2)
Vincia rosea	Chlorotic-necrotic rings malformed leaves	KK (2)
Vigna sinesis	Veinal golden mosaic, rings	KK (2)
Wedelia trilobata	Chlorotic-necrotic rings	KK (2)

[1] CB = Chantaburi, KK = Khon Kaen, KS = Kalasin, LPG = Lampang, LP = Lampoon, MS = Mahasaraka, NK = Nong, Kai, NKR = Nakorn Ratchasima, P = Prae PC = Prachinburi, RE = Roi-et, RY = Rayong SB = Singhaburi SK = Sakon-Nakorn, SR = Surin UD = Uttaradit.

Most of the diseased peanut samples contained BN but only some of the other species gave positive result with antiserum to BN. None of the samples however, reacted with anti TSWV-L or TSWV-I. Symptoms observed on peanut, under field condition, can be classified as mild, severe and necrotic patches types (Table 7). Symptom variation was also observed when the virus has been transferred to cowpea (Table 8). This may reflect the diversity of the causal virus. Single lesion isolation using cowpea was not successful, only a few isolates could be further transferred to peanut which gave rise to symptoms found on the original hosts. The majority of the isolates gave vein clearing and mild stunting on peanut after passage through cowpea. By using sap from the original sample, the TIP was lower than 50°C in most isolates.

Table 7. Symptoms observed on peanut infected with bud necrosis virus under field condition.

Type	Detailed symptom
I:Mild	Chlorotic spots or rings appear on young top leaves symmetrically or one sided. Stunting is not apparent, no necrosis. Under dense cropping it may escape unnoticed.
II:Severe	Similar to type I but the stems are severely stunted. Necrosis appear on young tips, stipules and petioles. The plants hardly bear pods. Leaves are reduced in size and malformed.
III: Necrotic	Chlorotic spots, rings or necrotic line pattern appear patches on leaves with necrotic patches. The plants are moderately stunted.

Table 8. Symptoms expression on cowpea KC 84 R (*Vigna sinesis*) 5-7 days after being inoculated with various isolates of bud necrosis virus.

Type	Symptom	Virus isolate
I	Few faint chlorotic spots which develop further to chlorotic patches or rings, localized on the inoculated primary leaves.	From 50% of peanut samples, all Physalis.
II	Numerous chlorotic rings which may coalesce to become chlorotic line pattern, localized on the inoculated	From 20% of peanut samples, most tomato and Spilanthes.
III	Numerous chlorotic and necrotic rings, localized on the inoculated leaves.	From 20% of peanut samples.
IV	As of III but systemic infection also occur as chlorotic spots or rings on uninoculated leaves.	Two isolates from peanut, 1 from tomato.
V	Numerous necrotic spots or rings, cucurbit,localized on the inoculated leaves.	Most isolates from 1 isolate from peanut.

From 200 seedlings derived from BN positive fruits only those of tomato gave positive DAC ELISA test at 1.3-2.5% frequencies. None from watermelon gave positive results indicating the inability of BN to transmit through seeds of this species. Seeds and seedlings of BN infected peanut were also indexed. Positive result at 2.5% were obtained in seed but none of these seeds showed sign of infection in the seedling stage. ELISA tests on these seedlings also gave negative result. Among 14 species of common weeds with BN-liked symptoms tested, only 5 gave positive ELISA results and the virus could be recovered from them. These weeds are *Spilanthes paniculata, Physalis minima, Synedrella nodiflora, Clemo viscosa* and *Vincia rosea*. Most of the crops except cowpea and soybean gave positive DAC ELISA result with BN antiserum.

Before PStV was fully characterized and reported in 1984, most people assumed viruses causing mosaic or mottling on peanut were an isolate of PMV. This also applied to Thai plant pathologists. Since it has been well established that most of the mottle or mosaic disease affecting peanut in Thailand is caused by PStV, it was proposed that information on peanut mottle virus in Thailand should be revised. A project was conducted as part of an M.Sc. thesis of a postgraduate student at Khon Kaen University. After an extensive survey of many peanut fields from late 1990 to early 1991, 2 samples of peanut leaves out of hundreds were indexed to contain PMV. From these samples, only the one collected from Ubon-rachathani has PMV which could be isolated. After being passed through the standard single lesion isolation in Top crop bean (*Phaseolus vulgaris*, cultivar Top Crop), the virus has been maintained in Tainan 9 peanut for further study. In brief, the isolate possesses all common properties of PMV except that it is more difficult to purify than those that have been reported. Results of the detailed study on symptoms developed on peanut after virus inoculation indicate that early symptoms could be used to distinguish infection of PMV and PStV. In addition, cowpea (*Vigna sinensis*) KC 84 R could be used as selective host for PStV. This cowpea cultivar is immune to PMV. The inclusion bodies at light microscopic level could also be used to distinguish PMV from PStV. By using a modified technique from that of Christie and Edwardson (1986) inclusion bodies of PMV appear spherical and granular adjacent to the nuclei while those of PStV are more spindle shaped and needle-liked.

United States

Peanut germplasm lines selected for study were *Arachis* species earlier reported to be resistant to PStV or PMV in addition to some species which were promising against TSWV in field tests. The majority of the wild species having resistant to all three viruses are in the section Rhizomatosae (Table 9).

Early season abundance of tobacco thrips (*Frankliniella fusca*) and incidence and disease progress of spotted wilt, caused by TSWV were compared in Florunner and Southern Runner peanut cultivars in field studies. In replicated plot experiments and large field quadrat studies, populations of tobacco thrips adults and thrips larvae were similar for the two cultivars (Table 10). Cultivar, time, and cultivar X time interaction effects on incidence of spotted wilt were significant in all replicated plot studies except one. In all experiments, incidence of spotted wilt progressed linearly in both cultivars. Linear regression of disease incidence over time indicated disease incidence increased more rapidly in Florunner than in Southern Runner. Final incidence of spotted wilt was lower in Southern Runner than in Florunner. Final apparent incidence of spotted wilt in Florunner was approximately twice as high as that in Southern Runner.

Table 9. Indexing of *Arachis* germplasm lines tested for resistance to PStV, PMV, and TSWV

Entry	Taxonomic Section	Origin (collector)[a]	Resistance	
			Mechanical[b] inoculation	Graft[b] inoculation
PI 262794 (*Arachis glabrata* (Benth.	Rhizomatosae	Brazil (GKP 9815)	1,2,3	1,2
PI 262817 (*Arachis* sp.)	Rhizomatosae	Paraguay (GKP 9570)	1,2,3	1,2,3
PI 262839 (*A.* sp.)	Rhizomatosae	Paraguay (GKP 9642)	1,2	NT
PI 276235 (*A.* sp.)	Arachis	Paraguay (GKP 10601)	1,2	NT
PI 421707 (*A. glabrata* benth.)	Rhizomatosae	Selection from Fla	1,2,3	1,2,3
PI 468141 (*A. diogoi* Hoehne)	Arachis	Brazil (GK 30001)	1,2,3	1,2
PI 468144 (*A. helodes* (Mart ex Hoehne)	Arachis	Brazil (GK 30029)	1,2,3	1
PI 468150 (*A.* sp.)	Arachis	Brazil (GK 30006)	2	NT
PI 468152 (*A.* sp.)	Arachis	Brazil (GK 30008)	0	NT
PI 468154 (*A.* sp.)	Arachis	Brazil (GK 30011)	0	NT
PI 468159 (*A.* sp.)	Arachis	Brazil (GK 30017)	0	NT
PI 468170 (*A.* sp.)	Erectoides	Brazil (GKPSc 30126)	1,2,3	1
PI 468171 (*A.* sp.)	Rhizomatosae	Brazil (GKPSc 30127)	2	NT
PI 468174 (*A.* sp.)	Rhizomatosae	Brazil (GKPSc 30131)	1,2,3	1
PI 468345 (*A.* sp.)	Arachis	Bolivia (GKSSc 30102)	1,2,3	1,2,3
PI 468363 (*A.* sp.)	Rhizomatosae	Paraguay (GKPSc 30116)	1,2,3	1,2
PI 468366 (*A.* sp.)	Rhizomatosae	Paraguay (GKPSc 30119)	1,2,3	2
PI 468370 (*A.* sp.)	Arachis	Paraguay (GKPSc 30124)	1,2,3	NT
PI 468371 (*A.* sp.)	Arachis	Paraguay (GKPSc 30125)	1,2,3	NT
PI 475998 (*A.* sp.)	Arachis	Bolivia (KSSc 36019)	1	NT
PI 476004 (*A.* sp.)	Erectoides	Bolivia (KSSc 36025)	1	NT
PI 476012 (*A.* sp.)	Arachis	Bolivia (KSSc 36033)	1	NT
PI 497578 (*A.* sp.)	Arachis	Brazil (VMoGeSv 7377)	0	NT
PI 497581 (*A.* sp.)	Arachis	Brazil (VSSv 7384)	0	NT

[a] Collectors initials: G = Gregory, Ge = M.A.N. Gerin, K = A. Krapovickas, Mo = J.P. Moss, P = J. Pietratrelli,
S = Simpson, Sc = A. Schinini, Sv = Glocimar P. de Silva, V = Jose F. M. Valls.
1 = Resistant to Peanut Stripe virus; 2 = Resistant to Peanut Mottle virus; 3 = Resistant to Tomato Spotted
Wilt virus; 0 = none; NT - not tested.

Table 10. Effect of Florunner and Southern Runner peanut cultivars on thrips populations and incidence of spotted wilt in Attapulgus, GA.

	Number of thrips[a]							
	Terminals (A)		Terminals (B)		Blooms		Disease incidence[b]	
	Adults[c]	Larvae[d]	Adults	Larvae	Adults	Larvae	11 June	1 August
Florunner	3.5	15	3.0	5.8	14.3	3.3	0.003	0.036
Southern Runner	4.3	22	5.8	7.5	14.3	2.3	0.002	0.019
LSD (P,2≤0.05)	NS[e]	NS	NS	NS	NS	NS	NS	0.008

[a] Comparisons of numbers of thrips were made only for untreated plots. Sample dates were 11 May for terminals (A) and 29 May for terminals (B) and bloom samples.
[b] Cultivar comparisons were made across in insecticide treatments.
[c] Mean number of adult *Frankliniella fusca* per five terminals or blooms per plot.
[d] Mean number of thrips larvae per five terminals or blooms per plot.
[e] Indicates that cultivar effects were not significant (P>0.05) according to analysis of variance.

Volunteer and transplanted peanut were sampled for thrips, *Frankliniella* spp., from November to April in seven fields in southwestern Georgia that had been planted with peanut the previous year. Thrips and roots from these plants were assayed for presence of TSWV with enzyme-linked immunosorbent assay. Totals of 1,414 brachypterous and 2,360 macropterous tobacco thrips, *Frankliniella fusca* (Hinds), 218 western flower thrips, *Frankliniella occodentalis* (Pergande), and 8,590 *Franklinella* spp. larvae were assayed during the study. The virus was repeatedly detected in adult tobacco thrips and thrips larvae collected from three fields. Virus incidence ranged from 0 to 6.2% in branchypterous adults, 0 to 10.0% in macropterous adults, and 0 to 0.9% in thrips larvae, depending on field and sample date. Tomato spotted wilt virus also was detected in two adult western flower thrips. The virus was detected in only 2 of 816 volunteer peanut roots.

An efficient system for plant regeneration from hypocotyl tissue has been developed by using thidiazuron (TDZ) to provide an alternative approach for peanut transformation using tissue electroporation, *Agrobacterium* and microprojectile bombardment. Hypocotyl tissue from mature seeds was exposed to TDZ for one week and then cultured in hormone-free MS medium for 5 weeks. Over 200 shoots developed from a single seed through organogenesis. Plantlets were readily obtained with 2 to 3 months by subculturing individual shoots and rooting in MS medium containing NAA. Regenerated plants were phenotypically normal and produced seeds in the greenhouse. Comparable regeneration frequencies were observed from numerous tested peanut genotypes, including 10 major US cultivars and a related species *A. glabrata*. Hygromycin-resistant explants were recovered after electroporation with plasmids containing the *hpt* gene. About 40% of the seed inoculated with *Agrobacterium* containing a binary vector with kanamycin-resistance, GUS genes, or both produced normal plantlets in the presence of high concentrations of kanamycin. GUS gene expression was also observed in growing plantlets after histochemical assay for GUS activity. Efforts are being made to identify true transformants by DNA analysis.

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TRAINING:

Current budgets permit Thailand cooperators one trip per year to an international meeting where they can present data and interact with other scientists to keep current with scientific advancements. Depending on the location, the budgets may also support cooperators training at a scientific laboratory. The budget for Nigeria is similar. Sufficient monies are not available for graduate student training in Nigeria or Thailand.

Drs. Steve Misari and Phindile Olorunju (Nigeria), Sopone Wongkaew (Thailand) and Mike Deom and Jim Demski (USA) attended the Groundnut Virus Diseases Working Groups Meeting in Dundee, Scotland. In addition to hearing numerous presentations on viruses of peanut, participants had ample time to interact with scientists from other institutions.

In Thailand, two students (Miss Rungrat Sawadirat and Ratchadaporn Palanasirimong kol) were given support from this project to conduct research on BN and yellow spot as part of a special problem course. Mrs. Yuwadee Chooprapawan was also supported to work on peanut mottle virus (Masters thesis).

Mr. Hassane Belen from the University of Ouagadougou traveled to Nigeria where he received training (from Dr. P. Olorunju) on the establishment of plots to select for resistance to groundnut rosette.

PLANS FOR 1993-1994:

Nigeria - obtain another years data on the inheritance study - analyze the data and interpret the genetic ratios of populations on susceptible and resistant plants - help establish a resistance screening test in Burkina Faso with project Tx/BCP/WA.

S.E. Asia - establish cooperative studies with the plant breeders to get virus resistance into acceptable peanut cultivars. Complete the surveys on the viruses infecting peanut. Obtain epidemiological information on rate and distance of virus spread.

United States - continue the evaluation of peanut cultivars or lines for resistance to TSWV in both field and greenhouse environments. Finalize the studies on TSWV yield loss, epidemiology and vector biology in peanut. Continue the program to transform peanut with the gene(s) of plant virus coat protein.

AAMU/FT/BF

An Interdisciplinary Approach to Optimum Food Utility of Peanut in Semi Arid Tropical Africa

Alabama A&M University
University of Ouagadougou, Burkina Faso

Principal Investigators: M. Elena Castell-Perez (Alabama) and Alfred S. Traore (Burkina Faso)

INTRODUCTION

This project was designed to address the constraints which limit the maximum utilization of peanut for human consumption in SAT Africa. Based on the surveys conducted in the earlier phase of this project, it was recognized that peanut utilization could be considerably increased if efforts were made: (a) to increase utilization of peanut into more refined/processed forms; (b) to improve packaging of peanut and peanut products to increase shelflife; (c) to utilize peanut flour (after extraction of oil) to increase protein value of cereal-based foods; (d) to improve the method of storage, postharvest handling and inventory management. Research has been conducted at Alabama A&M University and the host country (Burkina Faso) to improve nutritive value of cereal-based foods, to improve processing of peanut and to determine nutritional compositions of peanut during postharvest handling storage and processing. The project was extended for collaboration with the Food Research Institute in Accra, Ghana, for improvement of post-harvest operations and utilization of peanut.

Major Accomplishments

1. Development and characterization of peanut-fortified cereal-based staple foods: A cereal-based staple food (idli) with higher protein content was developed without drastically affecting its textural properties. A new product was developed by using sorghum instead of rice as the cereal. Results can be applied to other kinds of staple foods such as "toe" and "kisra". Peanut supplementation (up to 30% defatted peanut flour, DPF) of idli decreased moisture content and increased protein content by 63%. There were no significant differences in textural characteristics (compression force) of both traditional (rice-blackgram) and idli-like (sorghum-blackgram) samples. Peanut supplementation drastically affected the pasting properties of rice and sorghum flours. Viscosity parameters generally decreased as a function of %DPF. Time parameters were not significantly affected. Both unfermented and fermented batters observed pseudoplastic, shear-thinning behavior at the range of shear of 0-40 1/s. Fermentation increased viscosity of batters and also increased the degree of pseudoplasticity.

2. Flavor quality of peanut: Reference standards and other items that were needed for evaluating the flavor profile of peanut by gas chromatography were obtained.

3. Oil extraction studies: Several solvent systems and operational procedures were tried to extract oil from intact whole peanut seeds. The purpose of this investigation was to identify a method that could remove considerable amount of oil from intact seeds so that a lower fat containing peanut than the original peanut could be obtained. One solvent system showed encouraging results. However, using another extraction procedure, it was possible to successfully extract about 10-15% of oil from peanut. The eating quality of low fat peanut after the extraction of oil needs detailed investigation. Preliminary results are encouraging but flavor quality has to be determined.

4. Effects of microwave radiation on peanut: The conditions for roasting peanut using microwave energy were investigated. A suitable procedure was standardized and processing time was less than 2 minutes. Further studies on flavor and textural quality of the roasted peanut need to be conducted.

5. Extruded snacks: Equipment needed for production of a peanut-cereal snack bar has been acquired or repaired. The fabrication of the extruder die is nearing completion. Three graduate students have developed the experimental designs for investigation of physical properties, nutritional quality and storage stability of the extruded product. Data collection will be initiated in September 1993.

6. Improvement of traditional processing of roasted peanut: The influence of quenching and blanching time on the quality of roasted peanut was determined. The effect of roasting temperature on non-enzymatic browning and protein digestibility was also investigated.

7. Peanut paste packaging: A survey has been initiated to find a packaging material suitable for the marketing of peanut paste manufactured by a local factory (CITEC-HUILERIE) in Burkina Faso.

8. Fortification of traditional or staple foods: Scientists at the University of Ouagadougou undertook a research study on fortification of staple foods such as "toe" with peanut proteins. The physical, nutritional and organoleptic properties of the supplemented flour (sorghum/defatted peanut) were analyzed.

9. Studies on aflatoxin contamination of peanut: Growth inhibition experiments of a strain of Aspergillus flavus with an extract of Allium sativum were conducted and results were very encouraging. The proper method of application of the extract to peanut during storage needs to be determined. A correlation was established between some physico-chemical parameters of peanut seeds and their aflatoxin content. Water content, hygroscopic capacity of the seeds and lipid metabolism seem to be the main factors affecting the growth of aflatoxins in the peanut seeds during storage.

10. Mr. Ashok Mishra completed his M.S. Degree in Food Science at Alabama A&M University.

11. Mr. Philippe Nikiema completed his course work for his Doctorate Degree in Food Technology at the University of Ouagadougou in March 1993.

12. Dr. Castell-Perez and Dr. Onuma Okezie, Director of International Programs, Alabama A&M University, travelled to Accra, Ghana, and visited the Food Research Institute to determine possibilities of collaboration with Alabama A&M University within the objectives of the Peanut CRSP project in January 1993. They also visited Burkina Faso to review host country project activities and progress and future research plan. The proposal for expansion of the project to Ghana was approved in April 1993.

Expected impacts of the project

The major constraint in increasing peanut utilization in SAT Africa is the unavailability of peanut in affordable processed forms: packaged roasted peanut, peanut butter, defatted peanut flour, peanut milk, candies, and other confectioneries. Secondly, contamination of peanut with molds, insects, and mycotoxins further limits the utility for human consumption. The project is making efforts to enhance the capability in research at the University of Ouagadougou to address these constraints. It is expected that research results will lead to better utilization of peanut not only in Burkina Faso but also in other SAT African countries. Specifically, the research results will lead to

improvement of methods of storage, packaging, processing, and development of a variety of products. Further, the objectives of the projects include collaborative research with plant scientists, microbiologists and entomologists to improve the quality of peanut available for human consumption. Applications of results from research conducted on the use of Allium sativum as an inhibitor of aflatoxin production on peanut during storage will have a tremendous impact on the health conditions of the local population. The same objectives will be applied to Ghana where the conditions under which peanut and peanut 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. This emphasizes the urgent need to review and upgrade the existing processing methods and quality of traditional peanut products in the country.

Goals

General Goal

To foster interdisciplinary (nutrition, food science, social and economic) institution-based linkages between U.S. and LDC scientists serving major peanut producing and consuming populations of the Semi-Arid Tropic regions of Africa for the purpose of optimizing the food utility of the peanut.

Specific Goals

Specific goals of the project are consistent with the general goal of the peanut CRSP to develop collaborative research and development programs on the peanut between scientists at Alabama A&M University, the University of Ouagadougou in Burkina Faso, and the Food Research Institute in Accra, Ghana.

ORGANIZATION

USA (Alabama A&M University)

Dr. M. Elena Castell-Perez, Principal Investigator, Department of Food Science, Normal, AL, Food Engineer.
Dr. John C. Anderson, Co-principal Investigator, Department of Food Science, Normal, AL, Food Engineer.
Dr. Ramamurthi Jambunathan, Cooperator, Department of Food Science, Normal, AL, Food Scientist/Biochemist.
Mr. Simon Ogutu, Research Technician, Department of Food Science, Normal, AL, Food Scientist.

Burkina Faso

Dr. Alfred S. Traore, Principal Investigator, Food Biochemist.
Dr. Solibo Some, Cooperator, Entomologist.
Dr. Albert Ouedraogo, Cooperator, Entomologist.
Mrs. Lactitia Ouedraogo, Cooperator, Food Technologist.
Mr. Alain Traore, Research Assistant, Food Scientist.
Mr. Francois T. Ouedraogo, Cooperator, Food Technologist.
Mr. Philippe Sankara, Cooperator, Phytopathologist.
Mr. Darouda G. Traore, Research Technician, Food Scientist.

Ghana

Mrs. Kafui Kpodo, Principal Investigator, Food Scientist.
Dr. Wisdom A. Plahar, Co-PI, Food Scientist.
Ms. Hodare-Okae, Cooperator, Food Microbiologist.
Ms. N.T. Annan, Cooperator, Nutritionist/Biochemist.
Mr. R.K. Adjei, Cooperator, Agricultural Economist.
Mr. C.K. Gyato, Cooperator, Agricultural Engineer.

Graduate students and research projects for thesis

USA

1. Mr. Ashok Mishra: Rheological and structural characterization of idli and an idli-like product (graduated July 1993).

2. Mr. Bin Pan - Thesis Topic: Rheological and quality aspects of peanut-fortified wheat dough during microwave baking. M.S. Degree expected August 1994.

3. Mr. Samir Kumar - Thesis Topic: Low-fat microwave-roasted peanuts. M.S. Degree expected August 1994.

4. Mr. Surendra K. Singh - Thesis Topic: Low-fat peanut butter. M.S. Degree expected August 1994.

5. Mr. Iwan Surjawan - Thesis Topic: Physical and functional properties of a sorghum-peanut extruded wafer product. M.S. Degree expected August 1994.

6. Ms. Wichayada Intaratip - Thesis Topic: Nutritional assessment of sorghum and peanut-based wafers for military rations. M.S. Degree expected August 1994.

7. Mr. Brent Jones - Thesis Topic: Storage stability of sorghum-peanut wafers. M.S. Degree expected December 1994.

8. Ms. Linda Griffith - Dissertation Topic: Precooked weaning foods based on cereal/peanut/legumes composites. Ph.D. expected August 1995.

9. Ms. Nelly Duarte - Dissertation Topic: Development of peanut fortified non-extruded snack foods. Ph.D. expected August 1995.

10. Mr. Rolfe Bryant - Dissertation Topic: Control of oligosaccharide production in peanut. Ph.D. expected August 1995.

Burkina Faso

11. Mr. Simeon Nanema - Thesis Topic: Improvement of nutritional quality of toe on fortification with peanut proteins. Doctorat Degree expected December 1994.

12. Mr. Rufin Simde - Thesis Topic: Improvement of shelf life of peanut products (roasted peanut kernels and locally made peanut pastes). Doctorat Degree expected December 1993.

13. Mr. Philippe Nikiema - Thesis Topic: Physico-Chemical parameters evolution and aflatoxins production in peanut seeds during storage (graduated March 1993).

Accomplishments and approach in detail

Rheological Properties of Composite Flours and Idli Batters:

Increased attention has been focused on oilseeds as alternative sources of food proteins. Among the oilseeds, peanut or groundnut remains the best bet in developing countries in terms of its abundant cultivation and easy availability. Thus, the importance of continuing research on the development of new nutritious, high quality food products based on combinations of cereals (such as rice and sorghum) and peanut can not be ignored. Idli, a legume and rice based staple food is prepared by steaming a fermented batter. It is a major snack food consumed in

the southern part of the Indian subcontinent and it is very similar to the african "toe". Its appeal as a breakfast food is due to its textural and organoleptic attributes. Dehulled black gram has a major role in idli fermentation as a source of microorganisms and as fermenting substrate. Acidification and leavening are the most important changes occurring during idli fermentation. Successful utilization of plant proteins as ingredients depends largely on functional properties and rheological behavior. No research work has been conducted on the rheological characteristics of composite flours and batters for idli production. The purpose of this research was to investigate the effect of peanut fortification on the pasting properties and rheological behavior of sorghum and rice flours and batters and to evaluate the feasibility of developing a new sorghum-based idli like product. Results will be useful for application to important staple foods such as "toe" in the SAT african countries.

MATERIALS AND METHODS

Pasting properties of individual flours and composite (cereal-defatted peanut) flours were determined using a Brabender Viscoamylograph. Nine parameters were measured from the graphs: (1) pasting, (2) peak, (3) breakdown, and (4) cooling viscosities in BU, (5) initial pasting and (6) peak viscosity time in min, (7) initial pasting temperature in C, (8) swelling and (9) breakdown rate in BU/min.

The rheological behavior of regular idli and sorghum-based idli-like batters (fermented and unfermented) was evaluated using a Brookfield LVT viscometer and the spindle #4. The temperature was kept constant at 25°C. Data were transformed to apparent viscosity by using the power-law model relationship.

Moisture and crude protein content of the idli were determined using standard AOAC methods. Texture (compression force) was measured using an Instron Universal Testing Machine Model 1011. Samples were compressed up to 40% of their original height at a speed of 100 mm/min. The load range used was 10 kg. The hardness of the end products was measured in terms of units of compression force (kg/cm). Scanning Electron Microscopy (SEM) analysis was used to examine the microstructure of the fortified and unfortified idli samples.

Data were analyzed using a split plot design with two replications, two bases (rice and sorghum) and seven levels of defatted peanut flour (DPF) supplementation (subtreatments). Tukey's Studentized test was chosen for mean separation test among the various levels of DPF supplementation. Rheological data were analyzed using non-linear regression techniques. ANOVA tests were conducted to determine significance of results.

RESULTS

Pasting Properties of Composite Flours

Viscoamylograph curves were affected by supplementation of rice and sorghum flours. Results clearly indicated a drastic decrease in pasting properties of the slurries as peanut flour was added. The viscosity pasting parameters of the rice-DPF blends showed a 50% decrease as %DPF increased and changes followed a linear relationship. As an example, pasting viscosity decreased from an initial value of 8 BU for 100% rice flour to a value of 4 BU for the 70:30 (rice-peanut) supplemented flour. Cooling viscosity decreased non-linearly as a function of %DPF from a value of 400 BU (100% rice) to 105 BU (70:30). Time pasting parameters were not greatly affected by the level of %DPF. Initial pasting temperature increased linearly with a maximum of 10 C. Swelling and breakdown rates decreased exponentially with %DPF. Swelling rate decreased from a value of 100 BU/min (100% rice) to a value of 20 BU/min (70:30). Results indicate the drastic changes on cooking behavior of the rice flour due to peanut supplementation.

The effect of peanut supplementation on the pasting properties of sorghum flour showed a similar trend as for the rice flour. However, some differences were observed. No clear trend was observed for changes in pasting viscosity and the changes in transition viscosity (a decrease with %DPF) were best described by a power-law relationship. Initial pasting time decreased nonlinearly with %DPF by 7 minutes. The increase in initial pasting temperature was also described by a non-linear equation. Swelling rate decreased exponentially as %DPF decreased from a value of 34 BU/min (100% sorghum) to 8 BU/min (70:30). Breakdown rate was not observed for the sorghum-peanut blends. In summary, most pasting properties of rice and sorghum flour undergo drastic non-linear changes with the addition of %DPF. These results are useful for better process control (heating/cooling) of cereal-based foods.

