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ANNUAL REPORT 1992

Improving Global Production and Use of Peanut

The Peanut Collaborative Research Support Program

United States Agency for International Development Grant No. DAN-4048-G-00-0041-00

FOREWORD

The Peanut CRSP has completed ten years. Impacts of the research program are becoming evident. Several CRSP trainees are back in their host countries leading research programs, and U.S. students trained are becoming research leaders.

The Peanut CRSP was marred by the tragic and untimely death of Dr. Bharat Singh, the Food Technology Project Principal Investigator at Alabama A&M University, following a September 1992 visit to Burkina Faso. The 1992 Annual Report is dedicated to his memory and in appreciation to the many contributions he made to the Peanut CRSP, which is described on the following page.

Dr. Singh's illness and death came as he was developing his 1992 Annual Progress Report to include information obtained on his September 1992 visit with cooperators in Burkina Faso. We realize that the report presented has omissions in accomplishments, which will be included in the 1993 Annual Report as the new project leadership has opportunity to evaluate and assimilate the information.

Appreciation is given to the U.S. Agency for International Development for financial support of the program through Grant Number DAN-4048-G-00-0041-00, and to the participating U.S. and Host Country Institutions for cost sharing in the program. Moreover, commendations go to all the researchers and administrators whose efforts have made the program successful.

I look forward to working with all of you in the future, and anticipate that the program will extend beyond the present authorization date of June 30, 1995.

David G. Cummins
Program Director
Peanut CRSP
December 1992

The 1992 Peanut CRSP Annual Report
is Dedicated to
Dr. Bharat Singh
Principal Investigator, Alabama A&M University

Dr. Bharat Singh died at the age of 53 on October 11, 1992 after a short illness. He was born on February 21, 1939 in Gahmar, U.P., India. He received a B.S. Degree in biology from Banaras Hindu University in 1958, and an M.S. Degree in chemistry and botany from Ranchi University in 1961. He was a lecturer at St. Columbia's College in Bihar, India from 1961 to 1964. He left India in 1964 to pursue a Ph.D. in plant biochemistry at the University of British Columbia, Canada with the degree awarded in 1968. Dr. Singh worked from 1968 to 1972 as post-doctoral scientist and visiting assistant professor for the Medical Research Council of Canada and the Department of Nutrition and Food Sciences at Utah State University (United States). Since 1972 Dr. Singh was in the Department of Food Science and Animal Industries at Alabama A&M University, Normal, Alabama (United States) reaching the rank of professor in 1975. During the final year of his tenure until his sudden death he served as the interim department chairman. He initiated the action to organize the department in order to obtain and maintain Institute of Food Technologists accreditation of the food science program. He organized a cereal quality laboratory and coordinated research on utilization of agricultural wastes for ethanol production, funded by the U.S. Department of Energy. He was associated with the Peanut CRSP since 1980. He collaborated on the preparation of a State of the Art paper on the utilization of peanut under the Peanut CRSP Planning Grant with the University of Georgia. Beginning in 1982, he coordinated two Peanut CRSP Projects supported by a USAID Grant to the University of Georgia with a Subgrant to Alabama A&M University. One, entitled "Peanut Utilization in Food Systems in Developing Countries" with focus on the Caribbean, was in cooperation with the Caribbean Agricultural Research and Development Institute. The second, entitled "An Interdisciplinary Approach to Optimum Food Utility in SAT Africa", was in collaboration with the Food Research Center, Shambat, Sudan and the University of Ouagadougou, Burkina Faso.

For his research and training efforts, the Association of Research Directors of the 1890 Land-Grant Colleges and Universities in 1980 awarded Dr. Singh the prestigious Morrison-Evans Outstanding Scientist Award. During his career, his name appeared as an author on more than 75 technical presentations at professional meetings. He was the author or co-author of more than 85 technical publications. At Alabama A&M University, he taught several courses in food science, guided about 40 M.S. students to the completion of their degrees, and guided one Ph.D. student for the University of the West Indies, Trinidad. He was a member and served in various capacities of several professional organizations including the American Association of Cereal Chemists, the American Association of Oil Chemists, the American Peanut Research and Education Society, the Dixie Section of the Institute of Food Technologists, the Institute of Food Technologists, Sigma Xi, and the Southern Association of Agricultural Scientists.

He organized and served as first president of the Huntsville, Alabama India Association (1980-1982), and as vice president of the Federation of Indian Associations in North America, South Region.

Dr. Singh is survived by his wife Bibha, daughter Dibya, son Niten, son-in-law Sanjay, and granddaughter Dipty.

Bharat was a friend to many of us associated with the Peanut CRSP. He was always friendly and pleasant with something positive to say. His ardent support of the Peanut CRSP as a Principal Investigator and Technical Committee Member will be missed. Because of his life the world is a better place.

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EXECUTIVE SUMMARY

INTRODUCTION

Peanut is a crop grown in most countries, both developing and developed, between 40 degrees North and 40 degrees South latitude. The constraints to peanut production and use are similar worldwide, which gives a potential for collaborative research to relieve these constraints. Peanut can contribute to an increased food supply in areas where total food and protein supply is marginal.

It is becoming more and more evident that agriculture must be sustainable. Peanut contributes to sustainability because it can be productive while maintaining or enhancing the environment in at least these ways.

- Fixation of atmospheric nitrogen through bacterial symbiosis, thus returning nitrogen to the soil for its own use and for use by future crops.
- Provides a nearly closed canopy that minimizes soil erosion.
- A relatively short growing season that makes it fit within a range of cropping systems, both monoculture and multicropping, as well as intercropping with grain crops and under-story planting in tree crops. It can be planted late in the season in case previous crops have been lost or were poor producers.
- An important source of high protein and energy for humans, as well as a high-quality animal feed.
- Provides a source of cash income for rural and urban people.
- Helps meet need for vegetable oil.
- Tolerates drought conditions, including the drought-prone of Sub-Sahelian Africa. Peanut is also able to mature in the short rainy season of that area and escape drought.
- Suppresses weeds when intercropped with grain crops, which reduces labor-intensive weeding activities.

The Peanut CRSP was implemented in 1982. The CRSPs were created to implement the Title XII program of the United States Foreign Assistance Act of 1975 with a goal to prevent famine and establish freedom from hunger through land-grant university involvement in international development. To attain the goals, the research capability of both developing country and United States institutions is enhanced through training and support of research. The CRSP concept requires work on constraints that have global implications.

CONSTRAINT DRIVEN

The Peanut CRSP was designed around a set of constraints to sustainable production and utilization identified during the 1980-1982 Planning process. Based on the numerous advancements achieved by the Peanut CRSP during the 1982-1989 period, the External Evaluation Panel in 1989 evaluated the continuing validity of the following constraints and found them to be valid as a basic framework for the Peanut CRSP for the 1990-1995 period.