Rheological Characteristics of Idli Batter

Both fermented and unfermented traditional idli batters showed pseudoplastic or shear-thinning behavior (power-law behavior with a value of $n < 1$). Fermentation increased the degree of pseudoplasticity of the batters (lower value of the flow behavior index, n) and it also increased the viscosity of the samples (higher value of the consistency coefficient, m) (Table 1). The addition of %DPF up to 15% caused an increase in the viscosity values for the fermented batters. Addition of 30% DPF did not drastically affect the viscosity of the batters. It was also observed that fermentation becomes less important for the fortified batters at low values of shear rate, i.e., the values of viscosity were very similar at low shear rate values independent of the fermentation process at high fortification levels (30%DPF). These results should be helpful in the design of piping and pumping systems of such a fluid at low shear rates. In all cases, a power-law relationship best described the rheological behavior of the batters. Similar results were obtained with the sorghum-based idli batters which indicates that the use of an alternative cereal base did not change the rheological characteristics of the batters.

Table 1. Rheological behavior [values of the power-law parameters (m and n)] of the fermented and unfermented traditional (rice-based) idli-batters

Batter	Unfermented		Fermented	
(% DPF)	m (Pas^n)	n (-)	m (Pas^n)	n (-)
0	2.211	0.597	4.752	0.499
5	3.643	0.658	5.457	0.584
10	5.954	0.546	10.499	0.517
15	9.617	0.520	14.565	0.492
20	8.624	0.494	8.882	0.575
25	18.405	0.454	16.795	0.482
30	22.801	0.455	22.624	0.393

Proximate Analysis of Idli Samples

Moisture content of regular (rice-based) idli decreased as %DPF supplementation increased. The moisture content of the sorghum-based idli showed an increasing tendency starting from 5% up to 30% supplementation level. ANOVA results showed moisture content at individual level of DPF supplementation to be highly significant (P-value = 0.0016) and at the levels within the base it was significant (P-value = 0.0180). The change of base from rice to sorghum had a significant effect on the moisture content of the end products.

Protein content increased (63%) with an increase in supplementation level. ANOVA results showed that the individual level of supplementation was highly significant (P-value = 0.0001). The levels within the base were tested and found significantly different (P-value = 0.0658). The change of base from rice to sorghum, however, did show a non-significant effect.

The compression values in kg/cm of the rice-based fortified idli were almost equal (approximately 2 kg/cm) at all levels of DPF supplementation except at 25 and 30% where a slight increase in compression readings was observed (approximately 2.5 kg/cm). In the case of sorghum-based fortified idli-like products the values did not show a wide range of differences and the average value was 1.9 kg/cm. ANOVA results indicate that all the levels were not significantly different. Therefore, protein supplementation did not affect the "textural" properties of the idli and idli-like products and preparation of different rice and sorghum-based products with and without DPF did not result in any changes in hardness of the final product.

In conclusion, it was possible to produce a highly nutritious sorghum-based staple food without significant changes in organoleptic and textural characteristics. Results are encouraging in terms of possibilities of further utilization of crops commonly grown in the SAT african countries, such as sorghum and peanut.

Flavor Quality of Peanut:

A total of 65 peanut samples with two replicates each representing three different locations were obtained from Texas. They were examined, and one hundred seed weights were recorded. Reference compounds representing peanut volatiles identified by other investigators were run through the gas chromatograph and conditions for their elution patterns were standardized. Procedures for grinding peanut samples and determining the headspace volatile compounds were standardized. Acetone was used as the external standard. Headspace volatile compounds of all the 130 (65 cultivars, 2 replicates each) peanut cultivars were determined.

The following compounds were identified in peanut by comparing their retention times with those of standard compounds: methanol, acetaldehyde, pentane, ethanol, acetone, methyl acetate, dimethyl sulfide, 2-methyl propanal, 2-butanone, 2-methyl butanal, 3-methyl butanal, pentanal, n-methyl pyrrole and hexanal. The following relationship between headspace volatile components and trained flavor profile panel has been reported from earlier investigators (the component name followed by its flavor relationship is given): methane thiol- abusive drying; pentane, acetone, and dimethyl sulfide - musty after taste; 2-methyl propanal - fruity; 2-butanone - degree of roast; 2-methyl butanal, 3-methyl butanal - aging; pentanal - tongue or throat burn; n-methyl pyrrole - musty; and hexanal- beany. However the threshold values for objectionable flavor defects have been determined for the following compounds in relation to the values obtained for acetone: n-methyl pyrrole, 2-methyl propanal, pentane, and dimethyl sulfide.

Preliminary observations showed that among the flavor compounds, the concentration of n-methyl pyrrole associated with musty flavor was in much higher

concentration in these cultivars than its recommended threshold level. This observation is similar to that reported in an earlier publication where the flavor profiles of peanut cultivars that were grown in India were analyzed.

Data from this study and earlier studies therefore indicate that further screening of peanut cultivars and germplasm accessions is desirable to identify peanut cultivars that may have much lower concentration of n-methyl pyrrole. This method therefore offers hope to rapidly screen peanut samples to determine the concentrations of objectionable flavor defects and to select those that may have the desired flavor profile.

Aflatoxin Production During Peanut Storage and Its Possible Effects on Liver Cancer:

Fungus and their toxic metabolites, found in seeds and soils, have been a problem for humans and animals. Aflatoxins are among the most carcinogenic of the toxic natural substances. Countries located at the latitude ranges of 23°N and 23°S are the most affected by the toxic fungus invasion.

The main factors affecting growth of the fungus on seeds are relative humidity, temperature, gaseous composition of the storage environment, and storage time. Microflora invasion is usually associated with a high initial moisture content of the seeds. The interaction between temperature and relative humidity levels, and temperature itself play an important role on germination.

One interest in aflatoxin research is the detoxication of the contaminated products or the inactivation of the toxin. New methods are essential to ensure the good health of humans. Currently available methods are either not usable in every kind of food product or are too expensive for developing countries.

An alternative is to control some parameters such as water content, temperature, relative humidity and aeration in the raw materials in order to reduce the level of aflatoxin contamination. The objectives of this research were (1) to evaluate the changes on some physical and chemical parameters of peanut seeds during normal storage conditions in Burkina Faso, and (2) to determine a way to improve the storage conditions if necessary.

MATERIALS AND METHODS

Two local varieties of peanuts grown during 1989-1990 in Burkina Faso (Boanga and Wobgo) were obtained from the Entomology and Phytopathology Laboratories at the University of Ouagadougou. Twenty five (25) samples of each variety were used in this study. Samples were stored in plastic bags at 25-27°C (ambient conditions). Readings of temperature and relative humidity were collected every day at 8:00 am and 4:00 pm. Analysis of samples were made every 6 months from aliquots of the stored samples. Moisture content was determined using the air oven method. Lipid content was determined using the SOXLHET method with petroleum ethyl oxide as the solvent of extraction. Total protein content was determined using the KJELDAHL method. Total sugars content was determined using the method of Montreuil and Spite (1975). Water absorption capacity of the seeds was determined by placing 50 g of sample into a flask containing 200 ml of distilled water for 5 minutes. The seeds were then drained out and weighed. Aflatoxins extraction and determination was made according to the TRANSIA inmunoenzymatic method (AOAC, 1975).

RESULTS

Changes on Peanut Composition During Storage and Its Relationship to Aflatoxin Production

Protein content of the peanut samples decreased by 6-8.5% during storage. Total sugar content decreased by 5.5% for both varieties. Lipid content did not show

a drastic decrease but it was different for each variety: 1.9% for the Boanga variety and 3.5% for the Wobgo variety. Aflatoxin content increased by 120% for the Boanga variety and 300% for the Wobgo variety during the 12 months of storage. A relationship between protein, lipid and glucid content and aflatoxin production was therefore established. These results agree with results from previous research on the dynamics of carbohydrates metabolism, the role of amino acids and the influence of lipids metabolism on aflatoxin biosynthesis. In the case of stored peanut, lipids metabolism seems to be the determinant factor in production of aflatoxins.

Effect of Moisture Content and Relative Humidity on Aflatoxin Production

The average storage environmental conditions observed during the period June-July were 26°C and 60% relative humidity. The relative humidity decreased to 50% during December-January and it increased up to 70% in July-August. As expected, the moisture content of the stored samples showed a similar trend. Aflatoxin levels showed a constant increase during the storage period. The optimum values of relative humidity for growth of *Aspergillus flavus* were between 80 and 85%. This is important since aflatoxins biosynthesis is possible at a moisture content of 8%. Results on the two peanut varieties showed that the Wobgo variety contained twice as much moisture as the Boanga variety. On the other hand, the Wobgo variety lost moisture faster during storage. The reabsorption of moisture was the same for the two varieties when the relative humidity increased but the moisture content of the peanuts of the Wobgo variety was always higher. Aflatoxin levels were considerably higher in the Wobgo peanuts. Thus, moisture content of peanut during storage is a determining factor in the biosynthesis of aflatoxins. In conclusion, the higher the lipid and moisture content of the peanut seeds, the higher the levels of aflatoxin contamination (AFB1). Therefore, it can be said that peanut seeds from the Boanga variety are more edible especially if moisture content and relative humidity are not well controlled during storage.

Relationship Between Liver Cancer and Consumption of Aflatoxin Contaminated Peanut Paste in Bobo-Dioulasso, Burkina Faso

Chemical analyses revealed that aflatoxins (AFB1, AFB2, AFG1 and AFG2) are present in peanut at levels much higher than the permissible amounts of 250 ppb and toxicity levels of 300 ppb. A survey was conducted to determine the possible relationship between consumption of peanut paste and liver cancer. Thirty-five (35) families were randomly selected in the city of Bobo-Dioulasso. The average number of persons per family was 10 with 2 children under 2 years of age. The main form of consumption of peanut paste was as sauce for rice or "toe" and it was consumed as frequently as 5 days in a week. The average amount of peanut paste per meal was 544 g. Seventy percent of the peanut paste was purchased from local markets and 30% was purchased from a local factory (CITEC-HUILERIE). Fourteen percent of people used peanut paste throughout the year. Eighty-six percent preferred brown over white paste. Fifteen samples of manually made peanut paste were collected from three markets in Bobo-Dioulasso (5 samples per market) and tested for aflatoxin content. Results showed that 47% of the samples were highly contaminated with aflatoxins (>250 ppb). The average value was 265 ± 143 ppb (Table 2). In 14% of the families, each member consumed at least 14 ppb of aflatoxin per day. Since only 6% of aflatoxin consumed is excreted in the urine, an important amount of aflatoxins is accumulated in the human body which may contribute to a primary form of liver cancer.

Table 2. Aflatoxin levels in peanut paste samples from three markets in Bobo-Dioulasso

Sample Number	Market location	Paste coloration	Aflatoxin level (ppb as AFB1)
1		Brown	387
2		Brown	162
3	Accart-ville	Brown	142
4		Brown	559
5		Brown	148
6		White	407
7		Brown	165
8	Main market	White	132
9		Brown	116
10		Brown	116
11		Brown	48[illegible]
12		Brown	238
13	Saint-Etienne	White	335
14		Brown	311
15		Brown	258
Mean			265 ± 143

Isolation and Characterization of a Strain of Aflatoxin Producing Aspergillus and Inhibition Effects of *Allium sativum* Extracts on Its Growth:

Growth Inhibition Experiments

A strain of Aspergillus was isolated according to the method of Christensen (AOAC, 1975). Growth inhibition experiments were conducted using different amounts (0, 10 and 20%) of Allium sativum extract (crude or distilled). Total inhibition of growth of Aspergillus flavus was obtained with 20% crude extract after seven days of incubation at 30°C. Experiments with the distillate showed that either 10 or 20% was enough to obtain complete growth inhibition of the fungus.

Aflatoxin Inhibition Experiments

The BUSA method of aflatoxin analysis (AOAC, 1980) was used on methanolic extract of mould after 8 days of culture on Reddy medium. The strain still produced a small amount of aflatoxins at the rate of 4.1 ± 2.4 ppb for 100,000 spores in a flask containing 50 ml of medium. Thin layer chromatography was used for aflatoxin analysis and AFB1 and AFB2 were the major types produced. As expected, AFB1 and AFB2 are the most resistant types of aflatoxins.

Improvement of Traditional Processing of Roasted Peanut:

Roasting of peanut is one of the major economical activities of women in cities and villages of Burkina Faso. Such peanut is also a good source of quality proteins in the daily diet of the population. There is a strong need to improve the storage conditions of these peanut products (to ensure safety) as well as the technology for production of roasted peanut with acceptable organoleptic characteristics. Samples of traditionally processed roasted peanut were collected for chemical analyses and the effect of soaking and blanching treatments on protein quality was investigated.

Peroxidase Activity

Peanut seeds were soaked for 1-4 hours before steam blanching (5-15 min) and peroxidase activity was determined. Results indicated that peroxidase activity completely ceased for longer soaking and blanching times (Table 3). Peroxidase activity decreased from 0.305 unit/g for processing conditions of 1 hour soaking and 5 minutes blanching to 0.0 unit/g for soaking for 4 hours and blanching for 5 minutes. The effect of soaking time was not important when blanching time was increased to 10 and 20 minutes. This is significant because longer soaking times may cause considerable loss of nutrients.

Table 3. Peroxidase activity of peanut samples as a function of soaking and blanching time

PEROXIDASE ACTIVITY (unit/g)

Soaking time (hr)	Blanching time (min)		
	5	10	15
1	0.305	0.000	0.000
2	0.053	0.000	0.000
3	0.046	0.000	0.000
4	0.000	0.000	0.000

Influence of Soaking and pH on Loss of Peanut Proteins

Peanut seeds are traditionally soaked in salted water for a long period of time. Experiments on water containing from 0 to 5% of salt were conducted and the effect of salt content, pH and soaking time on the total amount of protein was evaluated. Results showed that protein loss may be as high as 5% and it increased as the pH increased from 7 to 8.5. However, protein loss decreased as the salt content increased (Table 4).

Non-Enzymatic Browning and Protein Digestibility as a Function of Roasting Temperature

The color and good flavor of the roasted peanut are due to non-enzymatic browning reactions. The browning index of the peanuts was measured at different roasting times (0-30 minutes) and temperatures (100, 120, 130 and 150°C). Browning index was considerably higher (a value of 7) for the peanuts roasted at 150C for 30 minutes as compared to peanut seeds roasted at 130°C (a value of 1.4) and 100°C (a value of 0.2) for the same time period). Roasting for 15 minutes reduced the values of the browning index to 3.8, 0.6 and 0.05 respectively. An optimum value of protein digestibility (%) was observed after 10 minutes of roasting for all temperatures and further roasting caused a slight increase on digestibility. It was also observed that the higher the roasting temperature the higher the protein digestibility of the peanuts (33% after 30 minutes of roasting at 130°C versus 15% after roasting at 100°C). In conclusion, roasting the peanuts at 130°C for 10 minutes seems to be the best processing conditions to obtain a good quality product (better flavor induced by non-enzymatic browning reactions and higher protein digestibility).

Table 4. Effect of salt, pH and soaking time on protein loss of peanut kernels for roasting

Amount of Protein Lost (g)

	Soaking time (hr)	% salt 0.0	2.5	5.0
pH= 7.0	1	0.100	0.050	0.020
	2	0.150	0.100	0.040
	3	0.200	0.120	0.080
	4	0.250	0.140	0.090
ph= 8.5	1	0.050	0.080	0.110
	2	0.060	0.110	0.120
	3	0.080	0.140	0.140
	4	0.110	0.141	0.160

Improvement of the Nutritional Quality of Peanut Fortified Toe:

Sorghum flour was supplemented with 20% defatted peanut flour to obtain an acceptable toe. Sorghum (variety S29) was obtained from the National Agricultural Research Center (INERA). Peanut (variety T32) was obtained from SOFIVAR (a local peanut dealer company). The physical properties (emulsion capacity, gelatinization capacity, water absorption capacity and fat absorption capacity) of the individual and composite flours were determined using standard approved methods. Proximate analysis of the flours indicated that peanut supplementation resulted in a 60% increase in protein content and the energy content decreased by 5%. However, the supplemented flour (80% sorghum flour, 20% defatted peanut flour) did not contain the optimal energy balance as provided by AGBESSI.

VITASET flour is a cereal-based product manufactured in France and delivered to Burkina Faso to be used as baby food. Since it is an imported product, few women can purchase it for their children. Proximate analysis results on the VITASET flour indicated that its energy content was 36 Kcal/100g higher than the energy content of the supplemented flour but its protein content was 2.3g/100g lower. Also, the price of supplemented flour is seven times lower (Table 5). These results are very encouraging in terms of developing an alternative high protein food product for use as baby food in Burkina Faso.

Table 5. Comparison of a commercial flour (VITASET) with peanut-supplemented sorghum flour

	Energy (Kcal/100g)	Protein (g/100g)	Fat (g/100g)	Price of 50g($US)
Sorghum flour	392.50	11.80	0.58	---
Peanut-sorghum flour (20:80)	374.0	19.70	1.15	0.03
VITASET	410.	16.0	10.00	0.25

Cooperation With the Private Sector (CITEC-HUILERIE) to Adapt the Size of Peanut Paste Packaging to the Requirements of Daily Family Consumption:

CITEC-HUILERIE is a factory which manufactures oil from peanut or cotton seeds located in Bobo-Dioulasso. It also manufactures peanut paste for local distribution. Since November 1992, this factory stopped the production of peanut paste because of the high cost of the packaging material. The package consisted of tin cans imported from France and they came in four sizes: 0.5, 1, 5 and 20 kg. The cans were very expensive and their size did not satisfy the daily requirements of an average family (10 persons). Since January 1993, efforts have been initiated to find a solution to this problem. Initial experiments to find an alternative package were conducted using a simple plastic bag. Results showed that the simple plastic bag was not suitable because acidity and lipid oxidation in the paste occurred very rapidly.

Publications and Presentations:

A. Manuscripts:

1. Singh, B. 1992. Aspects of groundnut utilization and possible improvements of indigenous foods in some countries of Semi-arid tropical Africa. In Groundnut - a global perspective: proceedings of an international workshop, 25-29 Nov 1991, ICRISAT Center, India, pp. 257-263.

2. Jambunathan, R. , Sridhar, R., Raghunath, K., Dwivedi, S.L. and Nigam, S.N. 1993. Oil quality characteristics and headspace volatiles of newly released groundnut (*Arachis hypogaea* L) cultivars. Journal of the Science of Food and Agriculture 61, 23-30.

3. Mishra, A. and Castell-Perez, M.E. 1993. Rheological characteristics of idli and idli-like batters. Manuscript in preparation for submission to the Journal of Texture Studies.

4. Mishra, A. and Castell-Perez, M.E. 1993. Pasting properties of peanut-fortified cereal flours. Manuscript in preparation for submission to Cereal Chemistry.

5. Nikiema, P., Traore, A. and Singh, B. 1993. Influence des aflatoxines sur l'evolution de la qualite nutritive de deux varietes d'arachide de Burkina Faso au cours du stochage. Submitted to Journal des Sciences Chimiques et Biochimiques (France).

B. Presentations:

1. Castell-Perez, M.E. and Mishra, A. 1993. Modeling changes in pasting properties of peanut-supplemented cereal flours. Institute of Food Technologists, Chicago, July 10-14.

2. Goode, A.J.II. and Castell-Perez, M.E. 1993. Pasting properties and sensory characteristics of peanut-fortified tortilla chips. Institute of Food Technologists, Chicago, July 10-14.

3. Mishra, A. and Castell-Perez, M.E. 1993. Rheological, nutritional and sensorial characteristics of peanut-fortified idli. Institute of Food Technologists, Chicago, July 10-14.

4. Mr. Philippe Nikiema, Mr. Rufin Simde and Mr. Simeon Rufin presented works related to their studies at the Regional Workshop on Peanuts, Burkina Faso, September 14-17, 1992.

International Travel:

- January 1993 - Visit to Burkina Faso. Travellers Castell-Perez and Okezie to review collaboration work at the University of Ouagadougou.

- January 1993 - Visit to Ghana. Travellers Castell-Perez and Okezie to establish MOU to conduct research in Food Technology as an expansion of the Peanut CRSP project.

Research Plan for 1993-1994

1. Research thrusts/endeavors planned for 1993 - 1994

United States

A. Peanut butter, peanut paste and roasted peanut quality improvement

1. Peanut paste is one of the most utilized product forms in Burkina Faso. It was found that packaging done in large tin containers and marketing of the larger sized products was a problem for a local manufacturer of peanut paste. A research plan has been developed to evaluate suitable packaging materials at affordable costs.

2. To develop low fat peanut butter using defatted peanuts and newly developed fat substitutes. A procedure for oil extraction from peanuts will be developed and standardized. The defatted peanuts will be used for manufacture of peanut butter and roasted peanuts. Research on textural characteristics and flavor quality of the peanut butter will be conducted. The optimum processing conditions for manufacture of the peanut butter will be obtained. Samples will be analyzed for flavor quality, viscosity and mouthfeel. Processing conditions for production of good quality roasted defatted peanuts using a microwave oven will also be investigated. Analysis including fatty acid composition, flavor profile and levels of antinutritional factors will be conducted.

B. Peanut and cereal-based food form developments

1. Earlier studies indicated that utilization of defatted peanut flour improves the nutrient values of cereal-based or tuber-based food products such as breads, kisra, and gari. The following studies are planned:

   a. Determination of functional characteristics of the composite including amylograph viscosity, oil absorption, water absorption, and gelatinization properties of composites made up of peanut/corn/sorghum/rice and soybean. Research will be completed in June 1994.

   b. Development of new foods using peanut and corn, soybean, millet and chickpea. Research will include proximate analysis, rheological properties, sensory evaluation and processing parameters. Research will be completed in May of 1994.

2. Pre-cooked weaning foods and porridges produced by pulverizing extruded materials formed by extrusion cooking of various combinations of peanut and other legumes including cow peas, soybeans and Phaseolus species with corn, sorghum, millet and wheat will be investigated to adapt approaches to include peanuts in appropriate combinations that should be safe and efficacious to improve the nutritional status of children and other at risk persons

establish suitable combinations of the ingredients as well as studies of processing parameters. This work is intended to be preliminary to the exportation and installation of an Insta-Pro extruder destined to be delivered to Burkina Faso.

3. Coordination is planned with research faculty of the University of Georgia Experiment Station on the temporary installation and shake-down operation of an Insta-Pro extruder. It is anticipated that a training exercise for host-country personnel will be arranged at an appropriate juncture after this shake down to familiarize particular key personnel in the further uses of this technology or its potential for their food development.

4. Quality assessment of peanut for processing in collaboration with scientists in a variety trial project at Texas A & M. will continue throughout 1994.

Host Country:

Burkina Faso:

A. The availability and economics of different packaging materials for peanut paste will be evaluated. Storage stability tests (microbiological and quality factors) will also be conducted. Homogeneity problems of the product will be addressed.

B. The use of sugar, garlic and honey as a means of improving the storage stability of roasted peanuts will be evaluated. Tests on acceptability of products will be conducted. Packaging formulation and shelf-life stability will also be investigated.

C. Fortification of cereals (sorghum, millet and maize) with totally or partially defatted peanut flour for manufacture of "toe", weaning foods. The development of new peanut and cereal-based products (composite flours, biscuits, etc.) will be initiated.

D. A survey of markets to determine the status of peanut products will be conducted. The use of Allium sativum extract to inhibit aflatoxin production will be investigated and the best method of preservation will be recommended.

E. Methods for drying of fresh peanuts will be tested for their efficiency in prevention of aflatoxin contamination.

F. To develop new products using peanut as the main ingredient.

Ghana:

A. Emphasis will be given to the improvement of peanut butter. Nutritional evaluation and quality assurance studies will be conducted. Existing processing methods will be evaluated and possible improvements identified.

B. A research plan on composite flours for production of weaning foods through extrusion will be developed in collaboration with researchers at Alabama A&M University. Local cultivars will be evaluated and their suitability for new products assessed.

C. Representative samples of peanut products will be taken at harvest, post-harvest, storage, processing and marketing points to screen for aflatoxin contamination. Quality evaluation of the samples will be carried out simultaneously.

GA/FT/TP

Appropriate Technology for Storage and Utilization of Peanut

The University of Georgia - Thailand and Philippines

Larry R. Beuchat, Principal Investigator UGA
Penkwan Chompreeda, Principal Investigator, Thailand
Virgilio V. Garcia, Principal Investigator, Philippines

INTRODUCTION

This project, as initiated in 1983, was directed toward evaluating procedures for handling, sorting, packaging and storing peanut. Objectives were to develop and demonstrate procedures to eliminate aflatoxin-contaminated seeds from lots received from farmers and to prevent growth of aflatoxigenic aspergilli through control of temperature and equilibrium relative humidity during storage. Maintenance of sensory quality of raw and roasted seeds was also a high priority.

Major effort is now being made to develop and adapt technologies to utilize peanut and peanut products in traditional and new food products which would be acceptable in Thailand, the Philippines, other Southeast Asian countries and the U.S. The choice of such products is based in large part on consumer survey response but also on intuition and insight to consumer behavior. Fundamental and applied research has been conducted in laboratories of all three collaborating institutions. Utilization of peanut and peanut products in a wide variety of food products has resulted in the development of several items which we believe are highly acceptable and have excellent potential for marketing. Additional marketing studies are needed to ascertain the potential for sales of such products in the Southeast Asian region.

Technology transfer to village scale peanut processors at Huay-Bong-Nua, Phroa District, Cheingmai Province, Thailand was fully established in FY93. Linkage with Cheingmai University through project investigators at Kasetsart University, Bangkok facilitated this effort. FY93 saw the initiation of a postharvest handling component in cooperation with Dr. Winit Chinsuwan at Khon Kaen University, Khon Kaen, Thailand. Dr. Manjeet Chinnan at UGA will direct this effort from the U.S. side. A field survey to determine peanut postharvest handling operations in Northeast Thailand was conducted.

Another major emphasis of the project is the training component. Thai, Filipino and American students are pursuing advanced degrees at UGA with support from the project. The M.S. and Ph.D. programs in the Department of Product Development at Kasetsart University have come into existence in part due to the judicious use of support provided by the project. Undergraduate student thesis projects at the Institute of Food Science and Technology at the University of the Philippines, Los Baños continue to be supported by the Peanut CRSP. A Postdoctoral Associate from Trinidad who received her Ph.D. while supported by the AAM/FT/BF project joined the UGA research team in FY93. Workshops on peanut utilization are expected to have even a bigger impact on processing and the nutritional well-being of consumers throughout Southeast Asia in future years as the project achieves fulfillment of its goal to have an impact on the entire region.

MAJOR ACCOMPLISHMENTS

A. Kasetsart University (KU) (Host Country)

Consumer acceptance and shelf-life studies on tuub taab were completed. Consumers rated all sensory attributes of tuub taab in the range of liked moderately to liked very much. They preferred tuub taab packed in polypropylene bags. Aluminum foil bags were the most suitable for preserving quality of tuub

taab, followed by glassine and cellophane. The shelf-life of tuub taab packed in polypropylene bags was less than 1 week.

Acceptability of a nutritious snack containing defatted peanut flour made using a single-screw extruder was high (93.3%). Seventy-five percent of the consumers surveyed are willing to pay $U.S. 0.20 (5 Baht) for 20 grams, if the snack was offered for sale. The incorporation of peanut tempeh flour into the snack increased the protein content to 12.9% compared to 5% in the unfortified formula. A sensory evaluation test using 50 consumers showed an acceptability rating of "liked slightly to moderately."

Textured vegetable protein was prepared using peanut flour containing 1% fat. Quality characteristics were comparable to Kaset protein (TVP from soybean flour).

Flavor sauce was produced using peanut meal as a raw material. The specific gravity, total nitrogen, amino acid nitrogen and sodium chloride contents were lower in the experimental sauce than those required by the Standard for Flavor Sauce (Thailand). However, aflatoxin was absent from the peanut sauce. Sensory evaluation of the sauce, compared to commercial sauces, revealed that the peanut meal sauce had better clarity and a lighter color.

Linkage was established with Khon Kaen University via Kasetsart University to conduct research for improving postharvest handling systems in Southeast Asia, particularly peanut growing regions of Thailand. Protocols for coordinating research, transferring funds, communicating research and expenditure reports were established. A questionnaire to examine existing postharvest handling operations in the peanut growing region of Khon Kaen in Northeast Thailand was developed and a field survey was conducted to identify constrains in the postharvest handling chain. In order to develop strategies for improved drying operation, a key component in peanut postharvest handling operation, existing technologies for drying agricultural commodities in Thailand were reviewed.

B. <u>University of the Philippines - Los Baños (UPLB) (Linkage Institution)</u>

The quality of soft peanut curd was improved using high peanut to water ratios. Microbiological studies revealed that storage life was 1 day at ambient temperature (30-40°C) and 7 days at refrigeration temperature.

Peanut milk residue was used for the formulation of pork- and liver-flavored spreads. The chemical composition of spreads is comparable to commercial meat products. General acceptability scores ranged from 4.4-5.3 (7-point hedonic scale). Pork and liver flavors can be used at a level of 0.5%.

A yogurt drink was prepared by combining peanut milk and reconstituted skim milk (RSM; 8% and 10%). Preliminary results indicate that 8% RSM is unsuitable while RSM is suitable for substitution.

Soft white cheese and a peanut milk concentrate were developed. Soft white cheese was made from peanut using a coagulant. Rennet, acetic acid and a combination of the two coagulants were tested. Only acetic acid was used for the production of soft white cheese from peanut milk. The most acceptable level of peanut milk substitution in making soft cheese was at 25%. Peanut milk concentrate was also developed. This product has potential for use as a drink and as a spread, depending on the flavor added.

To develop a bland tasting peanut, peanut seeds were soaked in various acids for various times, processed and then subjected to sensory evaluation tests. Results indicate that acid treatment can be used to produce bland tasting peanut.

The effect of processing and dilution during processing on detoxification of aflatoxin in contaminated peanuts were investigated. Based on calculated values,

the effect of dilution is minimal compared to the destruction in aflatoxin due to processing.

Commercial peanut butters and other peanut products were obtained from commercial sources and analyzed for aflatoxin content.

A metabolite produced by *Cladosporium fulvum* was extracted, isolated and purified. Studies were conducted to characterize the inhibitory effect of the metabolite on *Aspergillus parasiticus*. Conditions were optimized for maximum inhibition of growth of *A. parasiticus*. Studies were done to develop a process for the production of a stable form of the inhibitory agent from *C. fulvum* against aflatoxigenic fungi.

C. <u>University of Georgia (UGA)</u>

Peanut extract was used as a protein base for developing coffee whiteners in liquid and dried forms. To increase potential market acceptance of liquid whiteners from peanut, the feasibility of eliminating hydrogenated oils from the formulation was studied. An increase in peanut extract concentration and emulsifier level increased the whitening power of the product. However, whitening power equivalent to that of a commercial control was not achieved. Mixture response surface methodology was used to optimize the formulation of liquid whitener from peanut extract. A liquid coffee whitener was prepared using peanut extract, cottonseed oil, and water. Quadratic polynomials predicted responses of the sensory variables peanutty, milky, oily flavor, astringent, and surface layer thickness to the component proportions. Reduced cubic polynomials predicted color lightness, roasted nutty, oily suspension, viscosity, and stability in coffee from component proportions. Whitening capacity was maximum in a formula containing 50% extract. Increased oil content resulted in increased oily flavor and surface flavor thickness but decreased astringency ratings and stability in coffee. Storage of the whitener at 5°C was necessary to prevent microbial spoilage.

Changes in functional properties of peanut flour made from partially defatted peanuts fermented with *Rhizoporus microsporus* var. *oligosporus* and treated with steam were investigated. An ester-like aroma and soy sauce or meat-like flavors were detected in undried and oven-dried 22-h fermented peanuts, respectively. In general, nitrogen solubility (pH 4.0-6.0), emulsion capacity and viscosity, water adsorption, and water and oil retention of flours were increased as a result of the fermentation process. Steam treatment of non-fermented and fermented peanut flours for up to 45 min enhanced certain functional properties of flours.

A three-component mixture design was used to evaluate the combined effects of non-fermented (PDPF) and fermented (F-PDPF) peanut flours, feed moisture content, and extrusion temperature on physicochemical properties of extruded cornstarch-peanut flour based snacks. Moisture content, expansion ratio, bulk density, modified Kramer compression-shear force and color of extrudates were significantly affected by the amount of PDPF and F-PDPF in the formulation. Oil absorption by extrudates was only influenced by the type of peanut flour. Within the range of 30-34% added water, 16-20% PDPF and/or F-PDPF, and extrusion temperatures of 125 to 150°C, extrudates with a wide range of functional characteristics can be produced.

Three-component mixture response surface methodology was used to optimize the formulation of an extruded snack based on cornstarch and peanut flour. Flavor and texture acceptability were limiting factors in attaining the optimum formulation. Acceptable products were produced with formulations containing 12-20% non-fermented peanut flour, 0-8% fermented peanut flour, 30-31.5% added water, and 50% cornstarch. Flavoring the product with nacho cheese, cheddar cheese, or sour cream and onion enhanced overall product acceptance. Consumer evaluation of the snacks indicated a high potential for sale in the marketplace.

The effect of hydrogen peroxide treatment on the flavor, texture and color of peanut seeds was investigated. Gas liquid chromatographic analysis revealed that hexanal content of peanut increased with increasing hydrogen peroxide concentration (up to 0.225% in soaking solution) used, regardless of storage at 39°C for up to 3 weeks. No significant changes in ethanol content were observed after a 3-week storage time. Hydrogen peroxide treatment and storage did not significantly affect the color (lightness [L] and chroma [C]) and texture of the peanut. Furthermore, sensory panelists were unable to detect a difference in peanut brittle prepared from untreated peanut and peanut treated with 0.075% hydrogen peroxide for 1 min.

The effects of an added nutrient source, added aflatoxin, and the enzyme inhibitors p-chloromercuribenzene-sulfonic acid (PCMBS) and dithiothreitol (DTT) on the ability of *Flavobacterium aurantiacum* NRRL B-184 to degrade aflatoxin B_1 (AFB_1) were determined. In addition, the isolation of water-soluble degradation products resulting from transformation of AFB_1 by *F. aurantiacum* was also determined. Neither added nutrients nor added non-labeled toxin had a significant influence on the microbial transformation of AFB_1. These results suggest that microbial degradation of aflatoxin by *F. aurantiacum* is probably a mineralization phenomenon and not a co-metabolism. Similarly, neither PCMBS nor DTT had a significant effect on the ability of *F. aurantiacum* to degrade AFB_1, indicating that either -SH containing enzymes are not involved in the transformation of AFB_1 by the bacterium, or the chemical compounds investigated were ineffective inhibitors at the concentrations tested. Water-soluble degradation products resulting from detoxification of AFB_1 by *F. aurantiacum* consisted of at least one primary and several minor degradation compounds.

A cooperative working relationship was established with Khon Kaen University via Kasetsart University to undertake new research thrusts in postharvest handling of peanuts. Dr. Manjeet Chinnan is a new US investigator on this project to lead this research activity, whereas Dr. Winit Chinsuwan from Khon Kaen University is the host country counterpart. A questionnaire was developed with significant input from host country investigator, Dr. Chinsuwan, for the purpose of identifying constraints associated with various segments of postharvest handling systems.

GOAL

The goal of the project is to enhance the capabilities of scientists, technicians and students at KU, UPLB and UGA. In time, these scientists will assist in disseminating information on peanut utilization in its broadest sense to research scientists, teachers, government and industry personnel and laypersons on a global scale but particularly in Southeast Asia. The education and training made possible through the project will enhance possibilities to improve the nutritional well-being of the consumer. At the same time, the economic well-being of the peanut farmer, the peanut processor and the peanut marketer will also be improved.

OBJECTIVES (1992-93)

A. <u>Kasetsart University</u>

1. Continue investigations on improvement of processing and quality of tuub taab and determine shelf-life and consumer acceptance.

2. Determine the acceptability of nutritionally improved snacks containing defatted peanut flour and peanut tempeh flour.

3. Optimize processing conditions for preparing texturized protein from low-fat Thai peanut flour.

4. Continue studies on developing a seasoning sauce from peanut press cake.

5. Review technologies available for drying agricultural commodities in Thailand for possible use in drying of peanuts.

6. Develop a protocol to determine peanut quality, particularly the amount of aflatoxin in peanuts at various points in postharvest handling systems.

B. University of the Philippines - Los Baños

1. Continue product development and improvement studies on snack foods, sauces, spreads and fermented products containing peanut.

2. Utilize residue from the extraction of peanut milk.

3. Determine the effect of processing on aflatoxin content of naturally contaminated peanut.

4. Assess safety and quality of commercial peanuts and peanut products by continued monitoring of their aflatoxin content.

5. Identify and characterize compounds produced by *Cladosporium fulvum* which are inhibitory to growth of *Aspergillus parasiticus*.

C. University of Georgia

1. Optimize the formulation of a coffee whitener prepared from peanut.

2. Investigate the potential for using peanuts fermented with *Rhizopus oligosporus* (tempeh mold) as an ingredient in extruded snack foods.

3. Determine the stability of a peanut paste emulsion developed for use as an alternative to sesame tahina.

4. Determine the effect of hydrogen peroxide treatment on sensory qualities of peanut subsequently used in a food product.

5. Conduct experiments to determine the biochemical mechanism of detoxification of aflatoxin-contaminated peanut products by the bacterium *Flavobacterium aurantiacum*.

6. Establish cooperative working relationship with Khon Kaen University via Kasetsart University to undertake new research thrusts in postharvest handling of peanuts.

7. Develop a questionnaire for the purpose of identifying constraints associated with various segments of postharvest handling systems used by small peanut producers in Thailand.

ORGANIZATION AND PERSONNEL

A. Kasetsart University

Department of Product Development (KU)

Dr. Penkwan Chompreeda, Principal Investigator
Mr. Vichai Haruthaithanasan, Co-Investigator
Dr. Chintana Oupadissakoon, Co-Investigator
Mr. Paiboon Thamratuwasik, Co-Investigator
Mr. Sombat Khotaveewattana, Co-Investigator

Ms. Sirin Pussayaipaiboon, Graduate Student (M.S.)
Ms. Sumet Amnuaysirisuk, Graduate Student (M.S.)
Ms. Witida Chantrapornchai, Graduate Student (M.S.)
Mr. Tanawit Kitumnuaypong, Graduate Student (M.S.)
Ms. Nantana Chutimantanon, Laboratory Technician
Ms. Supa Kongkeawkaw, Research Technician (assisting, no support)
Ms. Kasina Boonsaeng, Research Technician (assisting, no support)
Ms. Chantana Kopayakkin, Research Technician (assisting, no support)
Mr. Chavalit Vitayanartpisal, Research Technician (assisting, no support)
Ms. Suwakorn Tachapiyatapan, Secretary (assisting, no support)
Ms. Wasana Chaijaroon, Typist (assisting, no support)

Department of Food Science and Technology, Cheingmai University

Dr. Narin Thongsiri, Cooperator

Department of Food Agricultural Engineering, Khon Kaen University

Dr. Winit Chinsuwan, Cooperator

B. University of the Philippines - Los Baños

Institute of Food Science and Technology

Dr. Virgilio V. Garcia, Principal Investigator
Dr. Ricardo R. del Rosario, Co-investigator
Dr. Reynaldo C. Mabesa, Co-investigator
Ma. Gracia L. Bailon, Research Associate
Lorelei Zoleta, Research Associate
Christia V. Almario, Research Associate
Helen G. Delos Reyes, Research Associate
Vilma V. Patricio, Research Associate
Raul D. Divina, Graduate Student
Dindo Y. Reyes, Undergraduate Student
Victor Suelto III, Undergraduate Student
Reginaldo C. Calinga, Undergraduate Student

C. University of Georgia

Center for Food Safety and Quality Enhancement

Department of Food Science and Technology

Dr. Larry R. Beuchat, Principal Investigator
Dr. Manjeet S. Chinnan, Co-Investigator
Dr. Robert E. Brackett, Co-Investigator
Dr. Tommy Nakayama, Co-Investigator
Dr. Anna V. A. Resurreccion, Co-Investigator
Dr. Lutgarda S. Palomar, Visiting Scientist (partial support)
Dr. Margaret J. Hinds, Post Doctoral Associate (partial support)
Dr. Flor F. C. Galvez, Post Doctoral Associate (assisting, no support)
Mr. Eric Line, Graduate Student (Ph.D.)
Mr. Witoon Prinyawiwatkul, Thai Graduate Student (M.S.)
Ms. Rudeepan Wattanapat, Thai Graduate Student (M.S.)
Mr. Anuvat Jangchud, Thai Graduate Student (Ph.D.)
Ms. Grace Divino, Filipino Graduate Student (M.S.)
Mr. William E. Chapman, Research Engineer
Ms. Jye-Yin Liao, Agricultural Research Coordinator I (assisting, no support)
Ms. Brenda Nail, Agricultural Research Coordinator I (assisting, no support)
Mr. Glen D. Farrell, Research Technician III (assisting, no support)

Mr. Lary Hitchcock, Research Technician III (assisting, no support)
Ms. Julia Heggie, Laboratory Technician II (assisting, no support)
Ms. Lynn Perkins, Research Technician II (assisting, no support)
Ms. Kimberly Hortz, Research Technician I (assisting, no support)
Ms. Sandra O'Pry, Research Technician I (assisting, no support)
Ms. Ann Autry, Secretary (assisting, no support)
Ms. Lydia Griffin, Secretary (assisting, partial support)
Ms. Rebecca Uber, Accounting Assistant (assisting, no support)

ACCOMPLISHMENTS IN DETAIL

RESEARCH

A. Accomplishments at Kasetsart University

1. Consumer Acceptance and Storage Stability of tuub taab

Tuub taab is a traditional Thai sweet snack. It contains 50% or more sugar and up to 50% fully roasted peanut. A systematic study was done to improve and standardize tuub taab quality through reformulation and process modification. Tuub taab containing 50% ground roasted peanut, 45% sugar, 4.75% glucose syrup and 0.25% salt was subjected to the process shown in Figure 1. Quality characteristics of the product are summarized in Table 1.

Consumer acceptance tests were conducted at a Technical College in Bangkok. Demographic characteristics and tuub taab consumption patterns of 154 Thai consumers are summarized in Table 2. Consumers consisted of 89 women and 65 men (primarily in their 20's) with vocational school diplomas and with monthly incomes of less than B 3,000. Consumers liked tuub taab mainly because of its flavor and they usually bought tuub taab from groceries and supermarkets, paying an average of 10 Baht/pack (10 pieces). Sensory score ratings by consumer, purchase intention and preferred packaging characteristics are given in Table 3. Consumers liked all attributes of tuub taab in the range of "liked moderately" to "liked very much." They preferred tuub taab packed in polypropylene bags, 5 pieces per bag. Consumers indicated that they would definitely buy the product packed in a polypropylene bag (10 pieces, 80 g) at 5 Baht.

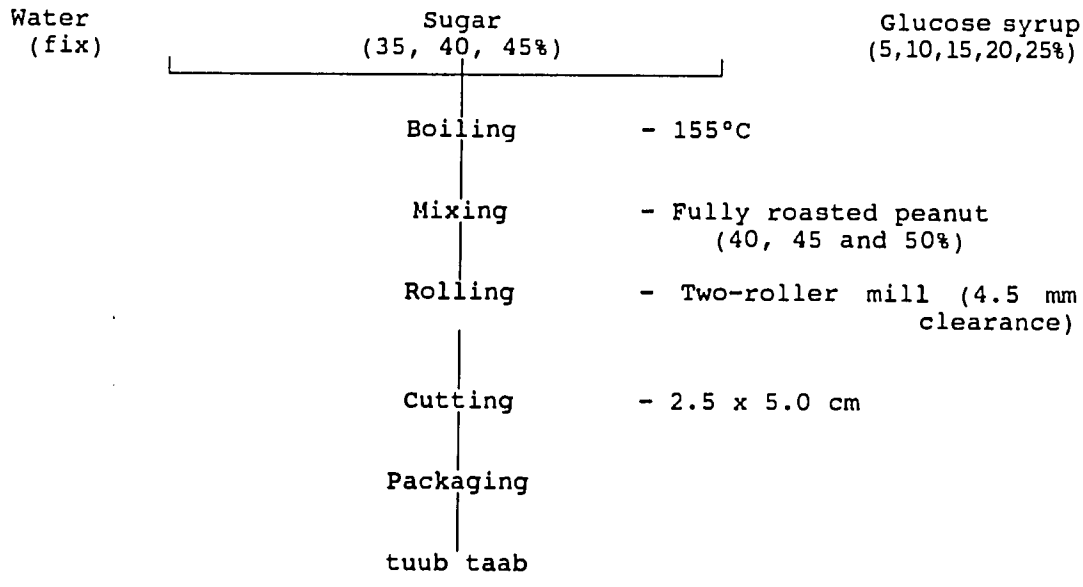

Figure 1. Flow diagram for improvement process of tuub taab.

Results of a shelf-life study of tuub taab packed in polypropylene, glassine, cellophane and aluminum foil bags and stored at room temperature (ca. 27°C) for 8 weeks are shown in Table 4. Aluminum foil bag was the most suitable package for tuub taab, followed by glassine and cellophane. The shelf-life of tuub taab packed in polypropylene bag was less than 1 week.

2. <u>Consumer Acceptance of Nutritious Snack Foods Containing Defatted Peanut Flour and Prepared Using a Single-Screw Extruder</u>

The Thai extruded snack market is a very competitive one. Consumers are mainly in the age groups of preschool children to university students. Extruded snacks in the Thai market are very low in nutritive value, particularly in protein content, since starch is the major component. Defatted peanut flour was incorporated into an extruded snack formula in an attempt to increase its protein content to at least 10%. Twelve formulae were produced using a laboratory-scale twin-screw extruder. Two formulations containing the highest protein content were selected for further study, one of which was judged by consumers to be most preferred. The formulation consisted of 37.2% potato granule, 14.0% pregelatinized potato starch, 28.0% potato starch, 19.8% defatted peanut flour and 0.5% emulsifier. Extruded snack pellets were produced using a factory scale single-screw extruder, deep fried at 190°C for 12 sec to obtain a puffed snack and then coated with onion seasoning (Figure 2). The finished snack product contained 2.6% moisture content, 11.83% protein, 30.94% fat, 46.88% carbohydrate, 5.68 % ash and 2.50% fiber and had an a_w of 0.24. The product contained less than 1,700 cfu of yeasts and molds per gram; *E. coli* was not detected.

Ingredients
|
Mixing
|
Transferring screw
|
Water → Mixing (moisture content of mixture = 30%)
|
Extrusion process
(temperature = 45°C;
pressure = 75 bar;
screw speed = 76 rpm)
|
Drying
(54°C → 55°C → 58°C;
drying time = 5 hr;
m.c. of final product = 8.2%)
|
Deep Frying
(Frying temperature = 190°C;
Frying time = 12 sec)
|
Seasoning with onion flavor
|
Packaging

Figure 2. Flow diagram for the processing of a snack base using a single-screw extruder.

Storage tests revealed that snacks packed in aluminum foil inserted in polypropylene bags could be stored at 25°C and ambient temperature for 2 months without affecting the quality. Consumer tests on the nutritious snack were conducted at 20 schools in Bangkok (24 students from each school). A total of 480 consumers between 6 to 14 years of age were surveyed. Results of acceptability tests indicated 93.3% of the consumers accepted the snack (Table 5). Mean hedonic scores for characteristics of the snack as rated by Thai school children (grades 1-6), are given in Table 6. Children liked all characteristics of the product, giving scores of about 7.4 (liked moderately) (1 = dislike very much, 9 = like very much). Consumers preferred polypropylene (59.4%) over other packaging materials; aluminum foil was the second choice (Table 7). Purchase intention as affected by the price consumes were willing to pay is shown in Table 8. Seventy-five percent of consumers were willing to pay $US 0.20 (5 Baht) for a 20-gram pack, if the snack were placed in the market.

3. Utilization of Peanut Tempeh Flour for Preparing a High-Protein Snack

Peanut tempeh was prepared by fermenting partially defatted peanut with *Rhizoporus oligosporus* for 18 hr. Flour prepared from dried tempeh was used for preparing snacks. The optimum tempeh snack base formula consisted of 48% cereal (wheat:rice = 10:30), 10% tempeh flour, 2% margarine, 1.5% baking powder and 38.5% water. Dry ingredients were mixed with water, kneaded to form dough, sheeted, cut, dried at 70°C for 15 min and deep fried at 180°C for 1 min, 45 sec. The snack base was coated with 15% pizza flavor and 5% salt. The pizza flavored tempeh had an a_w of 0.39 and contained 1.37 mg maloaldehyde/kg TBA, 5.63% moisture, 12.86% protein, 23.0% fat, 2.22% ash and 55.64% carbohydrate. The total microbial and yeast and mold populations in the product were less than 100 and less than 10 colonies cfu/g, respectively (Table 9). Product packaged in polypropylene bags could be stored for 20 days at 25°C or room temperature, while product packaged in aluminum foil could be stored for 28 days under the same conditions (Table 10). Results of acceptability tests using 50 consumers showed that the product was liked slightly to moderately.

4. Effects of Composition of Peanut Flour on the Quality of Texturized Vegetable Protein

Texturized vegetable protein (TVP) was prepared from partially defatted peanut flour using a village scale texturizer (165°C, 10 sec) (Fig. 3). The effect of fat content in peanut flour and moisture content of dough on shear strength, water absorption and bulk density of the TVP were determined (Table 11). Results of response surface analysis indicated that the use of peanut flour containing 1% fat in a dough containing 35% moisture gave TVP with shear strength of 20.3 Newtons, a water absorption capacity of 2.19 and a bulk density of 0.175 g/ml. The peanut TVP contained 7.15% moisture, 56.20% protein, 2.15% fat, 4.28% ash, 2.00% crude fiber and 27.86% carbohydrate, which was similar to TVP prepared from Kaset protein (soybean, Table 12).

5. Utilization of Peanut Meal for Flavor Sauce Production

The consumption of flavor (seasoning) sauces has increased significantly in Thailand in recent years. These sauces, widely used to flavor foods, are obtained by hydrolyzing protein with acid. Various protein sources such as mung bean protein waste, defatted coconut, pigblood, dehydrated alfalfa flour and soy meal are routinely used. Peanut meal, a by-product from the oil extraction industry, contains 30% protein. However, information on conditions required to hydrolyze peanut meal is limited. Information on flavor development in the hydrolysate is also meager. The purpose of this study was to investigate the feasibility of utilizing peanut meal for flavor sauce production, to determine

the optimal conditions for peanut meal sauce production and to study the effect of aging time on acceptability of the sauce.

Peanut meal was obtained from an oil extraction industry in Bangkok. Moisture, protein, fat, ash, carbo-hydrate and aflatoxin content in peanut meal were 6.03±14%, 35.63±0.80%, 4.79±0.37%, 4.58±0.02%, 48.97% and 1669.8 μg/kg, respectively. The particle size of peanut meal was 1.4-1.94 mm and the color, measured by the Munsell method, was 5 YR6/4. Peanut meal was hydrolyzed with 3.5, 4.0 and 4.5 N hydrochloric acid using ratios of 1:2.5, 1:3 and 1:4 (g:ml) at 15 psi (121°C) for 2.5, 3 and 4 h. The hydrolysate was neutralized to pH 5.5 with Na_2CO_3. The effect of peanut meal-to-acid ratio, concentration of HCl and hydrolysis time is shown in Table 13. Total nitrogen and amino acid nitrogen decreased with increasing ratio HCl. Acid concentrations of 3.5 N and 4.0 N gave higher total nitrogen content than did 4.5 N, while higher amino acid nitrogen was obtained using 4.0 N HCl. It was also observed that total nitrogen and amino acid nitrogen contents increased with increasing hydrolysis time. Therefore, a peanut meal-to-acid ratio of 1:2.5 hydrolyzed with 3.5 N and 4.0 N HCl for 3 and 4 h were chosen for further investigation.

Defatted Peanut Flour

↓

Weigh and add water

↓

Knead until flour becomes dough

↓

Weigh 15 g each

↓

Flatten by hand

↓

Texturize in village-scale texturizer at 165°C
Press for 10 sec

↓

Texturize protein

↓

Dry at temp 60°C for 1 h

↓

Package in polyethylene bag

Figure 3. Flow diagram for preparation of TVP.

Hydrolysate was pasteurized at 80°C for 15 min, inoculated with *Pediococcus halophilus* TISTR 430 and *Zygosaccharomyces rouxii* TISTR 5058 and aged at room temperature (30±2°C) for 2 weeks. The population of *P. halophilus* remained constant for 7 days and then decreased for the remainder of storage period while *Z. rouxii* increased slightly during the first 7 days, then decreased. The pH value and total soluble solids were not significantly changed during aging, regardless of inoculation with microorganisms. The clarity and color of the sauce were not affected by methods or aging or aging time. Flavor and taste increased with aging time.

The chemical and physical properties of sauces, compared to the Thai Standard of Flavor Sauce, are listed in Table 14. The specific gravity, total nitrogen, amino acid nitrogen and sodium chloride contents were lower than those required by Standard for Flavor sauce. However, aflatoxin was not detected in the final product. Sensory evaluation of revealed that the peanut meal sauce had better clarity and a lighter color than commercial flavor sauces. Peanut meal sauces

were also evaluated for acceptance by 30 panelists. Acceptance was at a level of slightly like to like very much.

6. Field Survey to Determine Peanut Postharvest Handling Systems in Northeast Thailand (KKU)

The objective of field survey for peanut postharvest handling systems in the Northeast is to identify opportunities for improving peanut quality. The survey was conducted in Khon Kaen, Roi-Et, and Kalasin provinces where peanut is mainly grown in paddy fields following rice in dry season with irrigation. Peanut is planted during December to January and harvested during April to May which is the beginning of the rainy season. Information to be obtained from the survey includes general practices for harvesting, stripping, drying, transportation, storage, and sale of the product. The survey results from 20 farmers in each province are summarized here.

Peanut planted area ranges from 0.21 to 1.60 ha/family with the average of 0.60 ha/family. With an average of 1.40 tons/ha, the average production is 0.84 tons/family. Peanuts is produced mainly by household labor of 4 persons/family. Approximately 70% of farmers harvest their peanut by pulling when the soil is still moist. However, for dry soil conditions harvesting is done by digging to avoid excessive harvest loss. The average harvesting capacity is only 0.04 ha/day which results in 13.5 days for an average harvesting operation.

Stripping of peanut pods is mainly done by manual picking pod by pod along with harvesting or when the plants are still green. This practice leads to a relatively low stripping capacity (25.4 kg/day) followed by a long time for stripping operation (13.3 days) but results in pods of good physical appearance. With this practice, separation of foreign materials is done along with stripping operation for which no further cleaning/separation of foreign materials is required. However, some farmers (35%) wash their pods after stripping. This is done only for peanut grown in heavy soil, which is not common in the Northeast.

After stripping, peanut pods are mainly dried directly in the sun near the house for average of 4.7 days. In some cases drying can be as long as 20 days. This is mainly for late harvested peanut which are done at the beginning of the rainy season. Approximately 15% of farmers observed mold on their pods.

Peanut is transported to the house by manual cart or carrying. This is due to a small amount of production. However, transportation for sale is arranged by traders. The period of on-farm storage before sale ranges from 0 to 60 days with the average of 19 days. Approximately 60% of farmers store peanut in gunny sacks, while the rest pile the crop in their houses. The latter practice is done when expecting for a short period of storage before sale. Approximately 42% of farmers store peanut for seed. The period of storage ranges from 0 to 8 months with the average of 2 months. The storage for seed is all done in gunny sacks.

Major buyers of peanut at farm gate are local traders and seed centers. Market channels of peanut in the Northeast and at the national level are shown in Figs. 4 and 5, respectively.

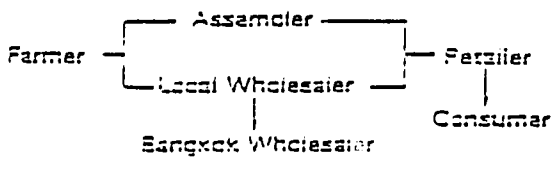

Figure 4. Market channels for peanut in Northeast Thailand.

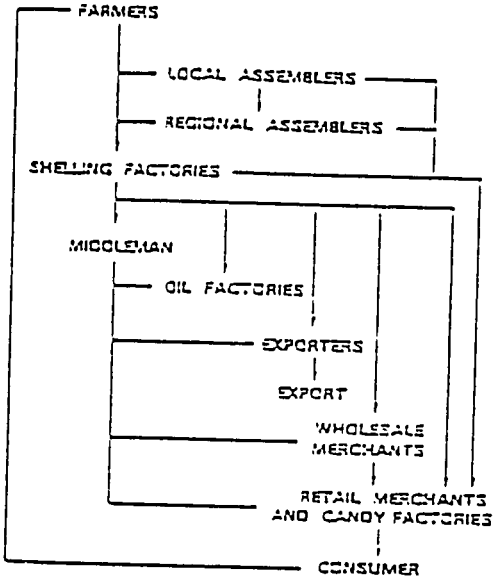

Fig. 5. Market channel for peanut at the national level in Thailand.

It is concluded from this study that in irrigated areas of the Northeast, peanut is grown by small farmers with average planted area of 0.60 ha/family and average production of 0.84 tons/family. Harvest and postharvest operations are done by hand, resulting in pods of good physical appearance but require a lot of time and labor. This leads to drying problem when drying is done during rainy season which could affect peanut quality. Thus, it is recommended that the quality of peanut be determined at all stages of harvest and postharvest operations; quality of seed stored on-farm should also be determined.