- Low yields because of unadapted cultivars and lack of cultivar resistance to diseases, insects, and drought;
- Yield losses due to infestations of weeds, insects, diseases, and nematodes;
- Health hazards and economic losses due to mycotoxin contamination;
- Food supplies inadequate and lack of appropriate food technologies to exploit a relatively well adapted peanut crop that is not generally considered a primary food source;
- Physiological and soil microbiological barriers to higher yields;
- Resource management (agronomic, engineering, economic and sociological) situations preventing efficient production and utilization;
- Inadequate numbers of trained researchers and support personnel;
- Lack of adequate equipment to conduct research ;
- Information not available to beneficiaries for support of production and utilization efforts.

In short, the Peanut CRSP enhances the potential of peanut as a crop for human food and animal feed in developing countries and the United States, as it contributes to the increase of rural incomes and sustains agricultural land. The collaborative research on peanut is producing new and improved technology that improves the well-being of people in developing countries and, in turn, benefits citizens in the United States.

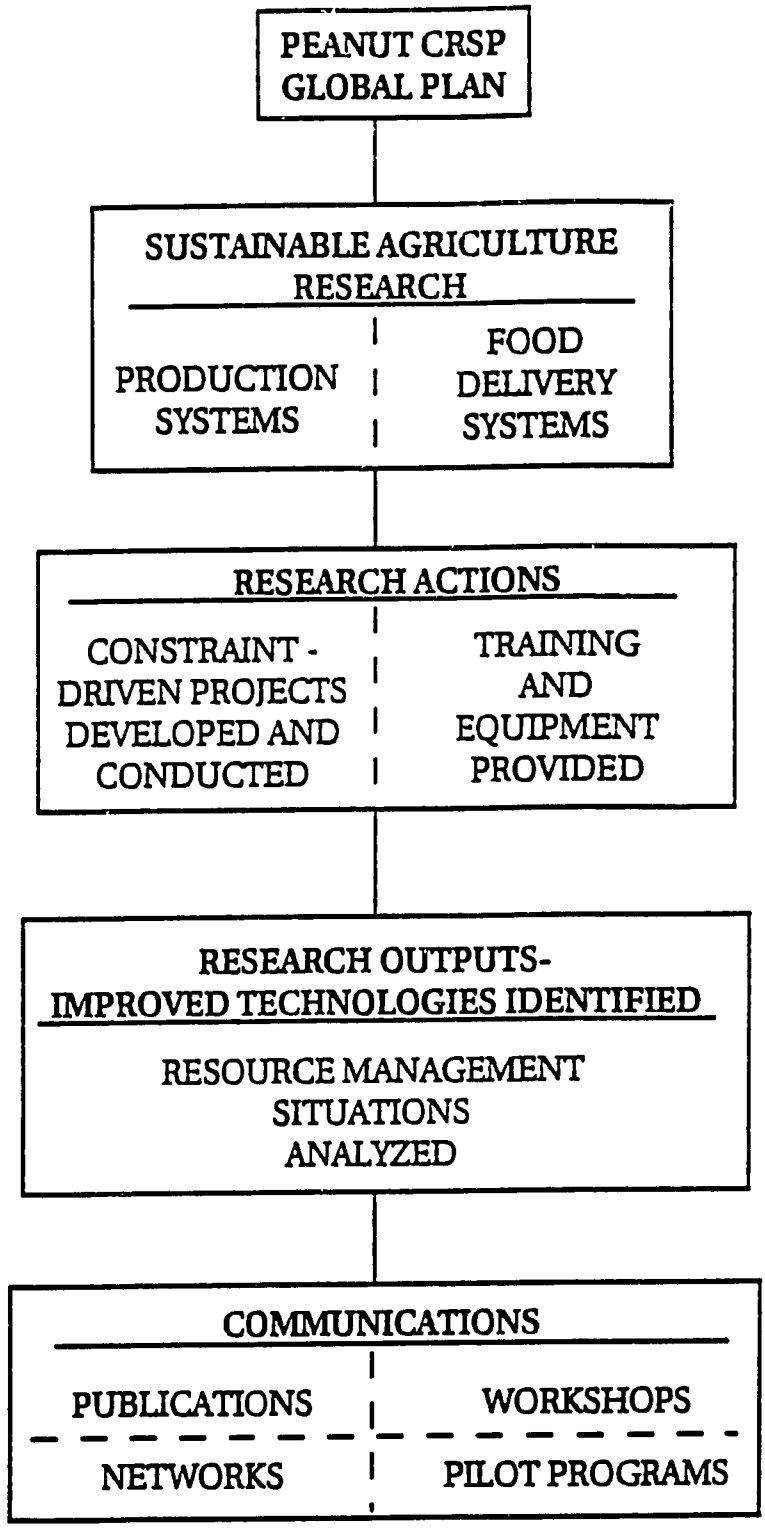
THE GLOBAL PLAN

Peanut has a global nature as a result of the wide distribution of the crop, the importance of the crop in both developing and developed countries, the marked similarity of production and utilization constraints worldwide, the potential for research to relieve production and utilization constraints so to better realize the potential of peanut to contribute to an increased food supply in countries where total food and protein supply is marginal, and the synergistic effect of international cooperation among international agricultural research centers and other donor groups.

Global Thrusts - Sustainability of production and delivery of food to the human population is a primary problem in the developing world. Based on the importance of peanut in contributing to sustainable production of food, and the problems facing optimization of the crop, the Peanut CRSP has three global thrusts to relieve the identified constraints to peanut production and utilization.

1. To develop sustainable agriculture production and food delivery systems that are environmentally sound is the major global research thrust of the Peanut CRSP to relieve the identified constraints to peanut production and utilization.
2. To resolve resource management research situations that restrict efficient management of production and utilization systems.
3. Communication of research outputs to clientele.

An integral part of the research actions is an enhancement of research capability for both the U.S. and the host countries through collaborative research, the provision of equipment, and the training of research and support personnel.



Beneficiaries: Developing country small farmers including rural women, food processors, rural and urban consumers.

United States farmers, processors, rural and urban consumers.

Figure 1. Peanut CRSP Global Plan.

Since its inception, the Peanut CRSP has enhanced research and technology transfer activities through synergistic relationships with other international organizations. Cooperative planning, support for research, and conduct of workshops and other outreach activities characterize these global relationships. Organizations include International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), ICRISAT Sahelian Center (ISC), French Center for International Agricultural Research and Development - Annual Crops (CIRAD-CA), International Development Research Centre-Canada (IDRC), and Australian Centre for International Agricultural Research (ACIAR). The External Evaluation Panel and the Administrative Review Team both recognized the benefits of cooperation with these organizations.

Paramount in the goals of the Peanut CRSP is providing information of value to its beneficiaries. The collaborative nature of the CRSP provides in two-way benefits with:

- Focus on solving constraints and improving the well-being of people in host countries,
- Results of value to the constituents of the participating U.S. institutions.