7. Review of Research on Grain Drying

Economically, the most important cereal grains in Thailand are rice and corn. Other valuable crops are soybean, mung bean, and peanut. About 20 million tons of rough rice are produced each year. The product value is estimated at 50,000-80,000 million Baht (25 Baht = 1 US$). Much less corn is produced. Its product value is about 10,000 million Baht each year. Problems of losses, in terms of both quality and quantity, arise mostly during drying and storage of cereal grain. It was estimated that losses may be as high as 25%. However, this figure seems to be too much overestimated. In most of the practice, losses may be around 5-10%, which is equivalent to about 3,250-6,500 million Baht for paddy each year.

Grain after harvesting is usually wet. As a result, respiration of grain and microbial growth occurs. Heat liberated from respiration may cause yellowing of rice grain. Under this situation, aflatoxin may be produced. This is the most serious problem in corn industry at present. At present, harvesting has been more mechanized. Combined harvesters are not popular in rice fields. Consequently, the problem of wet grain is becoming serious. Due to shortage of labor and increasing costs of labor, mechanical dryers seem to be more accepted compared with direct sun drying on concrete floor. Several types and scales of

mechanical dryers, both imported and locally fabricated, are available in Thailand.

There has been a significant amount of research and development work on grain drying during the past 15 years. Past research work may be categorized into design and testing of dryers and mathematical modeling of grain drying and drying systems. Several types of dryer and energy sources have been proposed. Some of them have been accepted. Various grain drying models have been developed and employed as a key for the determination of appropriate drying strategies. A detailed review of the research and development on dryers for agricultural materials in Thailand is presented in a Technical Report prepared by Chinsuwan (1993) as part of this project. Summary comments of that report are presented here.

Comparative studies of different mathematical drying models have been conducted. Near-equilibrium model is suggested for most of the application. A drying system model, including temperature rise by a fan and heat liberated from respiration process, has been developed. The system model is useful for the application of slow drying under tropical climates. Most of the research work on grain drying is devoted to the application at an individual farmer level. Most of the dryers developed have not been accepted due to economic reasons. Larger scale mechanical dryers are more economical and are now accepted in private rice mills due to the necessity to overcome the problem of wet paddy aroused from the acceptance of paddy combine harvesters. Appropriate strategies for grain drying have been investigated. Criteria to be considered are product quality, drying capacity and energy consumption. Operating parameters such as drying air temperature, air flow rate and fraction of air recycled are studied. For drying paddy two-stage drying is suggested, i.e., fast drying during the first stage and then followed by slow drying in the storage.

Development of new techniques or dryers, in order to reduce the cost or increase the drying rate and drying capacity, is still needed. Emphasis should be placed on large-scale application such as rice mills, cooperatives, and field crop traders. Optimum strategies, both for a dryer and a drying system, should be further investigated. Development or improvement of the existing drying system model may be needed. The model for a drying process alone may not be sufficient for the study of drying strategies.

B. Accomplishments at the University of the Philippines - Los Baños

1. Improvement of the Process for Making Soft Peanut Curd

The process for making soft curd from peanut was improved. The effect of peanut to water ratios of 1:6, 1:8, 1:10 and 1:12 was determined. At a ratio of 1:6, there was a net loss (economically) due to the high cost of raw materials. Agar-agar and sucrose were fixed at 0.4% and 6% (w/v) of the peanut milk extract, respectively, to make the process more easily done at the household or village level. Sensory evaluation tests were done on products made using ratios 1:6 to 1:10 using a 7-point hedonic scale (Table 15). Since a 1:12 ratio is used for soybean curd production, it was decided that this ratio should be tested also. Products were subjected to instrumental color analysis (Minolta color meter), curd strength tests (Neocurdmeter), proximate analysis and microbiological tests.

Microbiological tests were also done to determine the shelf-life of the products stored at refrigerated and room temperatures. Samples were plated on acidified potato dextrose agar (PDA), malt yeast extract (MYA) and nutrient agar (NA) to determine mold, yeast and bacterial populations, respectively. Sampling was done on a two-day interval until physical manifestations of microbial spoilage of products were observed, which was on the first day for samples stored at room temperature (30-34°C) and the 7th day for samples stored in the refrigerator.

The proximate composition of products is also shown in Table 15. The percentage protein and fat decreased with increasing peanut to water ratios. The lightness, hardness and a_w of products are listed in Table 15. a_w shows an increasing trend as the ratio increases in contrast to hardness values.

The average bacterial, mold and yeast populations during the six-day storage period at refrigerated temperature (5-10°C) are shown in Table 16. Bacteria are the predominant group of microorganisms in soft peanut curd. Because of the high temperature and high humidity in the Philippines, refrigeration is needed to prolong the shelf life of the product.

2. Development of Pork- and Liver-flavored Spreads from Peanut Milk Residue

Peanut milk residues were obtained from the extraction of peanut milk using a 1:6 peanut to water ratio. Residue contained 38.73% crude protein content, 20.76% crude fat and 31.33% total solids. Steaming and grinding alone or in combination were applied to residue before using them as a base for preparing spreads. Results from sensory evaluation using a 7-point hedonic scale are shown in Table 17. The desired qualities for a spread base are bland flavor and light color. The P6 treatment (steamed for 30 min and then ground) was chosen for further studies because it resulted in a product with light color, bland flavor, good texture and spreadability.

A preliminary screening of cornmeal flavoring agents resulted in choosing liver (Givaudan Co.) and pork (Actron Industries) for further study. Pork was tested at 0.5, 1.0 and 1.5% levels, while liver was tested at 0.1, 0.5 and 1.0%. Sensory evaluation of products resulted in high general acceptability scores for both flavors at 0.5%. Further testing using 0.5% pork or liver flavors were done.

Various formulations were done 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 pre-tested for addition to the formulations. These formulations were analyzed for proximate composition, a_w, pH, color, hardness and sensory evaluation. Table 18 shows the proximate composition of the test formulations as well a commercial brand of each liver spread and potted meat. Protein content was significantly higher in the commercial sample of liver spread compared to residue-based spreads. Fat is higher in residue-based spreads than in the liver spread but lower than the potted meat product. Fiber and carbohydrate contents are significantly higher in the residue-based spreads than in the commercial spreads, because they are from a plant source. Water activity, hardness, lightness and pH values are also shown in Table 18. 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 the liver spread (5.8) and potted meat (5.6). These results indicate that the peanut residue-based meat spreads need further heat treatment to prolong shelf-life.

Sensory evaluation scores are shown in Table 19. General acceptability scores ranged from 4.4-5.3 (7-point hedonic scale). Samples containing the pork-liver flavor combinations had higher ratings than samples containing individual flavors, although general acceptability scores were not significantly different from formulation A which contains 0.5% liver flavor. Results indicate 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.

3. Fermented Peanut Milk Drink

Yogurt drink was prepared from peanut milk and reconstituted skim milk (RSM). This was done because of the limitations of full-yogurt type products made from peanut milk. Stock cultures of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* were revived by inoculating (10%) into sterile RSM at 3 consecutive 12-h intervals at 37°C before addition to the peanut milk. A 3% inoculum (1.5%

each of the two cultures) was added to the milk; RSM at 8% and 10% levels were added to the peanut milk which was then incubated at 37°C for 24 h. The percent titratable acidity, pH, total soluble solids and organoleptic qualities were analyzed. Preliminary results (Table 20) show that RSM at 8% is unsuitable for yogurt drink preparation. The product using 8% RSM and peanut milk has a characteristic chalkiness and unpleasant taste. RSM at 10% was suitable for substitution and will be used for further studies.

4. Development of Soft White Cheese from Peanut Milk

Soft white cheese was developed from peanut milk. Problems concerning characteristic beany flavors were anticipated, so the incorporation of cow's milk into peanut milk was tested. Preliminary studies on the effect of homogenization and various concentrations of $NaHCO_3$ on physical and sensory qualities of the peanut curd were done. As the level of $NaHCO_3$ increased, the pH of peanut milk also increased. Homogenization did not affect pH of the milk or the product. Lightness of the product was not affected by the soaking solution but there was a slight increase in lightness when peanut milk was homogenized at 2000 psi (Table 21). Hardness of the product was only slightly affected by homogenization while the $NaHCO_3$ level had no effect on the curd firmness. Sensory evaluation results (Table 21) revealed that among the treated samples, curd made from unhomogenized peanut milk made from peanut soaked in 1.5% $NaHCO_3$ was the most favored.

Three types of coagulants (vinegar, rennet and a 1:1 mixture of vinegar and rennet) were tested using different mixtures of peanut milk and cow's milk (0:100, 25:75, 50:50, 75:25 and 100:0). Only acetic acid was capable of producing cheese from peanut milk. Rennet coagulated only the mixture containing the lowest amount of peanut milk (25%), while the 1:1 ratio of acid and rennet failed to coagulate any of the mixtures.

Cheese prepared using acetic acid was subjected to physico-chemical analyses and sensory evaluation. Table 22 shows the instrumental color analysis of the soft peanut cheese. The creamy yellow color of the control sample (100% cow's milk) was most desirable. As the level of cow's milk decreased, yellowness, and therefore desirability, decreased. The control cheese had the firmest cheese followed by 75:25 and 100:0 ratios of peanut and cow's milk (Table 22). This, however, was perceived differently by the judges who evaluated the samples. Mean sensory scores for texture showed that as the level of cow's milk decreased, firmness and desirability of the products also decreased. The a_w of the products was very high (0.96-0.99) while pH was in the low acid food category.

The proximate composition of the peanut soft cheese is shown in Table 22. Moisture content was highest in cheese made from a ratio of 25:75 milks and lowest at cheese made from 100% peanut milk. Protein decreased as the level of cow's milk decreased, since cow's milk contained higher protein than peanut milk. On the other hand, fat content increased as the level of peanut milk increased. However, the control, which was expected to have lower fat content, had higher fat than the other proportions. The highest fat content was detected in cheese made from 100% peanut milk. Ash content decreased as the level of peanut milk decreased.

Sensory responses of 10 judges rated cheese made from milk ratios of 0:100 > 25:75 > 50:50 > 75:25 > 100:0. The highest rating corresponded to "like very much" while cheese made from the next two ratios of milk received "neither like nor dislike" and "like slightly" ratings. Based on these results, the most acceptable level of peanut milk substitution in soft cheese was 25%.

5. Development of Peanut Milk Concentrate

Studies were conducted to develop a peanut milk concentrate which could be used to prepare a drink or a sandwich spread. The process for the preparation of the

concentrate is shown in Fig. 6. To determine the effect of pH of soaking solution to the milk, peanut was soaked for 12 h at various pH's (3.0, 7.0, 8.5). Carboxymethylcellulose (CMC) and natural vegetable gum (NVG) were also incorporated at a level of 0.2% (w/v) of peanut milk to improve the milk texture. Artificial flavorings, e.g. cream, almond, IFF brand cream fresh flavor at 0.2% (v/v) and IFF brand strawberry flavor at 0.01% (v/v), were evaluated for their ability to mask peanut flavor in the product. Dilution of the concentrate (1:3, 1:4,1:5) was also tested. A final formulation was derived after a series of sensory evaluations. Results in Table 23 show that products from peanuts soaked at pH 3.0 and pH 8.5 were best. The most acceptable products were obtained when 0.2% CMC was used rather than 0.2% NVG. These products had better texture due to increased protein dispersibility and solubility. Sensory evaluation revealed that cream fresh and strawberry flavors were more acceptable than cream and almond flavors. Strawberry flavored concentrate obtained from peanuts soaked at pH 8.5 rated highest, with a mean score of 5.7, while the other concentrates were also acceptable with mean scores 5.0, 4.6 and 4.1, respectively. In the instant milk drink, the ratio of peanut milk concentrate to water was most acceptable at 1:3.

Physico-chemical analysis of peanut milk showed that the protein contents were 20.34, 19.49 and 18.56 mg/ml if peanut was soaked at pH 8.5, 7.0 and 3.0, respectively. Total solids were 10.10, 10.04 and 8.47, respectively. The proximate composition of peanut milk concentrate containing cream fresh and strawberry flavors is shown in Table 23. The a_w of samples ranged from 0.895-0.905, while viscosity was 2.37×10^3 -4.75×10^3 dynes-sec/cm^3.

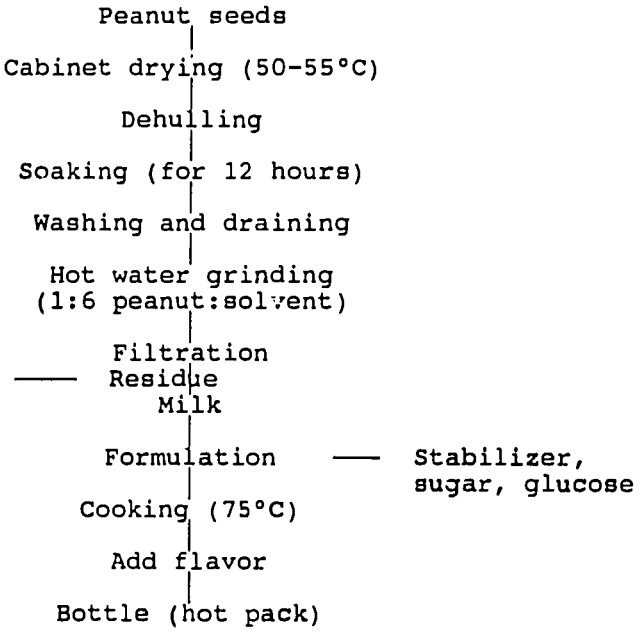

Figure 6. Schematic diagram for processing of peanut milk concentrate.

6. Development of a Bland Tasting Peanut

Peanut has limitations for application in foods due to its characteristic flavor. Preliminary work was conducted to develop a bland tasting peanut that would not only improve the nutritional value of food in which it is incorporated but also facilitate formulation, since it would readily absorb the flavor of the food.

The effect of soaking peanut in acid solutions (5% citric acid, 5% acetic acid, and 5% hypochloric acid) on color, flavor, beany flavor, and general acceptability of peanut was evaluated. Peanut seeds were soaked in acids for 1, 2 and 4 h. After soaking, seeds were rinsed with water, neutralized, and dried. The samples were subjected to a taste panel for evaluation.

Results of sensory evaluation (Table 24) show that the length of soaking time in a particular acid had no significant effect on characteristics of the product evaluated. All scores for peanut flavor, beany flavor and after taste were at the lower intensity value. This suggests that acid treatment could be used to produce bland tasting peanut, However, the samples should be compared with the control (peanut soaked in water) to validate this hypothesis.

7. Effect of Processing on the Aflatoxin Content of Naturally Contaminated Peanut

Peanut seeds containing aflatoxin were processed into sugar-coated peanut, peanut brittle, peanut bar, pastillas de mani, mazapan de mani, polvoron de mani, and peanut candy. The aflatoxin content of the finished product as a result of dilution was calculated and compared with the aflatoxin level before and after processing.

There was a decrease in aflatoxin concentration upon processing (Table 25). The possibility that dilution caused this reduction was also considered. Based on calculated values, the effect of dilution is minimal compared to the destruction due to processing. This finding may explain the non-occurrence of localized incidence of abnormally high rates of human disorders associated with aflatoxin in peanut in the Philippines, despite the fact that peanut is consumed extensively.

8. Aflatoxin Surveillance of Peanut Products

Forty-eight samples of different brands of peanut butter and other peanut products were obtained from 12 outlets in the Philippines (Los Baños, Makati, Divisoria, Cebu City and Cagayan de Oro City) from December 1991 to October 1992. Nine leading brands were monitored by collecting samples twice or thrice within the said period. Samples were analyzed for aflatoxin and water activity. Nine leading peanut butter brands were analyzed at different time intervals (2 to 3 samplings). Of the different peanut butter brands analyzed, six were positive for aflatoxin in at least one sample, while three brands (Lady's Choice, Gina and Kelly) were negative in all analyses. Among the contaminated peanut butters was Lily's a banned product reported to contain an alarming level of aflatoxin. Peanut products such as masareal, piñato, oven-baked peanuts and peanut brittle gave negative results. The a_w of all the peanut samples was not correlated with the degree of their aflatoxin contamination.

9. Microbiological Control of Aflatoxin in Peanuts

This study was undertaken to develop a suitable and practical technology of preventing or controlling growth of aflatoxigenic fungi on peanut and other peanut products using *Cladosporium fulvum*. Previous work concentrated on the evaluation of toxicity of the isolated organism and assessment of the effect of the extract against *Aspergillus parasiticus* on peanut dextrose agar. Work in FY93 was directed toward isolating the inhibitory metabolite produced by *C. fulvum* characterizing and identifying the metabolite inhibitory to the growth of *A. parasiticus*, optimizing conditions for maximum inhibition of growth of *A. parasiticus*, and developing a process for the production of a stable form of the inhibitory compound (from *C. fulvum*) against aflatoxigenic fungi.

Culture broth of *C. fulvum* harvested one week after inoculation showed inhibitory potential against *A. parasiticus*. Concentrated chloroform, acetone and ethyl acetate extracts also showed very strong biological activity, indicating that the active metabolite can be extracted from the culture broth using any of these organic solvents. Preliminary studies regarding the solubility of concentrated culture broth, extraction and purification by TLC, solid-liquid chromatography and gel filtration were geared toward the isolation of pigmented material, since earlier studies showed that the pigmented material exhibits a very strong inhibitory effect against *A. parasiticus*. Further studies on extraction and purification of the metabolite were conducted to confirm this result.

Peaks in the IR spectra of chloroform and ethyl acetate layers closely resembled each other, indicating their extraction efficiency. Preliminary HPLC data showed similarity in content of the concentrated crude chloroform layer and chloroform layer eluted initially in a short column of Sephadex LH 20. Chloroform extract eluted in Sephadex LH 20 yielded two color bands. Several fractions gave strong biological activity. However, bioassays showed that the active fraction is not necessarily the colored fraction. Although the colored fraction showed inhibition, the strongest activity was exhibited by the fraction eluted before the colored fractions. Therefore the metabolite inhibitory to *A. parasiticus* is not the red pigment per se but a compound associated with the coloring material or the red pigment.

Growth of *A. parasiticus* in peanut is suppressed for a period of 6 days only when the moisture content is about 9%. However, if the moisture content is maintained at 9% or below, there is complete inhibition of growth for more than three months at room temperature. No visible growth of *A. parasiticus* was observed in peanut inoculated with *A. parasiticus* and *C. fulvum*, indicating that inhibition may be due to the treatment applied (*C. fulvum*).

To determine the optimum pH for growth of *C. fulvum*, the mold was grown in malt extract broth (MEB) with varying pH levels. The cultures were incubated at room temperature for five days in a rotary shaker. Total mold count and biological activity were determined thereafter. Results showed that growth of *C. fulvum* was favored by alkaline pH. Generally, growth of *C. fulvum* increased as the pH of the medium became more alkaline. Cultures thus grown in MEB at pH 9.5-10 contained ca. 10^9 cfu/ml, which is about two log cycles more than the number of viable cells grown in MEB at pH 6.0. Biological assay results revealed a pronounced inhibitory effect on *A. parasiticus* when *C. fulvum* was grown in MEB at pH 9.5-10.

Work was done to modify the procedure for extracting *C. fulvum*. The first procedures used in extract the active metabolite from *C. fulvum* were carried out by using chloroform, ethyl acetate was done using a ratio of 1:1 (sample volume to solvent volume). Acetone extraction was carried out with activated charcoal. The solvents were evaporated at room temperature. These methods were simple, fast and acceptable; however, the previous procedures were not practical when large volumes of culture fluid have to be extracted. In order to overcome this inconvenience another extraction scheme was devised. The pH of the culture fluid was first adjusted to 3.5-4.5 using hydrochloric acid. Activated charcoal was then added (2%, w/v), mixed thoroughly and allowed to stand overnight. The mixture was filtered through a Whatman No. 40 filter paper on a Buchner apparatus and the residue was air dried, washed with acetone and filtered. The filtrate was evaporated to near dryness in a rotary evaporator using low heat (40°C). The concentrated extract was extracted three times with small amounts of chloroform which was then pooled into one container. A generous amount of anhydrous sodium sulphate was added to remove the moisture. The sodium sulphate was washed with a small amount of chloroform and filtered. The filtrate was evaporated again to dryness and the dried concentrated crude extract was stored in vials at 4°C for further analysis. The extract was subjected to a microassay test using paper discs inoculated with *A. parasiticus* and *A. flavus*. The extraction product was potent against the test organisms as indicated by the production of large zones of inhibition. Based on the results of this test, the modified extraction procedure can be used effectively.

The stability of the active metabolite from *C. fulvum* was investigated. The effect of heating on the activity of *C. fulvum* as inhibitory agent against *A. parasiticus* was determined. Five- to seven-day- old broth cultures were subjected to three heated at 70, 80 and 100°C for 20 min. The activity of the metabolite against *A. parasiticus* was not affected by heat treatment as indicated by the production of zones of inhibition which are comparable to the unheated control. The sensitivity of the metabolite to ph change was also determined. The pH of culture broth was adjusted to different pH's using 0.1 M NaOH and 0.1

M HCl. Significant changes in color of the culture broth were observed, which indicated that the pigment produced by *C. fulvum* during growth is not stable over a wide range of pH (Table 26). As the pH of the culture broth became alkaline, the color changed from dark, clear, red orange to clear violet. Likewise, its activity against *A. parasiticus* was also affected by pH change. The activity of the metabolite extracellularly produced by *C. fulvum* exerted maximum effect against *A. parasiticus* at pH 9.0-10.0. The activity of the metabolite decreased with acidic pH.

Preliminary studies on the preparation of a stable and suitable form of the active metabolite from *C. fulvum* for the control of the growth of *A. parasiticus* were done. The metabolite was prepared in pellet and powdered forms using cassava flour, rice flour, and cornstarch as carriers. The optimum drying temperature and drying time to produce good quality pelletized cassava flour and cornstarch were 55°C and two, respectively. However, with regard to rice flour, stable pellets resulted when longer drying time (4 h) was used. Storage studies on the pelletized and powdered forms of the bio-control agent revealed that products are stable even after three months at room temperature. Microassays on stored samples showed positive inhibition on growth of *A. parasiticus*. However, inhibition was not as potent compared to inhibition produced by *C. fulvum* culture broth per se. This can be attributed to a reduction in the concentration of the active metabolite in the formulation as affected by the addition of the carrier.

The efficacy of the pelletized and powdered forms of active metabolite from *C. fulvum* in controlling growth of *A. parasiticus* in peanuts was examined. Preliminary testing on the application of formulated pelletized and powdered materials was done using peanuts containing 7.51, 9.2 or 12.14% moisture. All peanut samples were inoculated with *A. parasiticus* prior to treatment of the antagonistic agent. Growth of *A. parasiticus* was not observed in treated peanut samples with moisture contents of 7.51% and 9.2%. However, after one week of storage at room temperature observable growth of *A. parasiticus* was noted on peanut with 9.2% moisture. Increased moisture content of the treated peanut samples (with moisture content of 9.2%) was observed after one week of storage and this could have favored the growth of *A. parasiticus*. Growth of *A. parasiticus* was not observed in peanut containing 7.51% moisture, even after prolonged storage. Peanut seeds containing 12.14% moisture supported mold growth within 4 days of storage at room temperature. Results from this preliminary experiment suggest that the use of an antagonistic agent to control the growth of aflatoxigenic fungi in peanut is possible, provided that the moisture content of peanut is maintained at or below 9%. Results will be further evaluated, verified and investigated to improve the efficacy of the system. Also the method of application of the antagonistic agent on peanut will be further studied to produce a maximum effect.

10. Dissemination of Research Information

Assistance was provided to personnel of DOST-Region 7 and farmers of Siquijor to identify peanut products for processing in their newly-formed cooperative (USAPPA, United Sawang Peanut Processors Association) on August 18-20, 1992. Activities included visits to peanut plantations and the processing area. Slide showing of peanut products existing in the Philippines were presented in a technology forum on peanut processing.

A lecture with slides showing peanut products and demonstrations of processing of selected peanut products were given to DA officers, leaders of cooperatives, trainers and selected farmers at the Agricultural Pilot Center (APC), Iguig, Cagayan, March 8-11, 1993.

A short course on peanut processing was conducted at the UPLB Institute of Food Science and Technology (IFST) on March 13-14, 1993. Two of the participants were from Bicol, while another one was from Nagcarlan.

A short course on peanut processing was conducted at the Technology Research Center (Manila) on April 1-2, 1993. Seven participants enrolled in the course.

Peanut butter samples from members of the Laguna Processors and Exporters Association (LAPREXA) were analyzed for aflatoxin content. Results showed that some of the samples have no aflatoxin while others have aflatoxin content below the maximum allowable level of 20 ppb.

Leaflets on peanut processing were disseminated during a short course on candy making which was offered to the International Rice Research Institute on April 24, 1993 at IFST.

C. ACCOMPLISHMENTS AT THE UNIVERSITY OF GEORGIA

1. Optimization of Liquid Whitener from Peanut Extract

Mixture response surface methodology was used to optimize the formulation of liquid whitener from peanut extract. Objectives were to model consumer responses to a liquid whitener from peanut which contains an emulsifier to enhance whitening power at varying levels of peanut extract, cottonseed oil, and water; and to determine the levels of peanut extract and water, and minimum amounts of cottonseed oil needed to produce an optimum formulation.

A three-component constrained simplex lattice mixture design was used. The mixture components were peanut extract (x_1), hydrogenated cottonseed oil (x_2), and deionized water (x_3). The proportion of each component was expressed as a fraction of the mixture and, for each treatment level combination or blend, the sum of the 3 component proportions was always equal to 100% of the mixture. As a result of preliminary studies, x_1 and x_2 were constrained to ranges of 0.20 to 0.70 and 0 to 0.05, respectively. To support a second or higher-order polynomial equation that represented a response behavior over the restricted simplex region, a total of 12 blends was identified.

Peanut extract was prepared following a modification of a procedure developed in our laboratory and described in the FY91 Annual Report. Hydrogenated cottonseed oil and mono- and diglyceride emulsifier were combined, heated and maintained at 80°C until needed. Corn syrup solids were dissolved in a mixture of peanut extract and deionized water, and heated to 40°C. Potassium phosphate, dibasic was added. The mixture was heated to 80°C. The oil-emulsifier mixture was added and heating to 80°C continued for 20 min. The whitener was homogenized twice at 2.76×10^7 Pa, pasteurized (65°C) for 30 min, bottled in sterile Mason jars, and stored at 4°C.

Eighty-four consumers evaluated the performance of the whiteners in coffee. The panelists were recruited from within the University of Georgia Agricultural Experiment Station in Griffin, GA and were screened to be users of dairy-based or non-dairy coffee whiteners. Panelists evaluated whitened coffee according to the performance variable solubility, whitening power, and color uniformity; and the sensory variables flavor acceptability, appearance acceptability, and overall acceptability using nine-point scales. Whitened coffee samples were prepared by dissolving 50 mL liquid whitener in 250 mL coffee maintained at 65-70°C in a hot water bath. The coffee was brewed using 1.9 L deionized water to 30 g ground coffee (Maxwell House Master Blend, General Foods Corporation, White Plains, NY).

Mean consumer ratings for the commercial control and the experimental blends are summarized in Table 27. Of the blends which contained oil in a proportion of 0.050, blends 9 and 10 (0.700 nd 0.533 peanut extract, respectively) were not significantly different ($p < 0.05$) from the control in terms of color uniformity and appearance acceptability. In addition, the whitening power of blend 9 was also not significantly different from the control ($p < 0.05$). All the blends evaluated had ratings for flavor acceptability significantly lower than that of the control, probably due to the absence of artificial flavor in the experimental

whiteners. According to label declarations, the control contained artificial flavoring agents. Only blend 3 had an overall acceptability rating not significantly different ($P < 0.05$) from the control. All other blends had significantly lower overall acceptability ratings.

Contour plots generated for the performance variables solubility, whitening power, and color uniformity indicated that consumer ratings for solubility increased with decreasing levels of oil. The use of oil in the mixture blend at a proportion less than 0.020 for all proportions of peanut extract and deionized water studied resulted in solubility ratings greater than 5 (some undissolved particles = 5). Consumers were satisfied (rating > 5) with the whiteness of coffee samples whitened by the formulations processed using blends of 0.200 to 0.500 peanut extract, 0 to 0.02 cottonseed oil, and 0.480 to 0.800 deionized water. The consumers were also satisfied with whitening power when blends containing 0.040 to 0.050 cottonseed oil were used with 0.700 peanut extract and 0.250 to 0.260 deionized water. The use of oil in the mixture blend at a proportion greater than 0.025 for all proportions of peanut extract and deionized water studied, resulted in color uniformity ratings greater than 5 (slightly uneven color = 5). The same result was true for mixture blends containing oil at proportions of 0.025 to 0.050 when peanut extract was used in the blend at levels of 0.450 to 0.700.