Host country beneficiaries are small-scale farmers, which include rural women, as well as food processors and both rural and urban consumers. Benefits come in the form of adequate quantities of more nutritious and safe food, and increased incomes.

United States beneficiaries are farmers, processors, and both rural and urban consumers.

The Peanut CRSP Global Plan (Figure 1) is a framework for the implementation of the program, and is a template against which progress toward reaching goals can be measured. Research is a dynamic process, not an event: consequently, Peanut CRSP management will revisit the Global Plan on a continuing basis to keep the CRSP abreast of changes in the international peanut research environment, while keeping in mind the contribution of advancements in research and maturation of technologies for transfer to beneficiaries on the continuing development of the program.

COLLABORATION

Peanut CRSP research programs are conducted collaboratively between scientists in host country and U.S. institutions. Constraints are addressed in the research that solve problems with the host country, while at the same time have regional and global implications. The research also has return benefits to the U.S.

MAJOR ACCOMPLISHMENTS

Research to address the constraints and solve the identified problems of peanut production and food delivery have been approached through the following major thrusts: Genetic Resources, Integrated Pest Management, Natural Resource Management, and Food Products and Consumer Use. In addition, research capability is enhanced through Human Resource and Institutional Development and Communication and Outreach of new and improved technologies is supported. Administrative and Management activities support the implementation and conduct of the program.

GENETIC RESOURCES

Improved Yield Ability

- Approval for release of Fleur 11 in Senegal was given based upon documentation of pod yield increase in excess of 30% compared to 55-437 (a common cultivar) during five-years of on-and off- station research.

- In Mali, the decision was made to increase seed of four breeding lines (73-28) M 13, HYQ (CG) S-49, and EH 310-9) for on farm tests in prospect of release to farmers based on performance in three years of on-station tests.

- In the Philippines, JL-24 was approved as a Philippine Seedboard cultivar in May 1992 and released as UPL Pn10. It yielded 11% more than the national check cultivar, BPI Pn2. UPL Pn10 is high yielding, large seeded, resistant to leafhopper, highly resistant to defoliators and moderately resistant to Aspergillus flavus invasion.

- In Thailand, Taiwan 2 x UF71513-1 was identified as a high yielding-boiling type peanut in Farm Trials by the Department of Agriculture and is being considered for recommendation as a new cultivar. It yielded more than Khon Kaen 60-2, the check cultivar.

Disease Resistance

- In Texas, another 250 peanut accessions, bringing to a total of 2260, were field screened for leafspot reaction at Yoakum. About one percent of the 2260 accessions have been considered worthy of further testing.

- In Texas, populations with selected parentage were developed and are under agronomic selection and generation advance to select for resistance to rosette virus (and termite) in Africa, and sclerotinia blight, spotted wilt virus, leafspot, rust, and/or Aspergillus flavus in Texas.

- In Thailand, peanut lines have been identified that have increased levels of leafspot and rust resistance. The lines will be further evaluated in the 1992 rainy season.

- In North Carolina, twenty-seven interspecific hybrids between cultivated and wild species were evaluated for resistance to early and late leafspot. Four of these lines were released as breeding lines.

- In Nigeria, fifty-seven lines (selected from 260) having less than 10% rosette virus infection in 1991 were planted in 1992. Thirty-three of these lines were free of rosette virus infection and show promise of some being acceptable to growers. Promising lines that yield from 2.5 to 3.0 metric tons per hectare are being multiplied for state trials.

Insect Resistance

- NC 343 has been identified by the Georgia/Burkina Faso Insect Management project as one of the lines most resistant to termite damage. Crosses were made by the Texas breeding project NC 343 and West African germplasm and a limited number of advanced lines sent to Burkina Faso for field testing.

Aflatoxin

- In Burkina Faso the breeding and food technology projects cooperated to determine possible differences in aflatoxin contamination in seed from different breeding lines of peanut. Although no line was aflatoxin free, comparatively less contamination was apparent in some lines than in others at all three locations. Evaluation of lines for aflatoxin production to avoid release of cultivars highly susceptible to aflatoxin production might be an important aspect in cultivar development.

Short Season

- Four short season (early maturing) lines and cultivars were again compared with check cultivars in Mali. This was the third consecutive year in which the four lines performed satisfactorily and seed will be increased in 1992 for on-farm trials in prospect of future release to farmers.

- In Thailand, breeding for earliness to develop high yielding peanut lines which mature in 80-85 days for use in short-season cropping systems have resulted in three lines which are superior to the local check. These lines will continue to be tested in expanded yield trials.

Drought

- Line-source irrigation was used in Texas to select for drought tolerance in peanut lines. The results show some variation in response to water levels among entries. Work will continue to identify drought tolerant germplasm.

Shade Tolerance

- On-farm trials of promising shade-tolerant lines were grown under coconut at four locations in the Philippines. IPB Pn82 82-25 consistently had the highest pod and seed yields.

Acid Soil Tolerance

- In the Philippines, some six lines continue to show tolerance to highly acidic soil conditions.

INTEGRATED PEST MANAGEMENT

- In Georgia, peanut lines have been screened for resistance to viruses for three years. Arachis diogoii and A. helades are two species that have good resistance, although not immunity, to peanut mottle and stripe viruses. Some lines have shown resistance, but not immunity, to tomato spotted wilt virus.

- In Burkina Faso, field treatment with various neem products has not provided any significant control of a variety of insects.

- The trips vector of TSWV continued to be surveyed in Georgia in different seasons. Brachypterous adults are prevalent during the winter in old peanut fields and are being tested as an overwintering source of the virus.

- In Burkina Faso, significant differences among peanut lines were noted in the percentage of pods injured by termites. A delay in harvest increased the incidence of pod scarification and

penetration. Several lines, NC Ac 343, NC Ac 2240, NC Ac 2242, NC Ac 2243, M 13, RMP 40, and RMP 12 had relatively high resistance to termite damage even when harvest was delayed.

- Termite injury to peanut pods increased linearly with an increase in days to harvest in Burkina Faso. This increase in pod injury was directly related to a decrease in soil moisture from an average of 6.8% at 90 days to 1.4% at 120 days. Maximum yields were recorded at 100 days after seeding to harvest.

- Twelve of 54 peanut genotypes were selected in Georgia in cooperation with the North Carolina State Insect Management Project for further evaluation for thrips, corn earworm and velvetbean caterpillar resistance. Compared to the Florunner cultivar, one line showed less thrip damage, two less leafhopper damage, and five less velvetbean caterpillar damage. Crosses with the line NC 343 continue to show resistance to a number of insects, including the three in this experiment.

- The improved use of insecticides was studied at several locations in the Philippines. Studies to evaluate insecticide timing, off-target effects, and incorporation into an IPM system, as well as the economic benefits, have improved the understanding of the use of pesticides.

- An excellent data base on genetic resistance of a number of peanut lines has been developed in the Philippines. The genetic resistance can be used in developing host plant resistance for use in IPM programs.

- Biological control studies in the Philippines on peanut using Trichogramma sp. and Bacillus thuriengensis for the control of Lepidopterous pests have been successful. The studies evaluate the thresholds and efficacy of alternate control strategies in farm settings, demonstrate the results to peanut farmers, and evaluate new techniques under farm conditions.

- In Thailand, studies emphasized the continued development of a sound data base for refinement of the IPM program, which included basic insecticide evaluations to improve the timing of application to increase pod fill. In addition, the IPM program uses host plant resistance, cultural, and biological control measures. Studies continue to follow the migration of thrips and the impact of thrips feeding on peanut yields along and in conjunction with the transmission of virus diseases.

- In North Carolina, studies using floral and feeding attractants provide information regarding rootworm treatment decisions. Current pheromone trap technology has enabled elimination of chemical treatments when less than 45 adult beetles are caught per week. Chemical treatments were reduced by about 16%, and work is now underway to refine the use of the trap by using the feeding attractants, oviposition traps, and soil moisture data along with the pheromone with an anticipation of further reducing chemical use.

- Current research in North Carolina on thrips overwintering and migrating into peanut fields have shown that thrips do not overwinter in the soil and only a limited number appear to migrate from small grains. When migration into the field occurs, the number of thrips in the air is quite large and this migration occurs before peanut emerges. There is continued movement into the field all season long. This overwintering and movement have direct

implications to the management of tomato spotted wilt virus in peanut.

NATURAL RESOURCE MANAGEMENT

- In Burkina Faso in a five-location yield trial, peanut yields were relatively low at the Bobo Dioulasso and Niangoloko locations despite high rainfall at these locations. Recent collaboration between the Peanut and Soil Management CRSPs has shown a low soil pH and high aluminum content at Bobo. The first-year of a multiple-year experiment to study the effect of soil amendments on soil pH and peanut yields was completed. Treatments included lime, phosphorus, lime + phosphorus, ash, and a control with three locally grown peanut cultivars. First year results showed a cultivar x soil amendment interaction.

- In response to grower concerns regarding relative performance of Tamspan 90 and Starr under non-irrigated production, replicated tests were conducted at eight locations in Central and Southeast Texas. Pod yields for the two cultivars in Central Texas were equal, while in the Southeast Texas tests Tamspan 90 yielded significantly more. Earlier results have shown its superiority over Starr under irrigated production, especially in soils infested with *Sclerotinia minor*, *Pythium myriotylum*, and *Rhizoctonia solani*.

- A socioeconomic study in Jamaica to determine the impact of a CRSP developed peanut variety, CARDI-Payne, showed that yields were 42% higher than traditional varieties.

- Studies in Senegal used row-spraying of conidial suspensions of *Aspergillus flavus* at different times in the growing season to increase aflatoxin contamination in peanut. Soil inoculation at pegging time resulted in higher aflatoxin levels in seed at harvest. Thus, the pegging-period is a decisive stage for peanut preharvest infection by *A. flavus* and subsequent aflatoxin contamination in the seed.

FOOD PRODUCTS AND CONSUMER USE

PRODUCT DEVELOPMENT AND EVALUATION

- Tests to determine the acceptability of a cheese-flavored peanut-based spread were conducted cooperatively between The University of Georgia and the University of the Philippines at Los Banos. The work involved 416 respondents at six central locations in the Philippines. The spread was acceptable to consumers who were willing to pay more for the spread than for peanut butter, but less than for a dairy-based spread. Discussions are now underway to work with a private Philippine food company to commercialize the product.

- Sustained production of peanut products made with defatted flour depends on a local source of flour. In Thailand, production of defatted peanut flour was done at the Department of Agriculture's pilot scale oil extraction plant. Quality of the flour produced from the local cultivar, Tainan-9, met the Indian Standard Institute and U.S. flour standards criteria for peanut flour for human consumption.

- Shelflife and consumer acceptance studies on a buttered caramel-flavored peanut snack developed from defatted peanut (33%) and tapioca flours (46%) were completed. Products packed in aluminum

foil bags can be stored for at least two months at ambient temperature without loss of quality. Ninety-five percent of the consumers surveyed indicated that the product was acceptable.

- Peanut tempeh (Rhizopus oligosporus fermentation) has high potential for use in the Thai food system. Supplementation of Thai sausage with 30% dried peanut tempeh resulted in no differences in sensory scores for color, flavor, texture, and consumer acceptability. Replacing dried shrimp with dried peanut tempeh in hot chili paste resulted in no difference in acceptability between vegetarian and non-vegetarian consumers.

- Curd and yogurt products are popular products in the Philippines. A previously reported soft curd was improved. Agar-agar was most preferred as a firming agent. The product was comparable with a commercial soybean soft curd in its physico-chemical characteristics, and plain or flavored formulations were acceptable to consumers based on sensory evaluations.

- In the Philippines, peanut residue following peanut milk extraction was utilized to formulate a cheese-flavored spread. Stability was comparable with that of commercial spreads, thereby requiring refrigeration to prolong shelf-life. Spreads offer a potential for use of the peanut milk residue as a human food.

- In Alabama, food extrusion research using different blends of full fat peanut and sorghum showed that peanut should be less than 20% of the mixture for optimum processing. These results will assist in the formulation of peanut-cereal food products acceptable to West Africa consumers.

- Food scientists in Burkina Faso continue to assist a peanut butter processor in assessing the product market ability. The product had good quality (consistency, shelf-life, acceptability), but appropriate packaging is needed that is both economical and protective of the product.

AFLATOXIN MANAGEMENT

- In Senegal, fifty samples of unrefined village-produced peanut oil from the Kaolack district were analyzed for aflatoxin B_1. Ninety-six percent of the samples contained levels from 5-254 ppb with an average value of 54 ppb. Twenty oil cake samples from the same locations contained aflatoxin levels from 49-160 ppb with an average of 67 ppb. Twenty samples of hand-picked roasted peanut from markets did not contain detectable levels of aflatoxin.

- A new minicolumn method for the rapid detection of aflatoxin M_1 in milk was developed. The new method has a detection limit below the action level of 0.5 ppb.

- Previous studies in Texas have shown that highly adsorbent clays in the diets of farm animals prevented the deleterious effects of aflatoxins. Studies with rats showed similar protection from aflatoxins, and more importantly no new metabolites were found in rats fed the clay-treated diets containing aflatoxin.

- In the Philippines, periodic monitoring of aflatoxin in commercial peanut butter samples obtained in sales outlets has been done over the life of the Peanut CRSP. Often excessively high aflatoxin levels have been found. Samples representing eight brands from two cities and three stores were tested recently. Only one brand

contained over 20 ppb aflatoxin and had 30-50 ppb (minicolumn method of analysis).