Peanut extract at levels of 0.620 to 0.700 for all levels of cottonseed oil and deionized water studied resulted in a product with unacceptable flavor when dissolved in coffee. Previous findings from our laboratory showed that liquid whitener from peanuts had a more intense bitter and toasted grain/cereal flavor, and astringent mouthfeel than commercial whiteners based on sodium caseinate due to differences in protein ingredients and the natural cereal flavor of peanut proteins. For all proportions of peanut extract and deionized water studied, the use of 0.005 cottonseed oil in the blend produced a formulation with acceptable appearance. Using 0.35 to 0.050 oil also resulted in acceptable appearance when 0.700 peanut extract and 0.265 to 0.250 water was used. The use of 0.500 to 0.700 peanut extract in the blend was unacceptable to consumers. The maximum amount of oil in the mixture that resulted in an acceptable whitener was 0.010. However, this must be blended with no more than 0.200 peanut extract and 0.790 deionized water. Lower oil levels were needed with increasing peanut extract in the blend.

Only consumer ratings for flavor, appearance, and overall acceptability were used to determine optimum formulations. Consumers may be used to rate sensory intensities of product characteristics if "in-depth product intelligence" is required, however, only consumer acceptance ratings are absolutely necessary to obtain optimal formulations. Among the whitener formulations studied, Blends 3 and 4 (Table 27) represent formulations within the optimum region. Consumers evaluated the solubility, whitening power, color uniformity, and appearance acceptability of these two blends as not significantly different from the commercial control ($P < 0.05$). Flavor acceptability ratings for the blends were significantly lower than the control.

2. Sensory Physical and Microbiological Quality of a Liquid Coffee Whitener from Peanut

This study was conducted to model the sensory quality and physical properties of liquid coffee whitener from peanuts using varying proportions of peanut extract, hydrogenated cottonseed oil, and water; to determine the effects of peanut extract, oil, and water on sensory quality and physical properties of the whitener; and to determine the microbiological quality of the whitener after storage at 5°C and 12°C.

A three-component constrained simplex lattice mixture design was used. The design mixtures consisted of coordinates of the vertices and uniformly spaced distribution of points on the face and sides of the constrained region of the

simplex factor space. Mixture components consisting of peanut extract (x_1), hydrogenated cottonseed oil (x_2), and deionized water (x_3) made up 89.7% of the whitener formulation. Proportions of each component were expressed as fractions of the mixture, and for each treatment level combination or blend, the sum of the component proportions equaled unity.

Peanut extract and whitener were prepared according to the procedure described in the previous section. Sensory evaluation, physical measurements (lightness, viscosity) and stability upon storage for up to 21 days were determined. Descriptors used by trained panel members to evaluate the performance of whiteners in coffee are listed in Table 28.

Regression analysis indicated that reduced cubic polynomials were adequate to predict the sensory variables of color lightness, roasted nutty, peanutty, milky, oily flavor, astringent, oily suspension, and surface layer thickness, and the physical variables viscosity and stability in coffee to x_1, x_2, and x_3. When the models were reduced to the quadratic form, calculated F values indicated that the sensory variables peanutty, milky, oily flavor, astringent, and surface layer thickness were sufficiently represented by the quadratic polynomial models. Predictive models were used to generate contour plots. The responses of eight sensory variables (toasted grain/cereal, painty, musty, woody/hulls/skins, bitter, sour, and sweet) and CIE lightness measurements of whiteners and whitened coffee to the component proportions could not be perceived by a reduced cubic or quadratic polynomial.

Lightness of whiteners and whitened coffee has been used to evaluate the performance and physical proper-ties of coffee whiteners. Change in instrumental lightness values of spray-dried whitener as affected by pro-cessing conditions was predicted by a second order polynomial equation. In this study, the amount of peanut extract in some formulations resulted in a high protein content which caused a separation from fat, with a con-sequent decrease in whitening capacity. The low protein content in other experimental formulations (20-30% extract) was not sufficient to maintain fat in dispersion; thus, also resulting in decreased whitening power. Increasing the proportion of oil used in the mixture blend generally increased panel ratings for oily flavor but decreased ratings for astringent. In coffee whiteners, oil combines with protein to give a sensation free from astringency.

Oil separation in most experimental formulations was visually apparent immediately after homogenization. The formulations with the highest amount of peanut extract had the highest degree of immediate oil separation. The formulation which contained no added cottonseed oil but 70% peanut extract exhibited some degree of oil separation after homogenization. This indicates that increased protein content resulted in fat separation and contributed to instability.

Predictive models were verified by replicating evaluations of corresponding sensory and physical characteristics using formulations 2 and 3 in the original mixture design. These formulations had solubility index values of approximately 100% up to 5 days refrigerated storage. Observed and predicted values were re-evaluated for each of the sensory and physical variables (Table 29). Calculated t-statistics indicated that the observed and predicted values for each of the sensory and physical variables of the two whiteners were not significantly different from each other at a 5% level of significance. Thus, the models generated in this study were adequate to predict the sensory and physical properties of experimental liquid whiteners containing peanut extract.

No psychrotrophic microorganisms were detected in whitener stored at 5°C for up to 21 days. On the other hand, microbial spoilage, i.e., sour off-odor and curd formation, was observed in formulations stored at 12°C after only 5 days. Refrigeration at 5°C or below will be necessary to preserve experimental liquid coffee whiteners processed in the manner described in this study.

3. Determination of Functional Properties of Fermented Peanut Flour

Fungal fermentation of solvent-defatted peanut flour has a profound effect on functional properties and would be expected to result in changes in qualities of foods in which fermented flour might be incorporated. Heat treatment can also significantly affect the functionality and subsequent performance of high-protein flours. The objective of this study was to investigate changes in functional properties of flour made from defatted peanuts which had undergone controlled fungal fermentation. The effect of treatment with steam was also investigated. Partially defatted (~27% oil), medium-sized blanched Florunner peanuts were prepared using a Carver hydraulic press. Moistened peanut press cake was inoculated with *Rhizopus microsporus* var. *oligosporus*, a mold commonly used to prepare soybean tempeh. After fermentation at 30°C for 22 h, peanut seeds were dried at 50°C for 32 h in a forced-air oven and ground into a flour using a Thomas-Wiley laboratory mill. Unfermented, partially defatted peanuts were also ground into a flour to serve as a control. The proximate composition, nitrogen solubility profile, emulsion capacity, emulsion viscosity, water adsorption isotherm, water and oil retention properties and color of flours prepared from fermented and control peanuts were determined.

Fungal fermentation caused slight increases in nitrogen solubility at pH 4.0-6.0, but decreased solubility at pH 8.0-10.0. The emulsion capacity of fermented and control flours was influenced by pH. Fermentation markedly increased the capacity at pH 2.0-10.0. Changes in emulsion viscosities followed a trend similar to that observed for emulsion capacity. Heat treatment had no apparent effect on equilibrium moisture content of flours as specific equilibrium relative humidity conditions. Fermentation increased water adsorbing properties, probably due to an increase in free polar groups on proteins caused by the breaking of peptide bonds by fungal proteolysis. Fermentation generally increased the water and oil retention capacity of peanut flour, whereas heat treatment decreased these properties. Color of flour prepared from fermented peanuts was darker than the color of control flour. This is attributed to more extensive Maillard reaction product formation in the fermented flour. The study revealed that fungal fermentation can be employed to enhance certain functional and physical characteristics of peanut flour, which might be beneficial in modification and development of food products.

4. Modeling the Effects of Formula and Extrusion Conditions on Physico-Chemical Properties of a Snack Product

Extrusion processing is extensively employed in the production of texturized vegetable proteins, snacks and other ready-to-eat foods. The objective of this investigation was to evaluate the combined effect of amounts of partially defatted peanut flour and feed moisture and process temperature on physico-chemical characteristics of a cornstarch-peanut flour based snack product using mixture response surface methodology. Comparisons were made using partially defatted flour made from fermented peanuts and unfermented peanuts.

Medium-sized Florunner peanuts were partially defatted (27% oil), moistened, inoculated with *Rhizopus microsporus* var. *oligosporus* and fermented at 30°C for 22 h. Oven-dried fermented kernels were then ground into a flour. Flour prepared from unfermented, partially defatted peanuts served as a control. Extrusion was carried out using a single-screw Wayne "Yellow Jacket" pilot scale plastics extruder. Barrel temperatures of 125, 138 and 150°C in zone #3 were evaluated for their effects on the physico-chemical properties of extruded products. A combination of a three-component constrained simplex lattice mixture design and a full factorial design was used to examine the combined effect of flour characteristics, feed moisture content and process temperature on extruded product characteristics. The amount of cornstarch in all formulas was 50% (wt/wt). Proximate composition, color, texture, bulk density and oil absorption properties of extruded snack-like products were measured.

The feed moisture content and the extrusion temperature markedly influenced the texture and appearance of extruded products. Within the range of 30-34% feed moisture, 16-20% fermented flour and extrusion temperature of 125 to 150°C,

extruders with various meat-like and soy sauce-like flavors were detected. Flavor development was attributed to the accumulation of free amino acids and peptides as a result of fermentation and the partial reaction and enhanced expression of these components when subjected to the conditions of extrusion.

Bulk density and expansion ratio of deep-fried products were, respectively, inversely and directly related to feed moisture content. In general, fried products containing high amounts of fermented flours were less crisp than products containing unfermented flour. The effect of extrusion on color lightness was insignificant. Increased moisture caused a decrease in redness of extrudates. Products containing increased amounts of fermented flour were characterized as being more brown in color.

The use of fermentation and extrusion technologies to produce acceptable snacks with higher protein content than the vast majority of snacks presently in the marketplace has good potential. Further research to document consumer reaction to snacks containing fermented peanut flour should be conducted.

5. Optimization of Sensory Qualities of an Extruded Snack Containing Peanut Flour

The successful development of new snack foods depends largely on the use of new forms and acceptable flavors. Using extrusion technology, a wide variety of snack products can be produced by simply changing processing conditions. The objective of this study was to optimize the formulation of an extruded snack based on cornstarch and peanut flour using response surface methodology. Consumer preferences for various flavored snack products were also determined.

Flour made from partially defatted peanuts (27% oil) that had been fermented with a mold (*Rhizopus microsporus* var. *oligosporus*) as well as flour made from unfermented, partially defatted peanuts was used in various formulations. Zone 3 extrusion temperature was maintained at 125°C and the cornstarch content was maintained a 50% for all treatments. Amounts of peanut flour and moisture in formulas were varied. Seventy-two people who consume snack foods such as corn chips, potato chips, cheese curls and similar products evaluated test products, based on acceptability of appearance, color, flavor and texture. Demographic data on age, sex, education level, and general information on snack food preferences were collected. Models were verified and consumer preference tests were conducted.

Sensory quality attributes were affected by product formulation. Formulations that scored 5.5 or higher for appearance, color, flavor and texture acceptability using a 9-point Hedonic scale (1=dislike extremely, 5= neither like nor dislike and 9=like extremely were used to attain the optimum formulation by superimposing contour plots. The optimum area was extrapolated to be 12-20% flour, 30-32% added feed moisture content and 50% cornstarch. An extruded deep fried product containing 14% unfermented flour, 5% fermented flour, 31% feed moisture and 50% cornstarch was used as a base to apply additional flavors. All flavored products had significantly higher scores for flavor and texture acceptability compared to an unflavored product. Flavor and texture of products flavored with nacho cheese, Cheddar cheese, and sour cream and onion were highly acceptable to consumer panelists.

Results indicate that snack products containing fermented and unfermented peanut flour have potential for success in the market. Scale-up production and further sensory and marketing research are essential to confirm demand for these snacks.

6. Optimization of a Peanut-Sweet Potato Cookie Formulation

Sensory quality and shelf life are attributes that influence the acceptability of cookies. The use of peanuts in foods is widespread. There is potential for its use in the U.S. as key ingredient or component combined with sweet potatoes in cookies. The formulation, however, needs to be optimized for the American consumer. In optimizing product formulation, it is essential to bring the consumer into the product development process at an early stage.

The objective of this research was to optimize the consumer acceptance of cookies containing crushed, toasted peanuts and sweet potato flakes using response surface methodology (RSM). Specific objectives were to: a) determine the effect of varying levels of sweet potato flakes and crushed toasted peanuts on the acceptability of the sensory properties of peanut-sweet potato cookies, b) evaluate the physical properties, color and texture, of peanut-sweet potato cookies from different formulations, and c) determine correlations between the physical properties and consumer acceptance of the sensory properties.

A 3 x 3 full factorial experiment using 3 levels each of sweet potato flakes and egg white was conducted. The amount of sweet potato flakes was varied from 0-120 g and that of egg white from 30-90 g. All formulations contained 120 g peanut and 80 g sugar. The experiment was replicated twice. Florunner (*Arachis hypogaea* L.) peanuts were toasted for 20 min, allowed to cool, deskinned manually and crushed. Sweet potato (*Ipomea batatas* L.) var Jewel were peeled, washed, flaked and blanched for bout 5 min. The blanched flakes were dried overnight at 113°F in a forced-air oven. All other materials including eggs (small size) were purchased from a grocery store in Griffin, GA. The egg whites were separated from the yolks and added to cream of tartar. The mixture of egg white and cream of tartar was whipped using the Sunbeam Mix Master for 5 min adding sugar gradually after 1 1/2 min. Peanut and sweet potato flakes were added by means of a cut-and-fold action using a spatula until the mixture was well blended. The mixture was portioned onto a greased cookie sheet using a melon scooper and spatula and shaped into cones. The cookies were baked at 300°F for about 23 min, allowed to stand for one min, loosened, cooked, and stored in sealed polyethylene (PE) bags.

Sixty (60) consumer panelists evaluated five samples each for consumer acceptance of color, shape, appearance, flavor, mouthfeel, and overall acceptability. Thirty (30) participants were randomly selected from the sixty for the verification tests. Objective measurements of color and texture were obtained. All statistical analyses were done using the Statistical Analysis System (SAS, 1985). The formulation was optimized using RSM. Optimum formulations should meet the following criteria: 1) consumers acceptance scores ≥ 6.0 for the attributes tested, 2) scores ≥ 4.0 for off flavor, 3) price ≥ 1, and 4) buying frequency ≥ 4.0. Verification experiments were conducted in duplicate using three selected treatments. The treatments included one within the optimum area, one near the optimum area with scores of 5.5, and one outside these two areas. A t-test was performed to determine if the observed values were different from the predicted.

All formulations containing all levels of egg white and up to 15 g of sweet potato flakes resulted in acceptable products (scores ≥ 6.0). Low levels of egg white combined with increasing levels of sweet potato flakes resulted in cookies with decreased acceptance scores for color, appearance, and shape. It was apparent that when using fixed amounts of peanut and sugar in the formulation, high levels of egg white may be used with any amount of sweet potato flakes to obtain cookies with acceptance scores of ≥ 6.0 for the said attributes. Otherwise, these two components should both be used at minimal amounts. The amount of sweet potato flakes in the formulation had a greater effect on consumer acceptance scores for flavor than that of egg white. As the amount of sweet potato flakes was increased, consumer acceptance scores for flavor decreased. The flavor contributed by the sweet potato flakes was obviously not acceptable to the American consumers.

The effect of increased amounts of sweet potato flakes on flavor, however, was not as deleterious as its effect on mouthfeel. Consumer acceptance scores for mouthfeel seemed to be the limiting factor during the optimization procedure. Only a very small area satisfied the requirement scores ≥ 6.0. The mouthfeel of the product must have had greater influence on the overall acceptability of the cookies than any of the other attributes followed by flavor. As was observed for both flavor and mouthfeel, as the amount of sweet potato flakes in the formulation was increased, the scores for overall acceptability of the product decreased. The amount of egg white did not affect scores for this attribute.

Verification trials revealed the predictive ability of all models developed, except for flavor. However, all opti-mum formulations had acceptable flavor. Significant correlations were observed between acceptability scores for the sensory attributes and physical measurements. However, the correlation coefficients were below 0.50. These have been considered moderately weak coefficients and practically worthless for predictive purposes.

The potential for an acceptable cookie with possibly enhanced nutritional value was demonstrated. Up to 15 g of sweet potato flakes, prepared as described, may be used with all levels of egg white employed in this study and with 120 g peanut and 80 g sugar to produce peanut-sweet potato cookies with consumer acceptance scores ≥ 6.0.

7. Viscosity Changes during Hydration of Peanut Butter

Attempts to modify the physical properties of peanut butter have been tried since the appearance of commercial suppliers. These have included additions of syrups, honey, milk solids, vegetable oils, and numerous other diluents. Water has been tried but the shortened shelf life precluded its advantages as a ready to eat shelf stable item. The hydration and use of tehina, a sesame seed butter, has prompted us again to look at water.

The manufacture of peanut butter consists of a series of steps to dehydrate the product and thus the product is a suspension of solid in oil whereas dairy butter is a water in oil emulsion. It was the purpose of this work to see if the transformation of peanut butter into an oil in water emulsion analogous to tehina could be achieved. Peanut butter was purchased at Kroger Co., Cincinnati, OH. Almond butter was purchased from California Almond Growers Exchange, Sacramento, CA. Tehina was purchased from Sirob Imports, Inc., Lindenhurst, NY. Pecan butter was prepared by grinding and finishing in a colloid mill with the final clearance of 0.1227 mm between stones at a temperature of 74°C.

Viscosities were measured during the hydration after additions of aliquots of distilled water of a 6% citric acid solution to 150 g of sample. After each addition, the mix was stirred with a spatula until the suspension was uniform. The Brookfield SynchroLectric Viscometer, Model RVT (Brookfield Engineering Laboratories, Stoughton, MA) was mounted on a Brookfield Helipath Stand and equipped with a TF spindle at 25 rpm. Product temperature was 25°C. Adhesion was estimated by measuring the force required to separate two plexiglass surfaces (7.5 cm dia.) holding ten grams of sample. The force was increased at a rate of 1900 grams per minute.

The results indicate that all the butters increased in viscosity after the addition of water. The increase reaches a maximum and then decreases. The increase and its occurrence varied with the particular species. The protein content of tehina is 18.2%. Peanut butter with a protein content of 9.1% shows only a small increase compared to the others. Almonds with a protein content of 18.6% similar to sesame at 18.2% show two maxima indicating two subgroups of proteins. Sesame and peanuts show a single broad maximum. However, when the diluent was citric acid, there appeared to be indications of two maxima. Examination of the emulsion under a light microscope revealed many droplets of oil in a continuous medium which was presumably aqueous. The adhesive character was considerably changed by the hydration and explains the stickiness of freshly eaten peanut butter.

8. Sensory Quality of Peanuts Treated with Hydrogen Peroxide

We have observed that treatment of aflatoxin-contaminated peanut in 0.075% hydrogen peroxide solution for 1 min resulted in a 90% reduction of aflatoxin content in a fraction separated on the basis of buoyancy. A yield of 85% from the contaminated lot with an aflatoxin content of less than 5 ppb in the segregated fraction can be achieved from lots with an initial aflatoxin content of 50 ppb. Oxygen generated from the decomposition of hydrogen peroxide by catalase offers some advantages in that it may have a bleaching effect and results in a smooth, attractive surface appearance.

The use of hydrogen peroxide, however, has raised concerns because of its strong oxidation property. The strong oxidizing power of hydrogen peroxide and the potential formation of hydroperoxides during drying may lead to the development of rancidity and of undesirable odors and flavors. The purpose of this study was to determine the effect of hydrogen peroxide treatment on the flavor, color and texture of peanut seed stored at 39°C for up to 3 weeks.

Medium-sized sound peanut seeds were submerged for 1 or 3 min in 0, 0.075 of 0.225% hydrogen peroxide and then dried in a forced-air oven. Drying time was less than 6 h. Testae were manually removed from seeds which were then sealed in plastic bags and stored at 39°C. Sensory qualities of treated and control seeds were determined after storage for 0, 1, 2 and 3 weeks. Seeds were analyzed for volatile compounds released into the headspace of sealed containers. Color and texture were measured instrumentally. Roasted seeds were incorporated into a peanut brittle formula and analyzed for sensory qualities using semi-trained panelists. Three replicate experiments were conducted and data were analyzed for statistically significant differences.

Regardless of the storage time, the amount of hexanal evolved from peanut treated with 0.225% hydrogen peroxide was greater than that of untreated peanut. Treatment in 0.075% hydrogen peroxide solution and storage for 1 week did not result in significant differences compared to control seeds. Treatment had no effect on evolution of ethanol from peanut. Treatment did not influence the lightness and chroma of peanut (Table 30). Likewise, texture was unaffected by the treatment conditions employed.

Peanut brittle was made from seeds treated with 0.075% hydrogen peroxide for 1 min. Results indicate that panelists were unable to detect differences in overall sensory quality of brittle containing treated and control peanut. The use of a hydrogen peroxide buoyancy system to separate aflatoxin-contaminated seeds from aflatoxin-free seeds is promising in terms of its effectiveness and lack of effect on sensory quality of end products.

9. Bacterial Degradation of Aflatoxin

The effects of an added nutrient source and added aflatoxin on the ability of *Flavobacterium aurantiacum* NRRL B-184 to degrade aflatoxin B_1 (AFB_1) was determined. Radioactively (^{14}C) labeled and unlabeled AFB_1 were added to phosphate buffer or tryptic soy broth containing cells. Analysis of radioactive CO_2, water- and chloroform-soluble portions of the cell supernatant fluids revealed that neither added nutrients nor added non-labeled AFB_1 had a significant influence on the microbial transformation of AFB_1 (Fig. 7). These results suggest that the microbial degradation of aflatoxin by *F. aurantiacum* is probably a mineralization phenomenon and not due to a co-metabolism. The ability of this bacterium to detoxify aflatoxin without the need of exogenous energy sources could be important to future endeavors attempting to use the organism, or the mechanisms responsible, in fermentation reactions.

The isolation of water-soluble degradation products from transformation of AFB_1 by *F. aurantiacum* was also determined. The normal UV absorbance maximum for AFB_1 at 362 nm is lost upon prolonged exposure of the toxin to cells of *F. aurantiacum*. Water-soluble degradation compounds are formed, one having a UV absorbance maximum of 394 nm. TLC analysis of the water-soluble degradation products revealed the presence of a fluorescent red/orange compound with an R_f similar to that of AFB_1. Low pressure liquid column chromatography of ^{14}C-labeled AFB_1 degradation products demonstrated the presence of at least one primary and several minor degradation compounds (Fig. 8). The concentration of the degradation compounds increases proportionally over time as the microbial transformation proceeds. Evidence of degradation products with increased water solubility suggests that a structural change in the AFB_1 takes place. This change may not involve complete aromatic ring cleavage, since UV absorbency is altered but not destroyed and fluorescence is observed, indicating an intact chromphore. No evidence of conjugate formation was observed since water-soluble

degradation product(s) had an R_f similar to that of AFB_1 when analyzed on TLC plates developed under similar conditions. This suggests that the degradation products are similar in size to the parent compound.

Finally, the fate of ^{14}C-labeled AFB_1 exposed to cells of *F. aurantiacum* in the presence of p-chloromercuri-benzene-sulfonic acid (PCMBS) and Dithiothreitol (DTT) was evaluated. PMCBS does not penetrate membranes but does inhibit sulfhydryl (-SH) groups. DTT is membrane-permeable and protects -SH from PCMBS. These compounds had no significant effect on the ability of *F. aurantiacum* to degrade AFB_1. These data suggest that either -SH-containing enzymes are not involved in the transformation of AFB_1 by the bacterium, or the chemical compounds investigated were ineffective inhibitors at the concentrations tested.

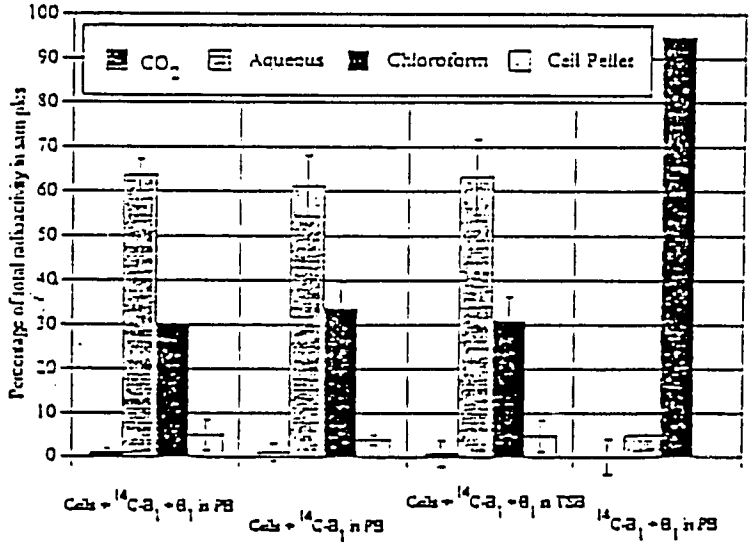

Fig. 7. Influence of added nutrient source and added non-labeled aflatoxin B_1 on radioactivity of CO^2, cell pellet and aqueous and chloroform fractions. Error bars indicate standard deviations.

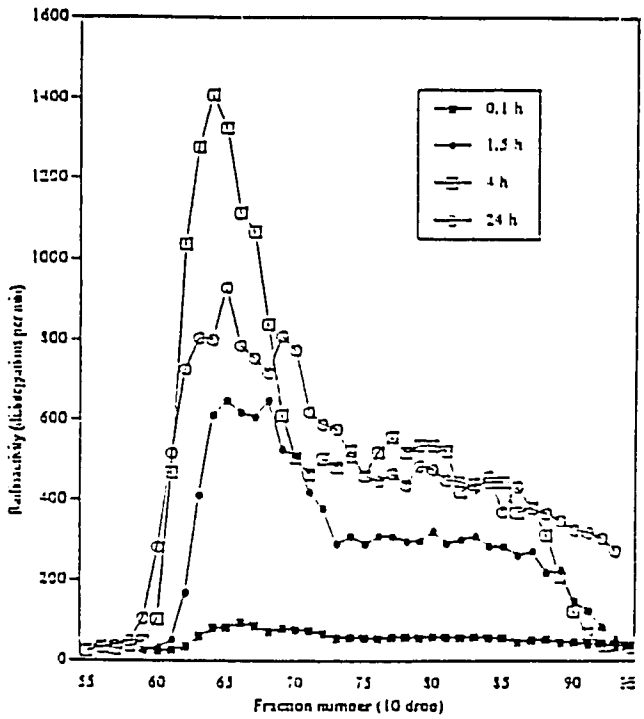

Fig. 8. Low pressure column chromatograph of water-soluble degradation products resulting from exposure of radioactively-labeled aflatoxin B_1 to *F. aurantiacum* cells for 0.1, 1.5, 4 and 24 h.

10. Development of Questionnaire for Identifying Constraints in Postharvest Handling Operations

A questionnaire was developed with a significant input from Dr. Chinsuwan (KKU) for the purpose of identifying constraints associated with various segments of postharvest handling systems used by small peanut producers in Thailand. The questionnaire was finalized in January, 1993 during Dr. Chinsuwan's visit to Georgia and the field survey was followed in Khon Kaen, Roi-Et and Kalasin provinces of Northeastern Thailand.

Items included in the questionnaire are as follows:

a. General information
   - Education level of household leader
     - Primary school
     - Higher than primary school
   - Size of family (persons)
     - Average number of household labor (person)
       - male, female
     - Peanut planted area (ha/family)

b. Harvesting practice
   - Harvesting method
     - Pulling, digging
   - Harvesting capacity (ha/man-day)
   - Duration of harvesting operation (days)

c. Stripping practice
   - Arrangement for stripping
     - Along with harvesting or after finish harvesting
   - Crop condition while stripping
     - Green, fairly green (no later than 3 days after harvesting)
   - Stripping capacity (kg/man-day)

(Stripping practice, cont'd.)
   - Pods with vine attached
     - Less than 5%, 5 to 10%, more than 10%
   - Foreign material
     - Less than 5%, 5 to 10%
   - Duration of stripping operation (days)
   - Method of cleaning/separating after stripping
     - No cleaning, washing, manual cleaning

d. Crop yield (ton/ha)

e. Drying
   - Drying of plant or pod
   - Drying place
     - Field, drying floor, near the house, roadside
   - Drying period (days)
   - Occurrence of mold

f. Transportation
   - Field to house
     - Manual cart, carrying, truck
   - For sale
     - Arranged by buyers, own arrangement

g. Storage
   - Method of storage before sale
     - In sack in the house
     - In sack under the house
     - Piling in the house
     - Piling under the house
   - Period of storage before sale (days)
   - Storage for seed
     - No, yes
   - Method of storage for seed
     - In sack in the house or under the house
   - Period of seed storage (days)

h. Sale of product
   - To village traders, other traders or seed centers

A summary of the results is given under Section A.6., above, and details are available in a report prepared by Chinsuwan (1993).