- In Georgia, the fate of ^{14}C labeled aflatoxin B_1 in the presence of an aflatoxin-degrading bacterium (Flavobacterium aurantiacum) was determined. The preliminary results suggest that the bacterium metabolizes the toxin rather than binding it to cell walls. The amount of $^{14}CO_2$ evolved by the process suggest that the normally chloroform-soluble ^{14}C-B_1 is rapidly converted to a water soluble degradation product. Bacterial degradation of aflatoxin could be of value in fermented food or feed products.

- The feasibility of separating aflatoxin-contaminated peanut seed from non-contaminated seed by treatment in hydrogen peroxide was studied in Georgia. Concentrations of hydrogen peroxide from 0.075 to 0.225% resulted in a reduction in aflatoxin content of the seed in the "sinker fraction" by 90% within one minute regardless of the initial aflatoxin content. The method promises to be of value as a separation technique in peanut processing.

- In Burkina Faso, peanut paste/butter samples were collected from industrial and traditional, small-scale manufacturers. Aflatoxin levels were higher in the paste from traditional sources. Since the major portion of the paste used is from traditional sources, methods to help these processors reduce aflatoxin content of pastes are needed.

- In Belize, the San Antonio Cooperative has adopted dryer and storage technology developed by the Peanut CRSP. The aflatoxin level in peanut is being monitored at the farm level in storage and when moved to market. Aflatoxin has not been detected above the tolerance level of 20 parts per billion in any sample. Moisture content of all stored peanut was recorded at less than 10%.

POSTHARVEST HANDLING AND STORAGE

- A harvester (lifter) is being fabricated in Belize based on designs developed by the Jamaica collaborating engineer, while he was a CRSP supported student at the University of the West Indies. It was tested and proven adapted to Jamaica soil conditions, and if it works on the heavy soils of Belize it will be a breakthrough in reducing harvest costs.

- A locally fabricated tractor-power-take-off-driven thresher was further modified in Belize to alter the size of the feeding tray and the slope of the discharge screen. The thresher is being evaluated by a number of farmers.

- In Georgia, a manual is being finalized that provides detailed plans and cost estimates for building the thresher that was modified, tested, and now used on farms in the Caribbean.

- In Georgia, a manual is being developed that will describe plans and estimated costs for construction of storage facilities that have been developed and evaluated in the Caribbean.

HUMAN RESOURCE AND INSTITUTIONAL DEVELOPMENT

TRAINING

Completed Ph.D. Degree in 1991-1992

Bachir Sarr, Senegal, at Texas A&M - Veterinary Public Health (Aflatoxins)
Julius E. Fajardo, Philippines, at Texas A&M - Plant Pathology

Completed M.S. Degree in 1991-1992

Therese Malundo, Philippines, at The University of Georgia - Food Technology
Rocelle Clavero, Philippines, at The University of Georgia - Food Technology
Xiaoyong Yan, China, at Alabama A&M - Food Technology
Tunde Koleosho, Nigeria, at Alabama A&M - Food Technology

Initiated or Continued Ph.D. program in 1991-1992

Mahama Ouedraogo, Burkina Faso, at Texas A&M-Breeding
Wootisuk Butranu, Thailand, at North Carolina State - Plant Pathology
C. M. Bianchi-Hall, Argentina, at North Carolina State-Cytogenetics
T. P. S. Rau, India, at North Carolina State-Cytogenetics
Eric Line, United States, at The University of Georgia-Food Technology
Nelly Duarte, Colombia, at Alabama A&M-Food Technology
Rolfe Bryant, United States, at Alabama A&M - Food Technology
Linda Griffith, United States, at Alabama A&M - Food Technology

Initiated or Continued M.S. Program in 1991-1992

Yolando Lopez, Colombia, at Texas A&M-Breeding
Jason Goldman, United States, at Texas A&M - Breeding
Rodante Tabien, Philippines, at Texas A&M-Breeding
G. F. Chappell, United States, at North Carolina State-Breeding
Gail McIntyre, United States, at North Carolina State-Breeding
Witoon Prinyawiwatkul, Thailand, at The University of Georgia-Food Technology
Rudeepan Wattanapat, Thailand, at The University of Georgia-Food Technology
Ashok Mishra, India, at Alabama A&M - Food Technology
Teresa Coleman, United States, at Alabama A&M -Food Technology

Shortterm training in 1991-1992

Mahama Ouedraogo, Burkina Faso Ph.D candidate at Texas A&M, to University of Ouagadougou to review collaborative research program.
Dr. Phindile Olorunju, Nigeria, P.I. virus project, to Malawi for Regional Groundnut (Peanut) Workshop.
Dr. Sopone Wongkaew, Thailand, P.I. virus project to Georgia for laboratory procedures.
Dr. Luthgarda S. Palomar, Department of Agricultural Chemistry and Food Science, Visayas State College of Agriculture - Philippines, to Georgia for product development training.
Chintana Oupadissakoon, Thailand-Food Technology, to U.S./APRES, Georgia

Host Country Institutions

The Peanut CRSP provides partial support to graduate students in host countries. During the past year, twenty-four graduate students completed or were enrolled in programs at Kasetsart University (six in Food Technology) and Khon Kaen University (six in breeding/agronomy) in Thailand; The University of the Philippines at Los Banos (three in Food Technology), and at the University of Ouagadougou, Burkina Faso (three in Food Technology).

COMMUNICATIONS AND OUTREACH

WORKSHOPS

Second International Groundnut Workshop, 25-30 November 1991 -held in cooperation with ICRISAT Center - India.

Five Representatives from the Georgia-Thailand-Philippines Food Technology project participated in the Fourth ASEAN Food Conference in February 1992 in Jakarta, Indonesia.

SPECIAL PUBLICATIONS

Simpson, C. E. 1991. Global collaborations find and conserve the irreplaceable genetic resources of wild-peanut in South America. Diversity 7:59-61.

Haruthaithanasan, V. 1991-92. Series of six articles in Bangkok Daily News (second largest newspaper circulation in Thailand) on peanut utilization research activities sponsored by Peanut CRSP.

Peanut CRSP Update - 1991. Available from Management Office.

Aflatoxin Research Review. Peanut CRSP Research Report 91-01. Available from Management office.

New Directions in Integrated Pest Management Technology Transfer: Research on Farmers, Attitudes, and Socioeconomic Impacts. Troost, Kay M. and others. Peanut CRSP Research Report 92-01. Available from Management Office.

Aflatoxin management brochure to increase awareness of problem - Published in French by Texas A&M/Senegal mycotoxin project. Available from Management Office or Texas A&M University.

International Arachis Newsletter. No. 10 Nov. 1991 and No. 11 May 1992. Published in cooperation with ICRISAT.

NETWORKS

ICRISAT - The Peanut CRSP networked with ICRISAT in general research exchanges, co-sponsored The Second International Groundnut Workshop from November 25-30, 1991, publication of the International Arachis Newsletter, and other special publications.

CIRAD-CA (Centre International en recherche agronomique pour le development - cultures annuelles) - Dr. Robert Schilling attended the APRES meeting in San Antonio, TX in July 1991 and discussed peanut research in West Africa.

CARDI - Peanut CRSP collaborates with the Caribbean Agricultural Research

and Development Institute, which helps extend technology to the CARDI countries.

PILOT PROGRAMS/TECHNOLOGY TRANSFER

- Technologies for processing oil-roasted and ground-roasted peanut developed by the Peanut CRSP were transferred to a group of seven housewives near Cheingmai, Thailand. The training provided included processing and marketing technology. The oil-roasted peanut has provided an 84% return over cost of the product and the ground-roasted has returned 40% over cost.

- A Pilot Program continues in the Philippines that extends CRSP technology (varieties and IPM) to farmers in the Cagayan Valley of Luzon, which is the major peanut growing region.

- New peanut varieties are being multiplied in a program with farmers in Thailand, which will accelerate the adoption of the new varieties on a wide-scale.

- An extensive program in Jamaica led by CARDI and the Jamaican Extension Service has caused adoption of the new CRSP developed CARDI-Payne variety, reported to be 20% of the Jamaica production in 1992. Yields are 42% higher than the traditional varieties as determined in a socioeconomic survey funded by the CRSP.

- Members of the San Antonio Cooperative in Belize and other farmers in the village that are not members of the Cooperative are using a dryer facility that was modified and enhanced through Peanut CRSP postharvest research and outreach. It is serving as a multi-purpose dryer for both peanut and corn. Other cooperatives are interested in constructing their own dryer.

ADMINISTRATION AND MANAGEMENT

The Peanut CRSP Management Group includes the Management Entity Office at the University of Georgia; 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 representation of the above four universities, an External Evaluation Panel with four independent members; an AID/R&D/AGR Project Manager; and a BIFADEC liaison.

Management Entity Activities - The Management Entity is responsible to AID and to the Participating U.S. and Host Country Institutions for management of fiscal and programmatic activities.

- Provided support to Investigators in project management, including travel requests, equipment purchase requests, and other activities.

- Prepared necessary reports including; Annual Report for 1991, quarterly reports, and quarterly Newsletter. Upgraded documentation of Annual Work Plans and Budgets.

- Prepared three special publications: Peanut CRSP Update-1991, Aflatoxin Research Review - Peanut CRSP Research Report 91-01, and New Directions in Integrated Pest Management - Peanut CRSP Research Report 92-01.

- Arranged and participated in two Board of Director's meetings plus

one conference call and two Technical Committee meetings (see Board and TC activities).

- Arranged Principal Investigators meeting at APRES-San Antonio, Texas, July 10-11, 1991.

- Active monthly with CRSP Council to foster Inter-CRSP research activities. Participated in Council meeting in Washington, DC in December 1991, and in March 1992. A major activity has been the development of a concept paper for a potential Inter-CRSP program in Niger.

- Coordinated CRSP inputs into the International Arachis Newsletter. Prepared articles for AID Weekly Newsletter.

- Coordinated Peanut CRSP component of grant from AID for socioeconomic impact studies in Thailand and the U.S.

- Traveled to Malawi in November 1991 and Ghana 1992 to discuss program linkages in these countries.

- Prepared a Peanut CRSP MOU and Work Plan for Inter-CRSP activities in Honduras. Proposal awaiting Mission approval.

- Finalized plans as member of Steering Committee and participated in the International Groundnut Workshop held at ICRISAT-India November 25-30, 1991.

Board of Director's Activities - 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 ME. The Board also acts on recommendations from the Technical Committee on budgets and programs.

- Conducted three meetings during the year: a meeting in San Antonio, Tx July 11, 1991, a meeting in Griffin, GA on April 13, 1992 and by conference call on June 30, 1992.

- Reviewed recommendations of the AID Administrative Review Team and EEP and assisted the ME in formulating actions on the recommendations, some of which had recommendations from the Technical Committee. Examples are; Policy and Operating Procedures Manual, a Strategic Plan, expansion of the TC, plan for increased EEP involvement, and increased socioeconomic activities.

- Considered recommendations from the TC and approved 1992-1993 Work Plans and Budgets.

- Dr. Johnny Wynne represented the Board at CRSP Council meetings in Washington, DC, December 11-12, 1991.

Technical Committee Activities - The Technical Committee is responsible for formulating and recommending to the Board program and budget plans.

- Conducted two meetings during the year: July 12, 1991 at San Antonio, TX , and May 20, 1992 at Griffin, GA.

- Prepared budget and work plan recommendations for 1992-1993 which included programming of the 10% budget decrease.

- Held elections to expand the TC to six members, which provides broader disciplinary representation.

- Dr. Olin Smith represented the TC at CRSP Council meetings in Washington, DC, December 11-12, 1991.

External Evaluation Panel - The EEP is designed to give an unbiased view of how the CRSP is progressing toward meeting its objectives. Plans were implemented during the year to have the EEP involved in evaluation on a more regular, continuing basis.

- Reviewed annual progress through an evaluation of the Annual Report and the Work Plans and Budgets.

- Reviewed plans for the use of the 20% increase in funds.

- In conjunction with another trip, one member visited Jamaica and briefly reviewed CRSP activities there.

AID Project Manager - The Project Manager interacted with the CRSP on a continuing basis, and provided the primary linkage for the CRSP with AID.

- Met with the Board in July 1991 and April 1992, and by conference call in June 1992. Met with the Technical Committee in May 1992.

- 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 the program.

BIFADEC Liaison - The liaison provides a link with BIFADEC for information and actions important to the Peanut CRSP.

- Participated in the Peanut CRSP Annual Meeting in San Antonio, TX in July 1991.

- Provided information on a regular basis to the CRSP from BIFADEC.

PEANUT CRSP IN RELATION TO THE EXPORT COMPETITION

SUMMARY

Host countries of the Peanut CRSP are not competitors in the export market for edible peanut. Some of the West African countries export some oil and oil meal, particularly Senegal, but the United States does not export oil and meal. Minor amounts of export show up in the U.S. Department of Agriculture-Foreign Agricultural Service data, i.e. Mali, which evidence shows is probably oil seed being shipped to a mill in another country. West African peanut production is now largely used for domestic oil and food.

INTRODUCTION

Activities of the Peanut CRSP are consistent with the overall goals of the Title XII program of the United States Foreign Assistance Act of 1975, which is to prevent famine and establish freedom from hunger through land-grant university involvement in international development. To attain the goals, the research capability of both developing country and U.S. institutions is enhanced through training and support of research. Inherent in the CRSP concept is the need to address constraints that have global implications.

In short, the Peanut CRSP enhances the potential of peanut as a crop for human food and animal feed in developing countries and the United States, as it contributes to the increase of rural incomes and sustains agricultural land. The collaborative research on peanut is producing new and improved technology that improves the well-being of people in developing countries and, in turn, benefits citizens of the United States.