TRAINING

Mr. Wiwat Wattanatchariya and Ms. Siri Pussayaipaiboon finished their M.S. degrees at KU. Wiwat accepted a position at Chaingmai University as a Researcher Scientist and Sirin resumed her work at a snack factory owned by her family.

Ms. Sumet Amnuaysirisuk, Ms. Witida Chantrapornchai and Mr. Tanawit Kitumnuaypong are making good progress toward meeting the requirements of the M.S. degrees at the Department of Product Development.

As part of the technology transfer activities at KU, a Workshop on Transfer of Peanut Production and Utilization Technologies in Thailand was held at KU (March 23-24, 1993) to commemorate the 10th anniversary of Peanut CRSP in Thailand and the 50th anniversary of KU. Summaries of accomplishments by all projects supported by Peanut CRSP were given. The Workshop was attended by more than 70 people, about half from the food industry. The Proceedings (128 pages) was distributed at the Workshop.

The project for transferring peanut roasting and marketing technologies at Huay Bong-Nua Village north of Chaingmai continues. Monitoring of activities is made on a regular basis by project investigators at KU and by the Extension Specialist in the Huay Bong-Nua region.

Mr. Raul Divina is working toward a Ph.D. degree at the Institute of Food Science and Technology, UPLB.

Dr. Lutgarda S. Palomar from the Department of Agricultural Chemistry and Food Science, Visayas State College of Agriculture, Baybay, Leyte, Philippines completed a 2-month session of training at UGA in methods for modeling and optimizing peanut formulations for product development. Dr. Flor Galvez (Filipino, Post Doctoral Associate) assisted Dr. Palomar in this effort.

Mr. Witoon Prinyawiwatkul (Thai) and Ms. Rudeepan Wattanapat (Thai) finished their M.S. degrees at UGA. Witoon has entered the Ph.D. program and Rudeepan returned to Thailand to seek employment with a food company.

Mr. Eric Line (American) completed his Ph.D. degree at UGA and has taken a position with the U.S. Department of Agriculture. While still a student at UGA, Eric won the 1993 College of Agricultural and Environmental Sciences E. Broadus Browne Ph.D. Graduate Student Research Award.

Ms. Grace Divino (Filipino) initiated her M.S. program at UGA in September, 1993.

Dr. Margaret J. Hinds joined the project as a Post Doctoral Associate in January, 1993. Half of Dr. Hinds' support is from Dr. M. S. Chinnan's project (GA/PH/CAR). Dr. Hinds received her Ph.D. from the University of Trinidad with financial support from Peanut CRSP and working under the direction of the late Dr. B. Singh at Alabama A&M University.

In February, 1993, Dr. Winit Chinsuwan trained several research technicians to conduct a field survey in three provinces of the Northeast region of Thailand.

Mr. Anuvat Jangchud (Thai) entered the Ph.D. program at UGA in March, 1993.

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c. April 5, 1993 - Flavored soft curd from peanut.
d. April 9, 1993 - Supplementary of peanut tempeh in snack food.
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PLANS FOR 1993-94:

A. <u>Kasetsart University</u>

1. Systematic development of peanut tofu products containing meats and vegetables will be done. Shelf-life and consumer acceptance of these products will be evaluated.

2. Research will continue to investigate the use of peanut tempeh in Thai foods. Vegetarian and non-vegetarian foods containing peanut tempeh will be tested for consumer acceptability.

3. Research will continue to investigate uses for texturized protein prepared from defatted peanut flour.

4. Preliminary work will be conducted to determine the behavior of defatted peanut flour in surimi.

5. Research to develop a cat food using good quality undersized peanut will continue. Shelf-life and acceptability of the product will also be tested.

6. Research on the development of instant dry Satay sauce from good quality undersized peanut will be conducted.

7. Work will be done to improve the quality of flavoring sauce made from peanut press-cake by increasing the protein content as well as reducing off-flavors.

8. Preliminary studies will be done to evaluate the potential for utilizing peanut hulls as a packaging material.

9. Guidance of three graduate students (W. Chantrapornchai, T. Kitumnuaypong, P. Suppakul) in the Department of Product Development will continue.

10. Department of Product Development will organize and conduct a Training Program, mainly for Indo-China countries (Cambodia, Laos, Vietnam) on the topic of quality and utilization of peanuts. The training program will be 1-2 months in length and include 3-5 participants from each country.

11. Socioeconomic data will be collected in the Chaingmai, Lampang area to complement data obtained in the Khon Kaen area.

12. Analysis of socioeconomic data obtained in the northeast and northern regions will be completed.

13. Work initiated in FY93 to examine existing agricultural dryer systems for their suitability to dry peanuts will continue. Plans will be made to adapt a typical multipurpose crop dryer for drying peanut. Particular emphasis will be given to the fuel source and the cost of operating.

B. University of the Philippines - Los Baños

1. Studies on the development and improvement of snack foods, sauces, spreads and fermented products utilizing peanut will continue.

2. Technical assistance to small industries and cottage scale operations producing peanut products will continue.

3. Assessment of safety of commercial peanut products by continued monitoring of aflatoxin content will be done.

4. Plans will be developed to collect additional data from another peanut growing region for the purpose of identifying constraints associated with various segments of postharvest handling systems.

5. A computer model will be developed for economic analysis and performance evaluation of a suitable peanut drying system.

6. Physical properties of one or two most common Thai peanut cultivars as related to handling and storage will be determined.

7. Further characterization of the metabolite(s) of *C. fulvum* responsible for inhibiting the growth of *A. parasiticus* and *A. flavus* will be done.

C. University of Georgia

1. Continue studies on the utilization of peanut.

2. Study the kinetics of acid hydrolysis of peanut flour to prepare peanut sauce.

3. The biochemical mechanism for degradation of aflatoxin *F. aurantiacum* will be further studied.

4. Plans will be developed to collect additional data from another peanut growing region for the purpose of identifying constraints associated with various segmeents of postharvest handling systems.

5. A computer model will be developed for economic analysis and performance evaluation of a suitable peanut drying system.

6. Physical properties of one or two most common Thai peanut cultivars as related to handling and storage will be determined.

7. A technology transfer project in cooperation with the Visayas State College of Agriculture in Baybay, Philippines will be launched.

INTERNATIONAL TRAVEL

Dr. Chompreeda attended a symposium, Advances in Sensory Food Science - Rose Marie Pangborn Memorial Symposium, held in Jarvenpaa, Finland, August 2-6, 1992. A paper on "Development of Butter Caramel Flavor Snack from Defatted Peanut and Pregelatinized Tapioca Flour" was presented.

Dr. Winit Chinsuwan travelled to Jamaica January 10-15, 1993 to participate in a Workshop on Improving Production and Quality of Peanuts in Caribbean and following that travelled to UGA January 16-21 to discuss project plans with Dr. Chinnan and Dr. Beuchat.

Drs. Beuchat and Nakayama attended and presented papers at a Workshop on Transfer of Peanut Production and Utilization in Thailand at KU on March 23-24, 1993. The Workshop was organized to commemorate the 10th anniversary of Peanut CRSP in Thailand and the 50th anniversary of KU. Project members at the KU Department of Product Development organized this highly successful workshop which included presentations by researchers representing all Peanut CRSP projects in Thailand. More than 70 people attended the 2-day program.

Dr. Beuchat presented a paper on aflatoxin degradation at the 8th International Union of Pure and Applied Chemists Symposium on Mycotoxins and Phycotoxins, November 8-11, 1992, in Mexico City.

Table 1. Quality Characteristics of reformulated tuub taab.

Characteristics	Value	Characteristic	Value
Size		Carbohydrate (%)	58.44
Width cm)	3.0	Reducing sugar (%)	3.19
Length (cm)	5.0	Sucrose (%)	49.02
Thickness (mm)	4.5	Total Sugar (%)	52.20
Weight/piece (g)	8	a_w	0.25
		Peroxide value	0
Color			
L	63.04		
a	5.31	Aflatoxin (ppb)	<10
b	23.01		
Moisture (%)	1.79	Total microbial count (cfu/g)	<30-380
Protein (%)	13.92	Yeast and mold (cfu/g)	20-90
Fat (%)	23.40	Coliforms (MPN/g)	<3.0
		Staphylococcus aureus	ND

Table 2. Demographic and other characteristics of 154 Thai consumers who evaluated tuub taab.

Item	Responding (%) (n = 154)	Item	Responding (%) (n = 154)
Sex		Reason for consuming tuub taab	
Male	57.8	Flavor	47.4
Female	42.2	Texture	19.9
		Nutritional quality	12.0
Age (years)		Price	13.2
Under 21	48.0	Processing	3.2
21-30	26.0	Other	4.4
31-40	16.2		
41-50	5.2		
Above 50	4.5	Purchasing place for tuub taab	
		Supermarkets	32.1
Education		Grocery in Bangkok	41.1
Secondary	11.7	Grocery outside Bangkok	21.4
High school	5.8	Vegetarian stores	4.2
Vocational school	59.1	Others	1.2
B.S.	18.8		
Higher than B.S.	4.5	tuub taab prices	
		10 Baht/pack (5 pieces)	41.1
Monthly Income (Baht)		10 Baht/pack (10 pieces)	47.7
Less than 3,001	51.3	30 Baht/pack (20 pieces)	4.7
3,001-5,000	24.7	Others	6.5
5,001-7,000	10.4		
7,001-9,000	5.2		
Over 9,000	8.4		

Table 3. Response of 154 Thai consumers to reformulated tuub taab.

Rating/Item	Sensory Attribute (%)						
	Size	Shape	Color	Aroma	Flavor	Crispiness	Overall
Extremely like	25.3	18.8	19.5	29.2	25.3	34.4	21.4
Like very much	22.1	22.7	27.9	33.1	40.3	31.2	31.8
Moderately like	33.1	33.8	24.0	24.0	26.6	21.4	39.6
Slightly like	7.8	10.4	12.3	6.5	5.2	7.1	3.9
Neither like nor dislike	4.5	9.1	9.7	3.2	1.3	1.3	2.6
Slightly dislike	5.2	3.2	5.2	3.2	0	2.6	0
Dislike	1.9	1.9	1.3	0.6	1.3	1.9	0.6
Mean score:	5.3	5.1	5.1	5.7	5.8	5.7	5.6

Amount for consumption at one time	
Less than 5 pieces	37.7
5-7 pieces	32.5
8-10 pieces	20.8
10-15 pieces	7.8
Others	1.3

Appropriate packages	
Polypropylene	61.7
Aluminum foil	16.9
Metalized	8.4
Cardboard can	10.4
Tin can	1.9
Others	0.6

Purchase intention for the tuub taab packed in polypropylene bag 10 pieces (80 g) at 5 Baht	
Definitely will buy	82.4
Undecided	13.0
Definitely will not buy	4.6

Table 4. Mean sensory scores for Tuub Taab stored in various packing materials at room temperature.

Storage time (week)	Sensory Attributes				
	Color	Rancid	Crispiness	Flavor	Acceptance
0	5.72	0	6.89	7.12	7.60
Polypropylene					
1	6.13	0.74	2.35	5.06	2.50
Cellophane					
1	6.50	0.78	6.75	6.62	6.92
2	5.78	0.50	5.87	6.46	6.05
3	6.04	1.88	3.28	4.76	2.68
Glassine					
1	6.32	0.62	6.48	6.28	6.47
2	6.14	0.50	6.04	6.32	6.30
3	6.08	0.92	5.98	6.10	5.99
4	5.81	1.74	3.0	5.14	2.92
Aluminum foil					
1	6.86	0.58	6.89	6.74	7.22
2	5.82	0.42	6.82	6.34	6.94
3	6.13	0.92	6.62	6.50	6.94
4	6.23	1.34	6.34	6.42	6.72
5	5.92	1.10	6.30	6.54	6.72
6	5.82	1.18	6.35	6.76	6.72
7	5.81	1.44	6.28	6.38	6.58
8	6.11	1.34	6.32	6.52	6.54

Table 5. Effect of sex and school grade on the acceptance for nutritious snack by Thai school children grade 1-6.

Acceptance	Sex		School Grade						Total
	Female	Male	1	2	3	4	5	6	
Acceptance	48.5	44.8	16.7	15.4	16.0	15.4	15.0	14.8	93.3
Unacceptance	4.0	2.5	-	1.3	0.3	1.3	1.5	1.8	6.5
Undecided	0.2	-	-	-	-	-	0.2	-	0.2

Table 6. Mean hedonic scores for characteristics of the nutritious snacks as rated by Thai school children grade 1-6 consumers.

Attribute	Sex		School Grade						Mean Score
	Female	Male	1	2	3	4	5	6	
Size	7.42	7.43	8.32	7.71	7.45	7.11	6.98	6.95	7.42
Shape	7.41	7.41	8.32	7.71	7.44	7.11	6.98	6.91	7.41
Color	7.42	7.44	8.32	7.71	7.49	7.11	6.98	6.95	7.42
Aroma	7.43	7.45	8.32	7.71	7.48	7.11	7.01	6.95	7.44
Flavor	7.43	7.45	8.30	7.69	7.50	7.11	7.01	6.99	7.43
Crispiness	7.43	7.45	8.34	7.71	7.49	7.06	7.16	7.04	7.45
Overall liking	7.42	7.47	8.34	7.71	7.49	7.11	7.01	7.00	7.45

Table 7. Attitude of Thai school children grade 1-6 consumers toward package of the nutritious snacks.

Package	Sex		School Grade						Total
	Female	Male	1	2	3	4	5	6	
Aluminum foil	17.5	12.5	5.0	5.0	6.9	4.2	3.7	5.2	30.0
Polyethylene	4.6	5.8	1.9	2.7	0.6	2.3	1.2	1.7	10.4
Polypropylene	30.4	29.0	9.8	9.0	9.0	10.2	11.7	9.7	59.4
Paper	0.2	-	-	-	0.2	-	-	-	0.2

Table 8. Effect of purchase intention on willingness of consumers to pay 5 Baht ($US 0.20) for a 20-g pack of nutritious snack.

Purchase Intention	Sex		School Grade						Total
	Female	Male	1	2	3	4	5	6	
Buy	39.6	36.0	11.7	10.4	13.8	13.1	12.3	14.3	75.6
Not buy	13.1	11.3	5.0	6.3	2.9	3.5	4.4	2.3	24.4

Table 9. Quality attributes of a pizza flavored tempeh snack.

Quality attributes	Value
Color L	44.45
a	16.09
b	24.01
a_w	0.39
Width (mm)	9.45
Length (mm)	25.40
Thickness (mm)	7.45
Calories (Kcal/100 g)	783.89
Compression force (Newton)	6.01
Puffing ratio (time)	1.50
Bulk density (g/100 ml)	29.32
Weight loss (%)	17.95
Fat absorption (%)	322.02
Composition	
Moisture (%)	5.63
Protein (%)	12.86
Fat (%)	23.00
Carbohydrate (%)	55.64
Ash (%)	2.22
Fiber (%)	0.65
Total count (colony/g)	<100
Yeast & mold (colony/g)	<10

Table 10. Mean sensory scores of a pizza flavored tempeh snack packaged in various materials and stored at 25°C or 32°C for 4 weeks.

Temp (°C)	Package	Time (wk)	Mean Sensory Scores		
			Color	Rancidity	Overall
25	Aluminum foil Laminated with Plastic	0	6.23 a	0.22 a	6.68 a
		1	6.31 a	0.31 b	6.58 a
		2	6.55 b	0.63 c	6.27 b
		3	6.53 b	1.03 d	6.01 c
		4	6.56 b	1.43 e	5.87 d
	Polypropylene	0	6.23 a	0.22 a	6.68 a
		1	6.57 b	0.38 b	6.30 b
		2	6.81 c	0.95 c	5.96 c
		3	6.80 c	1.74 d	5.36 d
		4	6.98 c	2.64 e	4.56 e
Ambient (32°C)	Aluminum foil Laminated with Plastic	0	6.23 a	0.22 a	6.68 a
		1	6.37 b	0.34 b	6.46 b
		2	6.48 bc	0.73 c	6.08 c
		3	6.59 c	1.13 d	5.78 d
		4	6.68 d	1.73 e	5.58 e
	Polypropylene	0	6.23 a	0.22 a	6.68 a
		1	6.59 b	0.42 b	6.09 b
		2	6.81 bc	1.26 c	5.90 b
		3	6.99 c	2.46 d	5.10 c
		4	7.16 d	3.46 e	4.30 d

[1]Values in the same column that are not followed by the same letter are significantly different ($P \leq 0.05$).

Table 11. Physical qualities of texturized vegetable protein prepared from partially defatted peanut flour and at various levels of moisture content in dough.

Fat/ Moisture (%)	Shear Strength (N)	Absorp- tion (times)	Diameter (cm)	Thickness (mm)	Bulk Density (g/ml)	L	a
1/30	18.88 a	1.96 bc	9.24 a	7.15 b	0.17 d	57.64 b	-0.50 a
1/35	20.30 a	2.19 b	9.07 b	6.85 c	0.17 d	58.54 b	0.70 ab
1/40	11.76 d	2.12 b	8.98 c	7.49 a	0.14 f	58.88 a	-1.12 cde
3/30	19.22 a	2.01 bc	9.32 a	6.88 c	0.22 a	59.40 b	-0.88 bc
3/35	11.79 d	2.68 a	9.14 b	6.32 e	0.16 e	59.91 b	-1.28 efg
3/40	12.14 d	2.09 b	9.08 c	6.02 h	0.21 a	q62.10 a	-1.08 cde
5/30	16.28 b	2.07 bc	9.25 a	6.87 c	0.17 c	57.68 b	-0.95 bcd
5/35	12.02 d	2.18 b	9.15 b	6.91 c	0.19 b	59.32 b	-1.20 def
5/40	11.49 d	2.02 bc	8.90 c	6.49 d	0.20 b	61.19 a	-1.45 fgh
7/30	15.09 bc	1.43 d	9.28 a	7.13 b	0.16 de	58.90 b	-0.98 cd
7/35	11.68 d	1.85 c	9.10 b	7.18 b	0.17 d	59.24 b	-1.64 h
7/40	8.33 e	1.84 c	9.00 c	6.05 gh	0.17 d	61.02 a	-1.91 i
9/30	15.22 bc	1.41 d	9.29 a	6.14 f	0.22 a	58.04 b	-1.20 def
9/35	14.10 c	1.42 d	9.06 b	6.11 fg	0.17 c	58.98 n	-1.51 gh
9/40	8.72 e	2.04 bc	8.88 c	6.32 e	0.17 d	61.15 a	-1.96 i

[1]Values in the same columns that are not followed by the same letter are significantly different ($P \leq 0.05$).

Table 12. Physical quality and chemical composition of peanut TVP and Kaset protein.

Properties of product	Peanut TVP	Kaset Protein
Physical		
shear strength (N.)	20.30	34.62
absorption (times)	2.19	2.43
L	58.54	59.27
a	-0.70	3.50
b	17.40	27.02
Chemical		
Moisture (%)	7.15	5.03
Protein (%)	56.20	50.16
Fat (%)	2.15	2.06
Ash (%)	4.28	7.01
Fiber(%)	2.00	0.48
Carbohydrate (%)	27.86	35.24

Table 13. Total nitrogen content and amino acid nitrogen content (g/L) in hydrolysates prepared using various peanut meal to acid ratios, acid concentrations and time.

HCL (N)	Meal:acid ratio	Hydrolysis time (h)[1]					
		Total nitrogen content			Amino acid nitrogen content		
		2.5	3.0	4.0	2.5	3.0	4.0
3.5	1:2.5 (g:ml)	21.49 a,y	22.34 a,y	23.37 a,x	16.01 a,y	16.63 a,xy	17.15 ab,x
4.0		22.17 a,x	22.47 a,y	22.55 b,x	16.39 a,z	17.06 z,y	17.77 a,x
4.5		21.82 a,x	22.04 a,x	21.83 b,x	16.51 a,x	16.70 a,x	17.07 b,x
3.5	1:3.0 (g:ml)	21.65 a,y	22.24 a,y	23.08 a,x	13.87 a,y	14.16 a,xy	14.56 a,x
4.0		17.96 b,x	18.57 b,x	18.70 b,x	14.01 a,y	14.21 a,y	15.68 a,x
4.5		17.90 b,y	18.51 b,y	18.70 b,x	13.98 a,y	14.60 a,xy	15.01 b,x
3.5	1:4.0 (g:ml)	17.15 a,y	18.01 a,x	18.14 a,x	10.67 a,y	11.20 a,xy	11.53 a,x
4.0		17.05 a,y	17.12 b,xy	17.87 a,y	10.50 a,y	11.25 a,x	11.36 a,x
4.5		16.49 a,x	16.94 b,x	16.61 b,x	10.97 a,x	11.33 a,x	11.36 a,x

[1]Values in the same column that are not followed by the same letter (a,b,c or x,y,z are significantly different ($P \leq 0.05$).

Table 14. Chemical composition and physical properties of flavor sauce made from defatted peanut meal.

Chemical composition and physical properties	Treatments[1]				Standard for Flavor Sauce, 8-1970
	AC	AT	BC	BT	
Specific gravity	1.19	1.18	1.19	1.18	>1.24
pH	5.60	5.62	5.75	5.73	5.0-6.2
Total nitrogen (g/l)	19.84	19.01	19.53	19.43	>30.0
Formaldehyde nitrogen (g/l)	16.75	16.48	18.47	17.38	-[2]
Ammoniacal nitrogen (g/l)	2.10	2.00	2.15	2.02	-
Amino acid nitrogen (g/l)	14.65	14.48	16.32	16.32	>20.0
Sodium chloride (g/l)	162.20	160.00	158.00	156.20	200-300
Aflatoxin	[2]	[2]	[2]	[2]	-

[1]AC, BC = traditional aging
AT, BT = microbial inoculation aging
[2]None detected

Table 15. Sensory evaluation of peanut soft curd using different peanut to water ratio.

Item	Peanut to water ratio[1]			
	1:6	1:8	1:10	1:12
Sensory attribute				
Color	4.63 a	3.53 b	1.97 c	
Aroma	4.10 a	4.53 a	5.13 a	
Texture	2.20 b	2.80 ab	3.27 a	
Sweetness	4.13 a	3.7 a	3.33 a	
Flavor	4.64 a	5.0 a	4.76 a	
Off-flavor	4.21 a	3.63 b	3.11 c	
General acceptability	4.45 a	4.72 a	4.66 a	
Proximate composition				
Moisture (%)	84.89	85.89	86.85	87.45
Ash (%)	0.33	0.28	0.26	0.18
Fat (%)	9.56	8.82	6.42	5.00
Protein (%)	3.63	3.15	2.08	1.61
Physical properties				
a_w	0.960	0.975	0.985	0.990
Hardness (dynes/cm^2 x 10^2)	6.27	5.68	4.42	4.13
Lightness L	77.0	82.5	74.6	81.8
a	24.1	24.7	24.6	23.1
b	6.8	6.1	6.6	6.8

[1]Values within each row that are not followed by the same letter are significantly different.

Table 16. Microbiological quality of soft peanut curd upon storage.

Microorganism	Storage time (h)	Peanut to water ratio[1]			
		1:6	1:8	1:10	1:12
Bacteria	0	4.5×10^2	1×10^3	4.35×10^3	6.8×10^3
	48	5×10^3	2×10^4	6.55×10^5	1×10^3
	96	1×10^5	1.5×10^5	1×10^6	8×10^6
	144	2.5×10^6	1.5×10^6	7×10^7	7.5×10^7
Molds	0	0	0	0	0
	48	5×10^3	1×10^3	5×10^3	5×10^3
	96	-	-	-	-
	144	1.15×10^4	3.05×10^4	3×10^4	3×10^4
Yeasts	0	0	0	0	0
	48	4×10^3	5×10^3	1×10^3	5×10^3
	96	-	-	-	-
	144	3.5×10^5	3.2×10^6	1×10^5	1.2×10^5

[1]Population (cfu/ml).

Table 17. Mean sensory scores for peanut milk residue pastes prepared using different treatments.

Quality attribute	Treatment[1]				
	P2	P3	P4	P5	P6
Color	3.8 a	3.7 a	4.8 ab	4.5 ab	5.7 b
Beany aroma	3.2 a	5.8 b	2.0 a	5.0 b	4.8 b
Beany flavor	4.1 b	4.9 b	2.0 a	4.9 b	5.1 b
Peanut flavor	4.3 ab	3.5 a	3.5 a	5.6 b	5.1 ab
Texture	3.4 a	3.6 a	3.5 a	5.6 b	6.0 b
Spreadability	3.6 a	4.4 a	3.6 a	5.6 b	6.6 c

[1]P1 (no treatment) was excluded in the SE because of disagreeable odor and flavor
P2 = steamed at 15 min; P3 = steamed at 30 min; P4 = ground and unsteamed; P5 = steamed at 15 min and ground; P6 = steamed at 30 min and ground
Values in the same row that are not followed by the same letter are significantly different.

Table 18. Proximate composition and physical characteristics of peanut milk reside-based meat spreads and commercial liver and potted meat spreads.

Formula Code[1]	Composition (%)[2]					
	Moisture	Protein	Fat	Ash	Fiber	Carbohydrates
A	64.82 b	8.83 a	8.32 b	0.92 c	1.65 b	15.46 c
B	64.97 bc	8.76 a	7.72 a	0.92 cd	1.57 b	16.05 c
C	63.82 a	8.42 a	8.36 b	0.99 cd	1.46 b	16.96 c
D	64.66 ab	8.74 a	8.04 ab	0.94 cd	1.64 b	15.97 c
E	63.82 a	8.89 a	8.34 b	1.00 d	1.79 b	16.16 c
F	64.35 ab	8.78 a	8.14 ab	0.92 cd	1.61 b	16.19 c
Liver spread	65.80 c	11.94 b	7.92 ab	0.82 b	0.21 a	13.32 b
Potted meat	67.18 d	10.32 ab	11.78 c	0.72 a	0.22 a	9.79 a

Formula Code[1]	Physical characteristics[2]				
	a_w	pH	Lightness (L)	Hue angle (tan b/a)	Hardness ($x10^3$ dynes/cm^2)
A	0.96 a	6.1 c	60.6 c	58.2 bc	5.09 bc
B	0.95 a	6.0 c	60.2 bc	53.0 bc	4.15 ab
C	0.96 a	6.0 c	59.8 b	58.2 bc	6.38 c
D	0.95 a	6.0 c	60.0 b	58.8 cd	4.16 ab
E	0.96 a	6.0 c	60.0 b	59.4 d	6.38 bc
F	0.94 a	6.0 c	59.9 b	58.7 cd	6.94 c
Liver spread	0.95 a	5.8 b	50.9 a	54.6 a	2.34 a
Potted meat	0.96 a	5.6 a	51.0 a	57.4 b	3.88 ab

[1]A - liver (0.5%); B - pork (0.5%); C - pork-liver (0.5%-0.5%); D - pork-liver (0.5%-1.0%); E - pork-liver (1.0% -0.5%); F - pork-liver (1.0%-1.0%).
[2]Values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

Table 19. Mean sensory scores of peanut milk residue-based meat spreads (7-point scale).

Quality attribute	Formula code[1]					
	A	B	C	D	E	F
Color	3.8	4.4	4.2	4.3	3.9	3.8
Meat aroma	3.7	3.4	3.5	4.1	3.0	4.4
Meat flavor intensity	4.4	3.1	4.5	4.3	4.2	4.1
Overall flavor	4.4 ab	3.1 a	4.2 ab	4.6 b	4.5 ab	4.8 b
Peanut flavor	4.3	4.4	4.1	4.1	3.9	3.3
Off-flavor	4.9	4.4	4.6	4.9	5.4	5.4
Texture	5.9	6.2	5.8	6.0	6.1	5.8
General acceptability	4.4 ab	3.9 a	5.0 ab	5.3 b	5.3 b	5.2

[1]Values in the same row that are not followed by the same letter are significantly different. See previous table for code description.

Table 20. pH and titratable acidity of peanut milk - RSM yogurt drink formulations

Substitution level 1(% peanut milk)	pH		% titratable acidity	
	8% RSM	10% RSM	8% RSM	10% RSM
100	5.67	5.22	0.08	0.14
75	4.57	-	0.22	-
50	4.45	4.15	0.39	0.67
25	4.33	4.10	0.41	0.85
12.5	4.38	4.13	0.43	1.00
10	4.45	4.10	0.53	1.07
5	4.50	4.15	0.58	1.12
0	4.57	1.03	0.49	1.26

Table 21. Lightness, hardness and sensory quality of peanut cheese prepared from unhomogenized peanut milk (UPM) and homogenized peanut milk (HPM).

		Concentration of $NaHCO_3$(%)[1]			
Item	Control[1]	0	0.5	1.0	1.5
Lightness (L)					
HPM	83.13	83.27	83.70	83.73	83.93
UPM	82.63	82.50	82.70	82.57	82.45
Hardness (dynes/cm^2, x 10^4)					
HPM	4.28	2.52	4.45	2.17	3.36
UPM	1.42	2.68	2.49	2.29	2.29
Sensory attribute (UPM)					
Color	2.6	1.9	1.7	1.5	2.1
Aroma	2.9	3.3	3.6	3.8	3.5
Texture	4.4 a	2.3 b	2.2 b	2.4 b	2.3 b
Peanut flavor	5.0 a	1.0 c	3.8 b	3.8 b	4.0 b
Beany flavor	4.9 a	2.5 e	2.6 d	2.8 c	3.0 b
Bitterness	3.9	3.4	3.7	4.0	3.9
Sourness	3.5	3.0	3.5	3.0	3.6
General acceptability	3.6	2.4	2.7	2.9	3.4
Sensory attribute (HPM)					
Color	2.6	2.0	2.5	2.7	1.9
Aroma	2.9	3.4	2.9	3.3	3.39
Texture	4.4 a	2.5 c	2.5 c	2.8 b	2.3 d
Peanut flavor	5.0 a	1.2 c	3.8 b	3.8 b	4.0 b
Beany flavor	4.9 a	3.0 c	3.1 c	3.1 c	3.6 b
Bitterness	3.9	2.9	3.2	3.4	2.9
Sourness	3.5	2.9	3.6	2.9	2.8
General acceptability	3.6	3.3	2.9	2.8	2.5

[1]Values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

Table 22. Physical, sensory and compositional characteristics of soft peanut cheese.

Item	Peanut milk:cow's milk ratio[1]				
	0:100	25:75	50:50	75:25	100:0
Lightness (L)	81.6 a	81.4 a	80.0 b	80.2 b	81.6 a
Chromaticity a	-3.7	-3.2	-2.8	-2.2	-1.7
b	14.5	12.3	10.7	8.8	7.2
Hardness (dynes/cm^2, x 10^4)	3.84	2.00	2.00	2.90	2.67
Sensory attributes					
Color	6.5 a	4.6 b	3.9 b	2.5 c	1.3 c
Aroma	5.3 a	4.7 a	4.2 ab	4.5 a	2.6 b
Texture	5.3 a	3.2 b	2.8 b	2.7 b	2.6 b
Peanut flour	6.7 a	4.9 b	3.9 b	2.6 c	2.5 c
Beany flavor	6.9 a	5.7 ab	4.5 b	3.4 c	3.7 c
Bitterness	6.6 a	5.9 ab	5.5 abc	4.8 bc	4.4 c
Sourness	6.4 a	5.0 ab	4.2 b	4.9 ab	1.3 c
General acceptability	6.8 a	4.4 b	4.3 b	3.3 bc	2.6 c
Water activity	0.96	0.98	0.99	0.99	0.99
pH	4.64	4.74	4.80	4.82	4.93
Yield	28.89 ab	32.00 ab	26.99 b	33.52 ab	34.92 a
Proximate composition					
Moisture	57.33 c	63.66 a	61.58 b	62.42 b	57.07 c
Protein	14.29 a	12.73 ab	11.14 bc	9.65 bc	9.07 c
Fat	19.65 b	13.93 d	17.49 c	19.98 b	25.41 a
Ash	5.20 a	4.94 a	3.10 b	3.12 b	2.90 b

[1]Values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

Table 23. Mean sensory scores, chemical composition, a_w and viscosity of peanut milk concentrate with peanut kernels soaked at different pH's and supplemented with flavoring agents.

				Soaking pH[2]			
	Soaking pH[1]			3.0		8.5	
Item	3.0	7.0	8.5	Cream F	Strawberry	Cream F	Strawberry
Sensory attribute							
Color	2.3 a	3.6 b	6.0 c	2.3 b	1.9 b	6.3 a	5.6 a
Peanut aroma	5.1 a	3.8 a	4.5 a	3.7 b	4.0 b	5.8 a	5.4 a
Peanut flavor	5.1 a	5.6 a	5.2 a	4.5 a	2.8 b	3.1 ab	3.1 ab
Beany flavor	3.6 a	4.4 a	4.4 a	3.5 a	2.4 a	2.8 a	2.4 a
Texture	2.7 a	2.6 a	5.4 b	4.2 a	4.7 a	4.8 a	5.2 a
Spreadability	6.1 a	4.6 b	6.8 a	4.1 b	5.1 ab	5.3 a	4.7 ab
General acceptability	4.6 a	4.9 a	4.6 a	5.9 a	6.2 a	6.1 a	5.9 b
				4.1 b	4.6 ab	5.0 ab	5.7 a
Crude protein (%)				14.82 b	13.09 b	17.20 a	16.90 a
Moisture (%)				49.15 a	48.90 a	48.40 a	48.30 a
a_w			0.905 a	0.900a	0.900 a	0.895 a	
Viscosity (x 10) (dynes-sec/cm)				3.42	2.37	4.75	4.06

[1,2]Values in the same row that are not followed by the same letter are significantly different.

Table 24. Mean sensory evaluation scores for peanuts treated with 5% acid solution for 1, 2 or 4 h.[1]

Item	Acetic acid			Citric acid			HCL		
	1 h	2 h	4 h	1 h	2 h	4 h	1 h	2 h	4 h
Color	4.42 a	4.25 ab	3.33 a	5.17 a	4.08 ab	3.83 a	3.92 a	4.00 a	3.83 a
Peanut flavor	3.33 a	3.75 a	3.67 a	3.01 a	3.58 a	3.42 a	2.50 b	3.33 ab	4.08 b
Peanut aroma	-	-	-	-	-	-	1.42 a	1.67 a	1.67 a
Beany flavor	2.58 a	3.58 a	3.75 a	3.58 a	4.50 a	4.00 a	3.25 b	3.42 b	4.42 a
After-taste	2.50 a	3.33 a	3.92 a	3.17 a	4.33 a	4.42 a	2.50 b	2.83 a	3.33 a
General acceptability	4.50 a	4.50 a	4.00 a	4.58 a	4.33 a	3.75 a	4.08 a	4.25 a	3.75 a

Color: 1 = light 7 = yellow
Peanut flavor: 1 = none 7 = very perceptible
Beany flavor: 1 = none 7 = very perceptible
After-taste 1 = none 7 = very perceptible
General acceptability: 1 = dislike very much 7 = like very much

[1]Values in the same row within each acid that are not followed by the same letter are significantly different ($P \leq 0.05$).

Table 25. Aflatoxin due to dilution and degradation by processing.

Product	Aflatoxin concentration (ppb)			Degradation (%)
	Initial	Due to processing	Due to dilution	
Sugar coated	96.6 ± 35.1	19.8 ± 2.4	49.1 ± 17.9	77.58 ± 10.6
Peanut brittle	155.2 ± 134.1	35.8 ± 50.6	62.5 ± 54.1	85.7 ± 20.2
Peanut bar	164.7 ± 21.1	20.6 ± 9.2	55.8 ± 7.1	84.5 ± 3.6
Pastillas de mani	215.2 ± 222.1	44.3 ± 52.8	96.6 ± 99.7	87.9 ± 5.0
Mazapan de mani	137.5 ± 56.8	11.1 ± 3.0	48.4 ± 20.0	91.7 ± 1.3
Polvoron de mani	88.7 ± 56.0	8.2 ± 11.6	41.1 ± 26.0	80.9 ± 27.1
Peanut candy	120.9 ± 7.9	29.4 ± 0.1	60.7 ± 3.5	75.7 ± 1.5

Table 26. Effect of changes in pH on the color of *C. fulvum* culture broth.

pH of sample broth		
Trial 1	Trial 2	Color of broth
3.2	3.3	clear, red solution
4.2	4.3	clear, orange solution
4.6	4.8	clear, orange solution
5.3	5.5	clear, red orange solution
5.7	5.8	dark, clear, red orange solution
6.4	6.5	clear, purple solution
7.0	7.1	clear, purple solution
7.5	7.6	clear, violet solution
8.2	8.3	clear, violet solution
9.1	9.1	clear, violet solution

Table 27. Mean consumer ratings on the commercial control and the experimental whiteners processed using varying proportions of peanut extract, hydrogenated cottonseed oil, and water.

	Component			Performance variables[a]			Sensory variables[b]		
Blend No.	Peanut Extract	Oil	Water	Solubility	Whitening Power	Color Uniformity	Appearance Acceptability	Flavor Acceptability	Overall Acceptability
1	0.700	0	0.300	6.17	4.46	4.79	3.83	3.96	3.67
2	0.533	0	0.467	8.24[d]	7.72[d]	8.04[d]	6.92[d]	5.44	5.92
3	0.367	0	0.633	8.79[d]	7.79[d]	7.58[d]	7.46[d]	5.54	6.25[d]
4	0.200	0	0.800	7.79[d]	6.88[d]	7.71[d]	6.79[d]	5.46	5.88
5	0.700	0.025	0.275	5.12	4.50	6.17	5.04	3.96	4.00
6	0.533	0.025	0.442	4.29	2.50	4.08	2.75	3.12	2.71
7	0.367	0.025	0.608	5.25	3.58	3.67	2.75	3.62	3.00
8	0.200	0.025	0.775	6.42	5.19	6.42	4.92	4.31	4.73
9	0.700	0.050	0.250	6.38	6.38[d]	7.92[d]	6.96[d]	5.12	5.50
10	0.533	0.050	0.417	4.33	5.58	6.92[d]	5.83[d]	4.00	4.17
11	0.367	0.050	0.583	4.29	4.12	5.12	4.00	3.75	3.75
12	0.200	0.050	0.750	5.46	4.71	5.25	4.62	4.62	4.04
Control[c]				8.65	6.98	7.80	7.00	7.13	7.33

[a]Consumer ratings based on nine-point hedonic scales anchored at the centerpoint and at the ends with the descriptors many undissolved particles (=1), some undissolved particles (=5), and no undissolved particles (=9) for solubility; extremely satisfied (=1), neither satisfied nor dissatisfied (=5), and extremely satisfied for whitening power; and very uneven color (=1), slightly uneven color (=5) and even color (=9) for color uniformity.

[b]Consumer ratings based on nine-point hedonic scales anchored at the centerpoint and at the ends with the descriptors dislike extremely (=1), neither like nor dislike (=5), and like extremely (=9).

[c]Control was a premium brand of a non-dairy liquid coffee whitener.

[d]Not significantly different from control ($p < 0.05$).

Table 28. Descriptors used by trained panel members to evaluate the performance of whiteners in coffee.

Descriptor	Definition
Appearance	
Color lightness	Hue of the whitened coffee
Flavor	
Aromatic	
Roasted nutty	Aromatic compound(s) associated with fresh hard-shell nuts
Toasted grain/ cereal	Aromatic compound(s) associated with a grain which has been sufficiently heated to caramelize some of the starches and sugars
Peanutty	Aromatic compound(s) associated with light-roast peanuts and having legume-like character
Milky	Flavor of pasteurized full cream cow's milk
Oily	Aromatic compound(s) associated with light-roast peanuts and having legume-like character
Painty	Aromatic compound(s)
Musty	Aromatic compound(s) associated with moldy and stale cardboard paper kept in an enclosed damp place
Woody/hulls/skin	Aromatic compound(s) associated with base peanut character and related to dry wood, peanut hull, and skins
Taste	
Bitter	Taste on the tongue associated with caffeine
Sour	Taste on the tongue associated with acids
Sweet	Taste on the tongue associated with sugars
Mouthfeel	
Viscosity	Tendency of the whitened coffee to resist flow
Astringent (also tongue sting/ throat burn)	Chemical feeling factor on the tongue described as puckering/ dry and associated with tannin and alum
Suspension Stability	
Oily	Presence of oil on the surface of the whitened coffee
Surface layer thickness	Degree of thickness of a distinct layer on the surface of the whitened coffee when viewed from the side

Table 29. Comparison of the observed and predicted values of two liquid whitener formulations for selected sensory and physical variables[a]

Variable	Blend No. 2[b]			Blend No. 3[c]		
	Predicted	Observed	|t|	Predicted	Observed	|t|
Sensory						
Color lightness	58.0	46.5	1.83	51.3	47.2	0.92
Roasted nutty	32.6	26.9	0.81	27.0	28.1	0.21
Peanutty	19.1	19.4	0.04	19.9	17.6	0.49
Milky	14.5	10.6	0.63	12.7	11.9	0.18
Oily flavor	19.3	20.7	0.14	18.6	18.3	0.06
Astringent	16.0	16.6	0.14	15.5	16.0	0.13
Oily suspension	19.1	25.4	1.27	18.7	23.2	0.83
Surface layer thickness	7.3	14.4	3.0	7.3	11.3	1.50
Physical						
Viscosity	4.07	4.09	0.71	2.67	2.70	1.41
Stability in coffee	98.47	98.43	0.44	96.02	96.02	0

[a]Only sensory and physical variables with responses to the proportions of peanut extract, cottonseed oil, and water used that could be predicted by a conical polynomial were evaluated. All observed values were not significantly different from their corresponding predicted values ($p < 0.05$).
[b]Formulated using a blend of 53.3% peanut extract and 46.7% water.
[c]Formulated using a blend of 36.7% peanut extract and 63.3% water.

Table 30. Color and texture of raw peanuts and peanuts treated with various hydrogen peroxide concentrations for 1 and 3 min followed by storage for up to 3 weeks at 39°C.

Treatment		Lightness, L				Chroma, C				Maximum force, N			
		Storage Period, Weeks				Storage Period, Weeks				Storage Period, Weeks			
Time	H_2O_2 (%)	0	1	2	3	0	1	2	3	0	1	2	3
0	Untreated	47.70	50.10	48.10	51.37	0.376	0.375	0.370	0.374	2.40	2.43	2.21	2.50
1	0	51.59	52.55	55.73	45.07	0.371	0.371	0.370	0.372	2.51	2.33	2.55	2.50
	0.075	51.35	47.32	46.65	52.55	0.375	0.370	0.379	0.372	2.23	2.50	2.71	2.35
	0.225	50.55	49.54	54.87	54.10	0.372	0.361	0.373	0.374	2.71	2.55	2.40	2.31
3	0	52.93	53.03	52.39	46.43	0.370	0.373	0.369	0.363	2.41	2.55	2.55	2.30
	0.075	55.01	52.51	51.24	52.73	0.366	0.371	0.371	0.375	2.71	2.73	2.45	2.53
	0.225	56.06	52.07	53.97	51.52	0.370	0.372	0.371	0.371	2.55	2.53	2.50	2.75

GA/PH/C

POSTHARVEST HANDLING SYSTEMS FOR THE SMALL-SCALE PEANUT PRODUCER

University of Georgia
Manjeet S. Chinnan, Ph. D.

Caribbean Agricultural Research and Development Institute
Dr. Joe Lindsay (PI-Jamaica)
Mr. A. K. Sinha (PI-Belize)

INTRODUCTION

Quality control of farm commodities begins on the farm and continues through postharvest handling, storage and processing steps until the point of consumption. Improper handling of peanut after harvest can reduce market value and decrease probability of consumption. Another factor affecting the probability of consumption of indigenously grown peanut is cost, which in turn is influenced by costs associated with production, harvesting and postharvest operations.

Need for improved postharvest operations exist not only in the Caribbean region but also in the Southeast Asian countries, such as Thailand and the Philippines, and other peanut growing regions of the developing nations. Emphasis in this project continues in the Caribbean region, whereas collaboration in Thailand has been initiated. This new collaboration is being undertaken at Khon Kaen University in conjunction with the peanut utilization project (GA/FT/TP) at Kasetsart University, Bangkok, Thailand, for an improved system of postharvest operations and providing linkage with the production and utilization aspects of peanuts. Details of the Thai collaboration is described in the GA/FT/TP report for this year.

ACCOMPLISHMENTS

Host Countries

1. Belize

Dryer: Members of the San Antonio Cooperative as well as non-members of the village are using a CRSP-designed dryer for drying peanut and corn. Thus, it is serving as a multiple crop dryer. Farmers have indicated the desire of replacing the gasoline engine used for powering the blower with an electric motor, which will be addressed during the next year.

Harvester: Based on the drawings provided by Mr. Urvan Wilson, Agricultural Engineer, Jamaica, a harvester was locally fabricated for testing in Belize. Field tests conducted have shown a limited success, however, additional tests are planned with peanut crop planted with various row spacings. If it works in Belize's heavy soils it will be a breakthrough in reducing cost of harvesting.

Aflatoxin: Aflatoxin level is being monitored at the farm level in storage and exporting peanut using the field kits (Aflatest cups). Aflatoxin level has not been detected above the tolerance level of 20 parts per billion in any sample. Moisture content of all stored peanuts was recorded at less than 10%.

Improving Quality of Peanut Products: Dr. Margaret Hinds, a postdoctoral fellow, working part time on this project is investigating into improving quality of peanut products in Belize. Tennessee Red is the primary peanut cultivar used in making peanut butter. Alterations to the current process to improve the stability of the product were provided by her. Samples of six peanut cultivars

grown in Belize were sent to UGA for analysis. Formulations containing blends of different cultivars will be evaluated for making peanut butter.

2. Jamaica

Peanut Sheller: A Mennonite-designed electric powered peanut sheller was evaluated and used for demonstration to the farmers. This type of sheller is in use in several areas of St. Elizabeth and Clarendon. This sheller is too expensive for a small farmer. However, it would be suited to cooperatives or if one farmer acquires and provides the service at a cost to other producers.

Pedal Operated Thresher/Winnower: A pedal-operated thresher/winnower imported from Thailand was demonstrated on several farms in Clarendon and St. Elizabeth. Four evaluations were carried out. Farmers are enthusiastic and at least one local equipment manufacturer has expressed interest in fabrication of the thresher.

Dryer/Storage Facility: This facility was visited during a workshop field trip in January. During the year several improvements were made to the drying/storing facility at Newton, St. Elizabeth. Although there have been ongoing discussions with the RADA (Rural Agricultural Development Authority) to manage and operate this facility, to date a suitable arrangement has not been worked out.

Socioeconomic Study: A proposal for research into the socioeconomic aspects of postharvest technologies in peanut production in Jamaica was developed in conjunction with the Institute of Social and Economic Research (ISER). The study will identify factors that affect the utility, functionality, and feasibility of specific postharvest technologies that are being introduced into this production sector.

Peanut Germplasm: Several peanut cultivars are being held and multiplied. This is intended to hold a set of certified seed stock from which farmers and others interested in acquiring and multiplying seeds can be supplied. Among the cultivars being held are:

CARDI-PAYNE	ICGV 88401	ICGV 88402
Kidang	ICGV 88403	ICGV 88405
NC-2	ICGV 88407	ICGV 88369
NC-7	ICGV 87184	

Peanut Field Days: During the year under review several field days were held. Approximately half of the participants were women farmers.

Workshop: A workshop on Improving Production and Quality of Peanut was held in Mandeville from January 12-14, 1993. The workshop was well attended (60 persons) by private sector, farmers, government officers from the Ministry of Agriculture, and ALCAN (Bauxite mining company). In addition, there were attendees from the Caribbean (Trinidad & Tobago, St. Lucia, Antigua and Belize), the US and Thailand. The first day consisted of the presentations made on global, regional and local perspective of production and postharvest handling of peanuts. The feature of the second day was a field trip to view production and processing of peanut. On the third and the concluding day a participatory discussion session was held to assess the present situation in the peanut culture in Jamaica and possible future recourse.

U.S. Institution - University of Georgia

A Pedal Powered Blower for Peanut Hull/Seed Separation: The purpose of this study is to construct a pedal-powered blower to use with an existing sheller design. It will increase the usefulness of the existing machine and provide experience in building smaller, lighter pedal-powered peanut processing

equipment. The blower will be totally separate and will not interfere with the normal operation of the bicycle.

A Portable Peanut Dryer for CARDI: Stationary dryers have been developed and built in both Belize and Jamaica. Limited success with these units, particularly in Jamaica, is because of the lack of suitable transportation. A design has been developed for a smaller, cheaper and portable system which would increase the likelihood of acceptance by farmer. The design chosen is for a 650 lb (300 kg) dryer that is transportable by a small bed pickup truck or directly mounted on a trailer frame.

Developing of Protocol for Measuring Aflatoxin Levels in Peanut and Peanut Products in Host Countries: Simple but effective screening methods for aflatoxin suitable for use both in field and lab are needed. Training of personnel in Belize to perform tests and confirmation of tests results at UGA is proposed. The system will operate as follows: (i) Preliminary field screening tests of freshly-harvested peanut (ii) Confirmatory testing of peanut in the lab in Belize. Freshly-harvested, dried and stored peanut and peanut products will be tested. (iii) Confirmatory testing of dried and stored peanuts and peanut products at UGA. Frequency of testing at UGA will be decreased when there is high correlation between results of (ii) and (iii). The system for training personnel in Belize is presently under development.

Use of Unhydrogenated Palm Oil to Stabilize Peanut Butter: This study was undertaken from a twofold perspective: (i) to decrease consumption of trans fatty acids by peanut butter consumers in the U.S., and (ii) to improve stability of peanut pastes and subsequently introduce or promote production of peanut butter in Peanut CRSP Host Countries where palm oil is also readily available. The main objectives of this study were to: (i) determine the ability of unhydrogenated, refined, bleached and deodorized palm oil (PO) to stabilize peanut butter, (ii) predict the optimum PO level, as influenced by storage temperature (ST), for stable, smooth peanut butter, and (iii) investigate the effect of peanut shell flour on the texture of peanut butter stabilized with PO. Response Surface Methodology (RSM) was used to find the optimum combination of unhydrogenated, refined, bleached and deodorized palm oil (2.0, 2.5 and 3.0%), peanut shell flour (0, 0.75 and 1.5%) and storage temperature (15, 25 and 35oC) to produce a stable product. RSM results predicted that 2.0-2.6% PO should prevent oil separation in peanut butter for at least one year at 21-24oC. Predicted formulations for optimum stability are being tested, and the relationship between temperature during the first 48 hr of storage and texture of products will be investigated.

GOAL

To develop a global model for evaluating the acceptability and profitability of peanut postharvest system(s) for Caribbean countries, in particular, and developing countries, in general, by developing or adapting technologies for the available economic and natural resources and by incorporating climate, socioeconomics and existing infrastructure for marketing and consumer acceptance factors.

OBJECTIVES

The proposed research is focused on attainable goals during the five-year period beginning July 1, 1990. Specific objectives are:

1. Identify the segments of the postharvest handling system, and various constraints, and develop a qualitative relationship(s) among the segments.

2. Evaluate the economic value of each postharvest handling operation or segment identified.

3. Identify existing technologies for adaptation or modification.

4. Evaluate the technologies identified for functionality and economic value.

5. Evaluate the anticipated change in quality loss.

6. Determine the physical properties of peanut pods and seeds.

7. Identify the input and output parameters of all the components of a global model, and build the model.

8. Develop alternative scenarios of integrated systems.

9. Test the global model in field for functionality and acceptability.

ORGANIZATION

U. S. Lead Institution: University of Georgia

Department of Food Science and Technology, Griffin
Dr. Manjeet S. Chinnan, Principal Investigator
Mr. W. Everett Chapman, Research Agricultural Engineer I
Mr. Glen D. Farrell, Laboratory Technician III
Mr. Anil Sharma, Graduate Student
Dr. Margaret J. Hinds, Post-doctoral Research Associate

Department of Agricultural Engineering, Griffin
Dr. Stanley Prussia, Professor

Department of Agricultural Economics, Griffin
Dr. Stanley Fletcher

Department of Agronomy, Tifton
Dr. Craig Kvien

Host Country Institutions:

CARDI (Caribbean Agricultural Research and Development Institute)

Belize
Mr. A. K. Sinha, Principal Investigator
Mr. Martin Lindo, Technician
Mr. N. McAndrew, Agronomist
Mr. B.O. Enriquez, Manager, BFAC.
Mr. J. Lisbey, Agronomist, BFAC.
Mr. J. Garcia, Agronomist, BFAC.

Jamaica
DR. Joe Lindsay, Principal Investigator
Dr. Janice Reid, Country Representative
Mr. Urvan Wilson, Project Research Engineer
Mr. Morris Taylor, Field Assistant
Mr. Neville Wright, Field Assistant
Mrs. C. Wilson, Extension Officer, RADA/MOA (Rural Agricultural Development Authority/Ministry Ministry of Agriculture

Personnel Changes:

Jamaica: Mr. Urvan Wilson, Project Engineer at CARDI - Jamaica, resigned from the project on November 30, 1992. Mr. Morris Taylor, Field Assistant, who has had a long association with the project was assigned to

the project. Mrs. Carol Wilson of RADA continued to liaise with the farmers and project personnel.

US: Mr. W. E. Chapman joined the staff as an Agricultural Research Engineer I in October, 1992, replacing Mr. Tal Oz-Ari for that position. Dr. Margaret Hinds joined the Department of Food Science Technology at Griffin as a Post-doctoral Research Associate. She was partially supported from the funds allocated to this project. Mr. Anil Sharma, a graduate student who was being partially supported from Peanut CRSP funds, left the program before completing the requirements for the degree.

APPROACH AND ACCOMPLISHMENTS IN DETAIL

I. Research

A. HOST COUNTRIES

1. Belize

The emphasis was on maintaining postharvest quality and reducing post production cost through improved post harvest handling operations including harvesting, threshing/stripping, shelling and storage.

Harvester

Mr. Urvan Wilson, Research Engineer at CARDI Jamaica, as graduate student under the project had developed peanut harvester/digger for heavy clay soils. Based on the drawings provided by him, a digger has been fabricated locally. The tests were conducted on two fields. One at the CARDI Field Station where peanut was planted in two rows on raised beds (1.0 m wide), and the other was at a farmer's field planted by hand without any definite row spacing. In both instances the planter did not successfully dig peanut plants from two rows. Therefore, testing will be done using various row spacing. Peanut crop was planted using 45, 60, and 75 row spacing for testing purposes at harvest time. Results will be reported next year.

Mechanical Thresher

A locally-fabricated PTO driven thresher was used by a number of farmer cooperatives and at the CARDI Field Station. The current appraisal of the output of the threshers and the cost indicated that a thresher/stripper of lower capital investment may have greater potential for use in the Caribbean. The project is considering obtaining a Thai (Khon Kaen) stripper/winnower for testing in Belize.

Dryer

The dryer installed in San Antonio, CAYO has been continually utilized by cooperative members as well as non-members on nominal payment basis. The demand for drying peanut was greater during the months of September to November when rains continued during the harvest time. There is a demand to replace the gasoline engine with an electric motor to power the blower for the dryer. This issue will be addressed in the next fiscal year.

Aflatoxin

Aflatoxin level in peanut was monitored at the farm level in storage facilities and for peanut for export. Aflatest cup method for rapid detection of aflatoxin was used. Ten samples were checked. To date aflatoxin level has not been detected above the tolerance level of 20 part per billion.

Peanut Butter in Belize: Improving Quality & Increasing Manufacture

Consumer acceptance of the locally-manufactured peanut butter has been very low mainly because of poor flavor and oil-separation. Tennessee Red is the only peanut cultivar presently used to make peanut butter. Alterations to the current process to improve stability of the product were provided to CARDI in March, 1993. Samples of six peanut cultivars grown in Belize were sent to UGA for analyses. Physical characteristics and percent crude lipid (d.b.) of the samples were measured. Cultivar ICGV-88369 appears to be the most suitable for peanut butter. However, because Tennessee Red (TR) is the most commonly grown and consumed cultivar, formulations for peanut butter containing blends of TR and ICGV-88369 will be developed. The composition and physical quality characteristics of these formulations will be assessed at UGA and their sensory attributes will be tested in Belize.

2. Jamaica

Peanut Sheller

A Mennonite-designed electric peanut sheller was evaluated and used for demonstration to the farmers. Results of preliminary evaluations are as follows:

Cost:	$1000 (US)
Capacity:	0.5 bushel/min (4.5 kg/min)
	30 bushels/hr (270 kg/hr)
Shelling by hand:	1.5 bushels/8-hr day (13.5 kg/day)
Cost of shelling by machine:	J$10/bushel (J$1.1/kg)
Cost of shelling by hand:	J$1.7/kg

One US dollar = 22 Jamaican dollar

The sheller is robust and reasonably priced. It is built locally in St. Elizabeth. Except for the electric motor, all materials used in the fabrication are locally available. Several screen sizes are available to accommodate large and small seeded peanut cultivars. The sheller has been well accepted by processors and middlemen in several locations in Jamaica. The sheller is in use in several areas of St. Elizabeth and Clarendon. This sheller is too expensive for a small farmer, however, it would be suited to cooperatives or if one farmer acquires and sells the service to other producers.