Host countries for the Peanut CRSP were selected based on several criteria, among which was the importance of peanut as a food crop and as an income generator for the rural population, the presence of an established research effort on peanut that would be enhanced by the CRSP collaboration to better meet the goals of Title XII, and the potential for the program to have regional and global impacts as well as in country. Presently, the Peanut CRSP is active in Burkina Faso, Mali, Niger, Nigeria, Senegal, Philippines, Thailand, and the Caribbean with focus on Jamaica and Belize.

Section 1.I.7. of the Grant precludes the use of funds provided by USAID for work in connection with the growth or production in countries other than the United States of an agricultural commodity for export which would compete with a similar commodity grown or produced in the United States. The purpose of this statement is to show that funds have not been used in a way to enhance competition with the U.S. peanut export market. In order to demonstrate this, the present export outlook of the Regions and Countries of the Peanut CRSP will be reviewed and analyzed.

PRODUCTION AND USE

Peanut production and use data for the CRSP host countries presented in the following table was compiled by Dr. Stanley Fletcher, Department of Agricultural Economics, The University of Georgia, Georgia Station. Dr. Fletcher is a part of a team that maintains a data base on the world peanut supply and movement in support of the U.S. peanut industry. The data is based on U.S. Department of Agriculture, Foreign Agricultural Service information. Another source of information, especially descriptive information on the West African peanut industry was "Peanut Production, Marketing, and Export: Senegal, Gambia, Mali, Burkina Faso, and Niger" by W.H.M. Morris and published by the Peanut CRSP.

West Africa - Peanut in West Africa was promoted by the French during the colonial period as a source of vegetable oil for France. Similar activities were supported by the British in the Anglophone countries of the Region. Following the independence of the West African countries in the early 1960's, a general decline in the production has occurred due to the loss of the oil market in Europe. Other oil crops produced in Europe have replaced the imported oil, and most of the export market for peanut oil has disappeared except for part of the Senegal production. These countries have traditionally never been exporters of edible peanut. West Africa is a vegetable oil deficit Region and imports palm and other oils to satisfy these needs. The imported oils are lower in price than the locally produced peanut oil, depressing demand that could be a satisfied with locally produced peanut. Peanut is an important food crop in the Sahelian region of West Africa with most of the oil and edible production consumed domestically, and the primary goal of the Peanut CRSP is to enhance the food use of peanut because of the high protein and energy content of peanut. Peanut is an important small-holder, subsistence farmer crop because of its importance as a food item for the farmer, as a cash crop on the local-urban market, a valuable forage for livestock especially in West Africa, and as a nitrogen supplying legume for sustainable production systems.

Export of peanut from these countries was and is primarily in the form of oil and oil meal. Some exports sometimes show up in the table, but this is oil seed for crushing in another country such as France.

Burkina Faso - Annual peanut production in Burkina Faso is about 155,000 metric tons per year. There is some peanut oil export, but the country is a net importer of vegetable oil. There is both commercial and village-level traditional oil production for domestic use. Food use is in pastes for soups and as snack and confectionery foods. Peanut CRSP research is underway to enhance the use of peanut flour in composite flours with cereals and in weaning foods.

Mali - Annual peanut production in Mali is about 95,000 metric tons annually. Similar to Burkina Faso, peanut oil production for export declined in the 1970's. There is commercial and village-level oil production for domestic use, and as a domestic food crop in the form of pastes for soups and as snack and confectionery foods.

Niger - Niger follows much the same pattern as Burkina Faso and Mali with peak peanut production in the 1970's. Rosette virus, drought, and prices has reduced production and export of peanut oil. Present production is about 60,000 metric tons per year. Domestic oil production from commercial and artisanal producers, peanut paste for soups, peanut cake for a fried cake called kulikuli, and snack peanut accounts for much of the production.

Nigeria - Nigeria is the most populated country in Africa. The need for vegetable oil and export to Europe during the British Colonial period stimulated a large production of peanut. During the early 1970's, drought, rosette virus, and urban migrations following the development of the petroleum industry caused a decline in peanut production. Hence, peanut has changed from a commercially important export oil crop to a domestic crop. The 400,000 metric tons of peanut produced is used for commercial and village-level domestic oil production, pastes for use in soups and other dishes, and other local food and snack items.

Senegal - Senegal is an exporter of peanut oil, but not edible peanut. In 1984-1985, 83,000 metric tons of oil was produced in Senegal and only about 33% was exported with the remaining 55,000 metric tons consumed locally. Additionally, considerable amounts of peanut is consumed as condiment in stews, soups, and as snack food. This puts Senegalese domestic consumption in the range of 75% of production.

Southeast Asia - Peanut is not an export crop in the countries of Southeast Asia. Many farmers grow small plantings for food and sale on the local markets. Peanut is an important rotation crop in many cropping systems. Domestic production and hence consumption in The Philippines and Thailand, host countries for the Peanut CRSP, is about 38,000 and 164,000 metric tons annually, respectively. Consumption is peanut butter, ground roasted for prepared dishes, roasted, boiled, confectionery, and other prepared dishes.

Caribbean - The Peanut CRSP collaborates in the Caribbean through the Caribbean Agricultural Research and Development Institute, with work primarily in Jamaica and Belize. Production is low, but peanut is an important crop to the small-scale farmers. Jamaica production is about 5,000 acres, and Belize production is less than 1,000 acres. Production is consumed domestically as peanut butter, snacks, and confectionery products. Production does not show up in world production data. Very small quantitites are sometimes traded within the member countries of the Caribbean Community (CARICOM), but since imports into CARICOM are restricted by extremely high tariffs it is of no concern in the export market.

Table 1. Peanut production and disposition in Peanut CRSP collaborating countries.

Region/ Country/ Year		Harvested area (1000 ha)	Yield (MT/ha)	Supply (1000 MT)			Disappearance (1000 MT)					
				Beginning stocks	Production	Imports	Food Use	Crushing	Feed & Seed	Total Use	Exports	Ending stocks
Burkina Faso												
	80	140	0.50	0	70	0	10	53	7	70	0	0
	81	140	0.55	0	77	0	13	58	6	77	0	0
	82	140	0.55	0	77	0	13	58	6	77	0	0
	83	140	0.57	0	80	0	16	58	6	80	0	0
	84	140	0.50	0	70	0	16	48	6	70	0	0
	85	180	0.71	0	128	0	20	93	15	128	0	0
	86	230	0.70	0	160	0	20	125	15	160	0	0
	87	230	0.63	0	146	0	20	111	15	146	0	0
	88	250	0.72	0	180	0	20	145	15	180	0	0
	89	230	0.70	0	160	0	20	125	15	160	0	0
	90	220	0.68	0	150	0	10	125	15	150	0	0
	91	225	0.69	0	155	0	15	125	15	155	0	0
Mali												
	80	97	0.95	0	92	0	14	68	7	89	3	0
	81	97	0.95	0	92	0	15	68	6	89	3	0
	82	97	0.82	0	80	0	12	59	6	77	3	0
	83	97	0.52	0	50	0	11	30	8	49	1	0
	84	97	0.46	0	45	0	9	30	4	43	2	0
	85	97	0.93	0	90	0	17	60	8	85	5	0
	86	97	0.93	0	90	0	17	60	8	85	5	0
	87	110	0.91	0	100	0	17	70	8	95	5	0
	88	115	1.00	0	115	0	17	85	8	110	5	0
	89	100	0.90	0	90	0	17	60	8	85	5	0
	90	110	0.91	0	100	0	17	70	8	95	5	0
	91	100	0.95	0	95	0	17	65	8	90	5	0
Niger												
	80	169	0.75	0	126	0	91	32	3	126	0	0
	81	150	0.80	0	120	0	75	42	3	120	0	0
	82	140	0.57	0	80	0	60	17	3	80	0	0
	83	159	0.47	0	74	0	51	20	3	74	0	0
	84	140	0.21	0	30	0	18	9	3	30	0	0
	85	100	0.40	0	40	0	27	10	3	40	0	0
	86	100	0.60	0	60	0	42	15	3	60	0	0
	87	100	0.45	0	45	0	27	15	3	45	0	0
	88	130	0.62	0	80	0	62	15	3	80	0	0
	89	110	0.55	0	60	0	42	15	3	60	0	0
	90	110	0.55	0	60	0	42	15	3	60	0	0
	91	110	0.55	0	60	0	42	15	3	60	0	0