Pedal Operated Thresher/Winnower

A pedal-operated thresher/winnower imported from Khon Kaen, Thailand was demonstrated on several farms in Clarendon and St. Elizabeth. Farmers and equipment manufactures were enthusiastic because of:

* Its light weight and easy maneuverability.
* Its potential use in areas without electricity or easy access to fuel for a gasoline powered engines.
* Its construction from locally-available materials.

At least one local fabricator has shown interest in the fabrication of the equipment. Four demonstrations cum evaluations were carried out. Preliminary results are shown below. Additional tests are planned during the next fiscal year.

Stripping Capacity:	18-24 kg/hr
Pods with vines attached:	10-15%
Broken pods:	2-4%

Dryer/Storage Facility

A facility at Newton, St. Elizabeth was visited during a workshop field trip in January. During the year finishing touches were made to the drying/storing facility . These included:

* Construction of pallets for raising peanut seeds from the floor.
* Rat proofing the building.
* Construction of ventilation ports near the floor area.
* Construction of security grill for protecting the engine and the hot air duct.
* Painting the interior and the exterior of the building.

Although there have been on going discussions with the RADA (Rural Agricultural Development Authority) to manage and operate this facility, a suitable arrangement has not been worked out to date.

Socioeconomic Study

A proposal for research into the socioeconomic aspects of postharvest technologies in peanut production in Jamaica was developed in conjunction with the Institute of Social and Economic Research (ISER). The study as proposed will examine socioeconomic factors that may be expected to heavily influence the production, handling and disposal (marketing and otherwise) of peanut in Jamaica. The study will identify the factors that are likely to affect the utility, functionality, and feasibility of specific postharvest technologies that are being introduced into this production sector. Several meetings have been held and a draft of the survey instrument has been prepared with technical inputs for specific outputs which can be correlated with project interventions. The proposed study will be carried out by the ISER on a subcontract from CARDI.

Distribution of CARDI-PAYNE Peanut

During the year forty farmers were given samples of CARDI-PAYNE peanut. In addition some farmers in a newly formed farmers cooperatives were given a bushel of peanut each. At the end of the crop they are to give back a bushel of seeds to the cooperative for distribution to other farmers.

Peanut Germplasm

Several peanut cultivars are being held and multiplied. This is intended to hold a set of certified seed stock from which farmers and others interested in acquiring and multiplying seeds can be supplied. Among the cultivars being held are:

CARDI-PAYNE	ICGV 88401	ICGV 88402
Kidang	ICGV 88403	ICGV 88405
NC-2	ICGV 88407	ICGV 88369
NC-7	ICGV 87184	

All the above cultivars have larger seeds than the local Valencia type. There has been much interest in the larger size peanut particularly to be used as cocktail or ball park nuts.

Alley Cropping Study

This is not one of the prime objective of the Peanut CRSP project, however, investigating the effect of peanut planting has been included as a part of the study described in this section.

Environment degradation is a serious problem in many locations in Jamaica. A large proportion of the land is sloping. Furthermore, most small-holder farmers

occupy areas in unstable, erosion-prone lands. In addition there are areas which are being disturbed by mining for bauxite and alumina. Among the prescriptions for sustainable soil management is the use of hedgerow cropping. The aim of this study's to test the impact of various hedgerows on soil management and on the growth of peanut/corn rotation system on reclaimed bauxite soils. Peanut reduced both runoff and soil loss as compared with corn.

Peanut Field Days

During the year under review several field days were held. About half of the participants were women farmers. The following are the activities performed at the field days:

Demonstration of mechanical aids, thresher/winnower and electric sheller.

Discussion of rotation of peanut with other crops.

Demonstration and active participation of farmers in rowing, fertilizer application, planting, covering, molding and crop protection.

Workshop

A workshop on Improving Production and Quality of Peanut was held in Mandeville from January 12-14, 1993. The workshop was well attended (60 persons) by private sector, farmers and government officers from the Ministry of Agriculture, and ALCAN (Bauxite mining company). There were in addition attendees from the Caribbean (Trinidad & Tobago, St. Lucia, Antigua and Belize), the US and Thailand.

The first day consisted of the presentations were made on the following topics:

Changing needs of the Caribbean - The potential for peanut.
Global perspective of peanut production and use.
Future trend in marketing of peanuts.
CARDI's role in technology transfer.
Quality & Constraints - Technology required to produce quality peanuts.
Peanut CRSP activities in the Caribbean.
    Production technology.
    Simple/low cost machinery and potential for animal powered equipment. Update of postharvest technologies in Belize. Update of postharvest technologies in Jamaica.
Opportunities and challenges in Jamaica's peanut processing industry. A private sector perspective was presented by a peanut processor. He highlighted certain constraints in available peanuts including quality, lack of a consistent source, and competition from cheaper imports and their resale in the Jamaican market.
Peanut production in Belize - A cooperative system. A success story of a cooperative system for production, postharvest handling and marketing system was presented.
Postharvest technologies in Southeast Asia. A feature paper of particular interest was the presentation of the speaker from Thailand on the development of small scale equipment for production and handling of peanut.

The feature of the second day was a field trip to view production and processing of peanut.

Stop 1: Pioneer Chocolate Co. The company makes peanut butter and Chocolate candies including peanuts. This processing facility uses CARDI-PAYNE variety in their products.

Stop 2: Mechanical drying and storage facilities developed with Peanut CRSP funding were viewed at Newton, St. Elizabeth.

Stop 3: Demonstration of motorized peanut thresher developed as part of the Peanut CRSP activities was conducted.

Stop 4: Blakey's Peanut Processing. Peanut processing, including roasting, blanching, packaging of whole nuts in various sizes as well as chopped nuts for ice cream topping were viewed.

On the third and the concluding day a participatory discussion session was held. Main points are:

Peanut cultivation is very attractive small farmer because of its drought resistance and its ability to be stored for prolonged periods if handled properly. The production system for the crop needs significant improvement.

Germplasm issues:

Cultivar CARDI-Payne selected from this project has much potential for the processing industry. Increased production of this cultivar needs to be encouraged.

Growers and processors request improved peanut cultivars with larger seeds and red testa.

Growers need a reliable source of certified seed material to improve peanut quality and productivity.

Peanut quality issues:

Improper storage and lack of price discrimination according to peanut quality contribute to poor quality peanut production. There is much potential for increased processing of local peanut if quality could be improved, as local peanut would be less expensive for processors to purchase.

Communication:

There is no regular means of communication among growers, processors, and marketing groups. Participants recommended the establishment of a farmers group to be responsible for communicating their interests and to get information exchange of information and marketing information.

That group would also make a formal request to the Extension Service to provide up to date information to growers on improved methods of seed storage to improve peanut quality and reduce dependence on imported peanut for processing. Improved and cost effective postharvest handling systems is key to number of problems faced by the small producers.

B. U.S. INSTITUTION - UNIVERSITY OF GEORGIA

Pedal-Powered Blower for Peanut Hull/Seed Separation

The purpose of this study is to construct a pedal-powered blower to use with an existing sheller design. It will increase the usefulness of the existing machine and provide experience in building smaller, lighter pedal-powered peanut processing equipment. The design will utilize a standard adult sized 610 - 660 mm (24-26 inch) bicycle. The blower will be totally separate and will not interfere with the normal operation of the bicycle.

On-site investigations revealed that the pedal-powered sheller, as built, was too large and heavy for easy portability. Any additions to the unit would only result in an increase in weight. The opportunity for acceptance by local farmers who lack motorized transport, would decrease.

Inexpensive, manual units used in Southeast Asia and available through manufacturers around the world weigh 58 kg (127 lb) or more. Economics aside, this is simply too heavy to be considered truly pedal-powered and portable.

Methods Followed

In 1986 a literature search was begun in our laboratory to develop a knowledge base on pedal-powered, portable equipment for farm use. Applications for processing peanut were of particular interest. By mid 1991, a working prototype sheller had been designed and built. It was later shipped to Belize for use by CARDI as a demonstration and test unit. In late 1992 plans were made to incorporate more features onto the basic sheller unit. Specifically, a blower for separation of kernels and shells was needed. Literature was collected and examined. Current information on hand shows a variety of mechanical devices utilizing human power through a pedal arrangement. A design review of the sheller being used in Belize points out the need for weight reduction in the existing design. Formulation of a new light-weight design, utilizing native materials and locally obtainable, recyclable parts is sought.

Major Factors Studied

A review of the literature suggests a maximum design output of 0.35 kw (1/2 HP) would be feasible. This is the maximum sustainable power available from a steady 24 kmph (15 mph) effort by an average person on level ground. Tests with a small squirrel cage fan show a velocity of 2500 ft/min is more than adequate to separate seeds from hulls. A preliminary test of adding fins to a bicycle wheel will be tried. A design based on using a 3.8 liter (1 gallon) paint can as the blower housing will be tried. Sheet metal from the cans will also be used to fabricate other components. Other arrangements will include a power take-off unit that will link the bicycle and blower. All components should be those normally available in an economy where bicycles and other such commercial products are found. Use of special tools or methods such as machining and welding will be limited. Salvaged and reconditioned parts shall be used where possible to hold down costs.

List of Relevant Literature

Groundnut shellers/strippers project, Final Report, IDRC File No.3-P-82-0174. Department of Agricultural Engineering, Khon Kaen University, Khon Kaen Thailand, January 1987.

Tools for Agriculture, A buyers guide to appropriate equipment, Intermediate Technology Publications Ltd., 9 King Street, London, WC2 8HW, UK, 1985.

Appropriate Technology Handbook, A guide to practical books for village and small community technology, Volunteers in Asia, Box 4543, Stanford, California 94305, 1986.

A Handbook on Appropriate Technology, Third Edition, The Canadian, Hunger Foundation, 323 Chapel Street, Ottawa, Ontario, Canada K1N 7Z2, March 1983.

A Portable Peanut Dryer for CARDI

Peanut crop drying must be done quickly, but with control, to maximize yield and crop stability. Too much heat leads to off-taste product, too little or too slow can lead to spoilage. A moisture reduction rate of 2% per hour yields good results. Unpredictable weather patterns require frequent re-scheduling of harvest activities and interrupts the drying process. Moreover, most farmers have small scattered plots that may not justify large, stationary equipment. Stationary dryers have been developed and built in both Belize and Jamaica. Limited success with these units, particularly in Jamaica, is because of the lack

of suitable transportation. A smaller, cheaper and portable system would increase the likelihood of acceptance by farmers.

Major Factors Studied

The design chosen is for a 650 lb (300 kg) dryer that may be transported on a small bed pickup truck or directly mounted on a trailer frame. This capacity is chosen to allow transport of the dryer and a load of peanut at the same time. Alternately, the unit can be removed to allow the truck, to go elsewhere while the dryer is in use. The drying unit will consist of an all wooden hopper with a false bottom to allow air passage through the crop. A kerosene based burner provides the heat source. Ventilation is supplied by a gasoline or electric powered fan. The unit could be mounted on a small trailer. An alternative is to construct the hopper as a separate unit that can be loaded onto a small pickup truck or larger transport vehicle. The utility here is that the truck could deliver the unit to the site and then be used for other tasks while the dryer is in use.

A dryer made entirely of wood could be constructed. This would be cheaper and easier to construct than the metal frame unit. Such a unit must be transported empty to avoid overstressing the hopper. Additional modifications could include increasing the fuel capacity of the burner and blower to eliminate the need for frequent refueling during drying. This modification is not recommended unless done by a professional familiar with local safety code requirements for such systems.

Basic requirements:

1. Bin size 6 x 3 x 3 feet deep, plywood construction with angle iron frame. Wooden frames should only be used for stationary use and should be transported empty.

2. Fan -- Dayton 4C329 pressure blower, 1200 CFM at 1 inch static pressure, 3 HP direct electric drive.

3. Fan can be modified to accept a 3 HP horizontal shaft gasoline engine Briggs & Stratton series 80200.

4. Burner -- Dayton 3E043 50-140 thousand BTU kerosene heater. Galvanized duct work as required.

<u>Developing of Protocol for Measuring Aflatoxin Levels in Peanut and Peanut Products in Host Countries</u>

Peanut grown and stored in humid conditions have the potential of high incidence of <u>Aspergillus</u>. Increased use of peanut dryers by the farmers also suggests the importance of developing organized testing of peanut in the field as well as after drying and during storage. Thus, simple but effective screening methods for aflatoxin suitable for use both in field and lab are needed.

Training of personnel in Belize to perform tests and confirmation of tests results at UGA is proposed. The system will operate as follows: (i) Preliminary screening tests of freshly-harvested peanut in the field (ii) Confirmatory testing of peanut in the lab in Belize. Freshly-harvested, dried and stored peanut and peanut products will be tested. (iii) Confirmatory testing of dried and stored peanut and peanut products at UGA. Frequency of testing at UGA will be decreased when there is high correlation between results of (ii) and (iii).

Several screening tests requiring simple, inexpensive equipment have been assessed and found to be reliable. However, the Target test (Terratek Inc., Salt Lake City, Utah) has been selected because materials and reagents can withstand

tropical temperatures. The Target test will be suitable for use both in field and lab in Belize. Confirmatory tests at UGA will utilize the Aflatest Mycotoxin

System and Procedure for Grain and Feed Samples (Vicam, Somerville, MA). The system for training personnel in host countries is presently being developed.

Unhydrogenated Palm Oil to Stabilize Peanut Butter

This study was undertaken from a twofold perspective: (i) to decrease consumption of trans fatty acids by peanut butter consumers in the U.S., and (ii) to improve stability of peanut pastes and subsequently introduce or promote production of peanut butter in Peanut CRSP Host Countries where palm oil is also readily available.

Unhydrogenated (refined, bleached and deodorized) palm oil has a relatively low melting point (36-39°C) compared with those (> 60°C) of the hydrogenated vegetable oils used as stabilizers for peanut butter. Thus, we envisaged that peanut butter stabilized with palm oil (PO) only would be softer in texture than commercial brands. Therefore the addition of peanut shell flour (PSF) to increase firmness was also investigated.

The main objectives of this study were to: (i) determine the ability of unhydrogenated, refined, bleached and deodorized palm oil (PO) to stabilize peanut butter, (ii) predict the optimum PO level, as influenced by storage temperature (ST), for stable, smooth peanut butter, and (iii) investigate the effect of peanut shell flour on the texture of peanut butter stabilized with PO.

Response Surface Methodology (RSM) was used to find the optimum combination of unhydrogenated, refined, bleached and deodorized palm oil (2.0, 2.5 and 3.0%), peanut shell flour (0, 0.75 and 1.5%) and storage temperature (15, 25 and 35°C) to produce a stable product. For palm oil treatments, additional ingredients were 4.71% granulated cane sugar, 0.79% salt and roasted seeds to total 100% by weight. Peanut butter samples made with 1.25% FX (a commercial stabilizer), 93.25% roasted seeds, 4.71% sugar and 0.79% salt were used as standards.

To facilitate quantification of oil separation, 20 mL aliquots of peanut butter (52-60°C) were drawn by vacuum pump into 25 mL graduated pipets. Pipets were plugged at their bases and stored in a vertical position at 15, 25, or 35°C.

Oil separation, texture and color of all treatments were measured after 0, 1, and 2 weeks storage. Triplicate determinations per treatment were performed for texture and color, whereas six replicates per treatment were evaluated for oil separation. Data collected after 2 weeks storage were considered to be adequate for obtaining meaningful information on the stabilizing ability of PO.

To obtain response surfaces, the RSREG procedure of the Statistical Analysis System Institute (Cary, NC) was used. Response variables investigated were percent oil separation, texture, hue angle (arctangent of b*/a*) and L value (lightness) of color. RSREG showed ($P < 0.05$) that oil separation was affected by palm oil, peanut shell flour and storage temperature; texture was affected by storage temperature only; and peanut shell flour was the main parameter affecting color. The model developed for texture from Equation 1 showed no significant lack of fit and explained 90% of the variability. However, transformations had to be performed to improve fit of models for oil separation and color attributes. Contour plots were generated from the best fitting models for all four response variables. However, only the overlay representing the common region for minimum oil separation and acceptable color is included in this report.

After comparison of oil separation in the controls and commercial samples with USDA specifications for oil separation in peanut butter, a maximum of 0.5% oil separation after 2 weeks storage at 30-35°C was arbitrarily established as an indicator of stability for formulations stabilized with palm oil. Implications

from the above and the manufacturers' recommended shelf life and storage temperature for commercial samples and for peanut butter stabilized with FX further suggest that PO formulations within the constraints set should remain stable for at least 1 year at approximately 21-24°C. Only those formulations conforming to this constraint are discussed.

Plots generated with PO fixed at constant levels indicate that all samples containing 2% PO should be stable, formulations with 2.5% PO should not contain more than 1.4% PSF, and peanut butter made with 3% PO must not contain more than 0.6% PSF and would be less stable than samples with lower levels of PO. Figure 1 with temperature fixed at 35oC shows those combinations of PO and PSF that would result in maximum stability. There is an inverse relationship between PO and PSF: with predicted PO as high as 2.6% at 0% PSF and as low as 2.0% if 0.9% PSF is used. Thus 2.0-2.6% PO should adequately stabilize peanut butter.

Limits were set to accept stable formulations with color attributes that showed < 5% variation from the Fix-X samples. Plots generated for hue angle of the palm oil treatments with temperature fixed at 35°C indicated that there was a slight decrease in hue angle of the peanut butter treatments as the level of PSF was increased. Treatments containing approximately 2.5% PO and 1.5% PSF should have the smallest hue angle (77.9°) which would be 2.1% less than that (79.6°) of the FX controls. Therefore hue angles of all the palm oil treatments should be within the limit set. The L value of the palm oil treatments was significantly affected by both PSF and PO. Peanut butter became darker (lower L value) as PSF was increased. However, at constant PSF%, 2.3-2.5% PO should produce lighter samples. To obtain products which would not be more than 5% darker than the controls, a maximum of 0.8% PSF may be permitted. Comparison of regions for optimum stability with L value indicated that combinations of 2.0-2.6% PO with 0.0-0.8% PSF should produce samples within the constraints set for acceptable stability and color.

Storage temperature was the most significant factor affecting textures of both the FX and PO samples: treatments stored at 15°C were the firmest.

Comparison of peanut butter samples containing unhydrogenated palm oil with samples containing commercial stabilizers (after accelerated shelf-life storage) indicated the potential of PO to effectively stabilize peanut butter. RSM results predicted that 2.0-2.6% PO should prevent oil separation in peanut butter for at least one year at 21-24oC. These levels of palm oil should not significantly affect color of the peanut butter. Peanut shell flour may not increase firmness of samples stabilized with 2.0-2.6% PO. If incorporation of PSF is desired, a maximum of 0.4% PSF may be used to obtain stable samples that are <5% darker than those without PSF.

Predicted formulations for optimum stability are being tested, and the relationship between temperature during the first 48 hr of storage and texture of products will be investigated.

II. Training

U.S. Institution Personnel: W.E. Chapman visited Belize and Jamaica during the period of November 11 - 19, 1992, to provide technical assistance in the use of postharvest equipment.

CARDI-Jamaica Personnel: Morris Taylor, Dr. Joseph Lindsay, Carol Wilson and Urvan Wilson offered technical assistance and training as needed to peanut growers in Jamaica. A three day workshop was held in Mandeville on improving production and quality of peanuts. About 60 people attended the conference out of which more than 50% were peanut producers, handlers and processors. The details of the workshop are given elsewhere.

CARDI-Belize Personnel: CARDI personnel provided training to two Extension officers of the Ministry of Agriculture, one agronomist and one Extension officer of the BFAC (Belize Federation of Agricultural Cooperatives. Members of five cooperatives associated with BFAC received lectures on production and postharvest handling of peanut in May/June 1993.

PUBLICATIONS AND PRESENTATIONS

Chapman, W. E. 1993. Peanut CRSP Activities in the Caribbean: Postharvest Technologies, Update - Jamaica. Paper presented at the Workshop on Improving Production and Quality of Peanuts in the Caribbean, Mandeville, Jamaica, January 12-14, 1993.

Chinnan, M. S. 1993. Quality and Constraints - Technology Required to Produce Quality Peanuts. Paper presented at the Workshop on Improving Production and Quality of Peanuts in the Caribbean, Mandeville, Jamaica, January 12-14, 1993.

Chinnan, M. S., Cooper, B. R. and Wilson, U. 1992. Handling and processing of peanuts in Americas. Pages 241 - 248 in Groundnut - A global perspective: proceedings of an international workshop, 25 - 29 Nov 1991, ICRISAT Center, India (Nigam, S. N., ed.). Patencheru, A.P. 502324, India: International Crops Research Institute of Semi- Arid Tropics.

Cooper, B. 1993 Peanut CRSP Activities in the Caribbean: Production Technology - Cultivar Selection and Cultivation Practices. Paper presented at the Workshop on Improving Production and Quality of Peanuts in the Caribbean, Mandeville, Jamaica, January 12-14, 1993.

Enriquez, B. 1993. Peanut Production in Belize - A Cooperative System. Paper presented at the Workshop on Improving Production and Quality of Peanuts in the Caribbean, Mandeville, Jamaica, January 12-14, 1993.

Fletcher, S. 1993. Future trends in marketing of peanuts. Paper presented at the Workshop on Improving Production and Quality of Peanuts in the Caribbean, Mandeville, Jamaica, January 12-14, 1993.

Lindsay , J. 1993. Peanut CRSP Activities in the Caribbean: Simple/low cost machinery and potential for animal powered farm equipment. Paper presented at the Workshop on Improving Production and Quality of Peanuts in the Caribbean, Mandeville, Jamaica, January 12-14, 1993.

Sharma, A. and Chinnan, M. S. 1993. Development of a device for evaluating spreadability of semi-solid foods. (Abstract) CoFE'93. The Third Conference of Food Engineering, February 21 - 23, 1993. Chicago, IL.

Sinha A. K. 1993. Peanut CRSP Activities in the Caribbean: Postharvest Technologies, Update - Belize. Paper presented at the Workshop on Improving Production and Quality of Peanuts in the Caribbean, Mandeville, Jamaica, January 12-14, 1993.

PLANS FOR 1993-1994

US

Identification of the segments of the postharvest handling system and various constraints.

Efforts from FY 92-93 will continue in this area. Cooperation with a faculty member from the Department of Social Sciences at the University of West Indies at Mona, Jamaica, is to continue.

Evaluation of economic value of individual postharvest handling operation or segment.

Completion of thrust A will allow transformation of Qualitative relationships in A into quantitative relationships. This information will be obtained in coordination with the host country cooperators and agriculture economists as needed.

Adaptation or modification of existing or developed technologies.

A thresher developed at the Khon Kaen University, Thailand, has been obtained and its testing under the Jamaican conditions will be coordinated. A similar thresher will be obtained for Belize for testing there.

Evaluation of technologies identified for functionality and economic value.

Cost of building and operating a dryer and a storage facility will be evaluated.

Evaluate the anticipated change in quality loss.

Work on systems approach for quality evaluation will continue.

Determine physical properties of peanut.

Work on coating of shelled and unshelled peanut with starchy, cellulosic, and proteinaceous materials for enhanced storage life will be continued.

Peanut Use.

Alternative processing approaches to improve the quality of food products made from Caribbean grown peanut will be studied. Emphasis will be given on improving the stability and quality of peanut butter using novel approaches such using palm oil or peanut shell flour as a stabilizer.

Identify input and output parameters of all the components to build a global model.

Progress has been made in FY 92-93, further emphasis will be given in FY 93-94.

Linkage with Honduras.

The approach taken will be to participate in a workshop to be organized in Honduras on peanut production, postharvest handling and utilization system. Dr. Chinnan and Dr. Larry Beuchat (PI - GA/FT/TP) will participate. Following which plans will be developed to conduct research in the area of postharvest handling and use of peanut. This objective was identified in FY 92-93 but no progress could be made because an appropriate Memorandum of Understanding was not in place.

Host Country

Jamaica

Evaluate improved postharvest technologies for functionality and economic feasibility

1. Evaluate the mechanical dryer built in St. Elizabeth parish.

2. Complete construction of a storage facility which was begun last year adjacent to the above mentioned dryer.

3. Conduct experiments to determine optimum conditions (storage) for best quality and longer storage life.

4. Conduct economic evaluation on peanut storage.

5. Construct peanut lifter locally for the project in Belize.

6. Conduct feasibility studies on various postharvest systems comprising different combinations of postharvest technologies.

7. Begin socioeconomic studies on postharvest systems applicable to Jamaican conditions. Appropriate survey instrument will be developed in collaboration with the Department of Social Sciences at the University of West Indies at Mona, Jamaica.

Belize

Economic evaluation of various postharvest handling operations or segments

1. A small peanut thresher similar to the one imported by Jamaica from Thailand will be acquired. Once this thresher is found successful and acceptable to small peanut farmers then it will be fabricated locally. A request to the drawings will be made form Dr. Winit Chinsuwan in Thailand.

2. The San Antonio farmers will be provided specifications for obtaining an electric motor for the blower for the drier.

3. One of the driers will be fitted with a butane gas burner to replace the kerosene burner. Comparative cost will be assessed.

4. Hopkins Farmer's Cooperative will be assisted to install a dryer for peanuts and other grains.

5. A peanut lifter has been fabricated locally based on the drawings provided Mr. Urvan Wilson, former Research Engineer with CARDI-Jamaica; this will be tested on two soil types.

6. Work to continue to have a blower for the pedal-powered sheller; assistance to be provided by the Research Engineer at Georgia.

7. A motorized sheller will be imported from Jamaica for testing and later local fabrication.

8. Set up 2 acre plot to test the feasibility of using various post harvest technologies in an integrated fashion.

Assessment of aflatoxin levels at different time periods of storage.

1. Also, see Objective E under University of Georgia thrusts.

The composition of peanut butter will be assessed by using selected varieties of peanut.

1. Primary work will be done at Georgia. Peanut seed will be supplied by Belize.

Project Redirection Proposed

There is a need to conduct research on increasing the use of locally-grown peanut in the Caribbean; this is to be achieved by improving the quality of their existing value-added products or identifying and developing new products for the

Caribbean consumers. Dr. Margaret Hinds, a native of Trinidad, is currently being partially (20%) supported on GA/PH/C, would be supported for the whole year to conduct this research.

Research on postharvest handling aspects of peanut will be enhanced in the Southeast Asia region by continuing to shift emphasis from the Eastern Caribbean region. Initial focus on postharvest handling will be in Thailand providing linkage between the peanut production and utilization research. Future increase in postharvest activities in Thailand and other regions of Southeast Asia will depend upon availability of funds and any further shift of Peanut CRSP funds from the Caribbean and Central American region.

This project (GA/PH/C) will develop linkages with Central America, particularly, Honduras. GA/FT/TP will also be involved in planning future research activities in the area of peanut utilization in Honduras and the Caribbean. The extent of this activity will depend upon the funding level and establishment of Memorandum of Agreement between Peanut CRSP and host country.

INTERNATIONAL TRAVEL

U. S. Participants

Manjeet Chinnan travelled to Jamaica in October, 1992 to review project activities and finalize the plans for the regional workshop planned for January, 1993, in Jamaica.

W. E. Chapman traveled to Belize (Nov. 11-14, 1992) and Jamaica (Nov. 15 - 19, 1992) to familiarize himself with the host country activities and provide needed technical assistance to the collaborators.

Dr. Manjeet Chinnan, Dr. David Cummins, Mr. W. E. Chapman and Dr. Stanley Fletcher travelled to Jamaica (January 10 - 15, 1993) to participate in the Workshop held in Mandeville, Jamaica, January 12 - 14, 1993. The workshop was entitled: Improving Production and Quality of Peanut in the Caribbean.

Host Country Participants

Mr. A. K. Sinha traveled to Jamaica in October to review project activities and plan the final phases of the preparations of the Workshop to be held in Jamaica in January 1993.

Mr. A. K. Sinha (CARDI - Belize), Dr. Brian Cooper (CARDI - Antigua), Dr. B. Clarke (CARDI - ST. Lucia), Dr. Sam Parasram (CARDI - Trinidad), Mr. B. Enriquez (BFAC - Belize), Dr. Winit Chinsuwan (Khon Kaen, Thailand) participated in the Workshop held in Mandeville in January 1993.