Table 1 .continued

Region/ Country/ Year		Harvested area (1000 ha)	Yield (MT/ha)	Supply (1000 MT)			Disappearance (1000 MT)					
				Beginning stocks	Production	Imports	Food Use	Crushing	Feed & Seed	Total Use	Exports	Ending stocks
Nigeria												
	80	650	0.82	0	530	0	220	204	106	530	0	0
	81	479	0.89	0	428	0	178	165	85	428	0	0
	82	600	0.66	0	396	0	165	152	79	396	0	0
	83	600	0.99	0	591	0	246	227	118	591	0	0
	84	550	0.91	0	500	30	220	210	100	530	0	0
	85	520	0.77	0	400	43	189	174	80	443	0	0
	86	660	0.61	0	400	30	166	184	65	415	0	15
	87	800	0.59	15	475	0	324	100	45	469	1	20
	88	700	0.50	20	350	0	234	75	40	349	1	20
	89	700	0.50	20	350	1	265	55	40	360	1	10
	90	740	0.50	10	370	0	265	55	40	360	0	20
	91	750	0.53	20	400	5	304	60	40	404	1	20
Senegal												
	80	1064	0.49	0	521	0	101	258	159	518	3	0
	81	1080	0.81	0	878	0	128	574	170	872	6	0
	82	1121	0.99	0	1109	0	154	636	249	1039	0	70
	83	937	0.61	70	568	0	187	285	150	622	16	0
	84	874	0.64	0	560	0	275	185	100	560	0	0
	85	607	0.97	0	587	0	181	284	120	585	2	0
	86	808	1.01	0	817	25	222	500	120	842	0	0
	87	846	1.10	0	932	31	165	580	142	887	1	75
	88	903	0.76	75	690	30	181	465	118	764	1	30
	89	784	1.04	30	815	30	149	582	116	847	3	25
	90	915	0.73	25	670	30	140	445	117	702	3	29
	91	900	0.77	20	695	30	148	450	119	717	3	25

Table 1. continued

Region/ Country/ Year		Harvested area (1000 ha)	Yield (MT/ha)	Supply (1000 MT)			Disappearance (1000 MT)					
				Beginning stocks	Production	Imports	Food Use	Crushing	Feed & Seed	Total Use	Exports	Ending stocks
Philippines												
	80	39	0.77	0	30	0	18	0	12	30	0	0
	81	56	0.88	0	49	0	30	0	19	49	0	0
	82	48	0.75	0	36	0	22	0	14	36	0	0
	83	46	0.91	0	42	0	24	0	18	42	0	0
	84	47	0.89	0	42	4	29	0	17	46	0	0
	85	50	0.88	0	44	8	52	0	0	52	0	0
	86	45	0.91	0	41	17	53	0	5	58	0	0
	87	51	0.90	0	46	27	68	0	5	73	0	0
	88	50	0.90	0	45	25	65	0	5	70	0	0
	89	46	0.76	0	35	35	67	0	3	70	0	0
	90	46	0.80	0	37	38	71	0	4	75	0	0
	91	48	0.79	0	38	40	74	0	4	78	0	0
Thailand												
	80	100	1.29	15	129	0	63	36	10	109	22	13
	81	117	1.26	13	147	0	61	42	13	116	31	13
	82	117	1.24	13	145	0	69	29	19	117	29	12
	83	120	1.23	12	147	0	78	41	19	138	3	18
	84	125	1.38	18	172	0	108	34	15	157	5	28
	85	123	1.40	28	172	0	116	35	14	165	3	32
	86	125	1.35	32	169	0	125	35	15	175	3	23
	87	118	1.37	23	162	0	125	30	20	175	3	7
	88	119	1.43	7	170	0	125	28	20	173	1	3
	89	120	1.34	0	161	0	137	5	18	160	1	0
	90	122	1.33	0	162	0	138	3	20	161	1	0
	91	123	1.33	0	164	0	140	3	20	163	1	0

TX/BCP/WA

Disease-Resistant Peanut Varieties for Semi-Arid Environments
Texas A&M University

Institut Senegalais de Recherches Agricoles
University of Ouagadougou Institut Developpement Rural
Institut Nationale de Recherches Agronomiques du Niger
Institut d'Ecomonie Rurale

O.D. Smith, Principal Investigator
J.C. Mortreuil (Senegal); P. Sankara (Burkina Faso);
D. Soumano (Mali); A. Mounkaila (Niger);
A.M. Schubert, C.E. Simpson, W.J. Grichar (TAMU)
Co-Investigators

INTRODUCTION

Ecosystems in developing countries of West Africa place severe restraints on peanut production. Rainfall in the region is poorly distributed and the soils are characterized by having low fertility, organic matter, and water-holding capacity. Plant pathogens, arthropods, mycotoxins, and ineffective cultural practices further limit production. Peanut producers possess small landholdings and, at best, use minimal inputs of pesticides and irrigation. Thus, breeding and growing varieties that are disease resistant and drought tolerant will serve as the best means of improving peanut quality and quantity in this region that is challenged to balance between population growth and food supply.

The 1991 rainfall was adequate in all five research sites in Burkina Faso. The Niangoloka site received over 1300 mm of rainfall while the other locations had less than 760 mm (Table 1). Rainfall was poorly distributed at all locations. Rainfall tended to be high at planting and during the first half of the growing season, but was extremely low during the second half of the growing season.

Rainfall started late in Senegal (second week of July) and total rainfall at the two research sites was lower than in 1990 (347 mm in Bambey and 512 mm in Nioro).

In West Africa, the tests were hand planted, spaced 15 cm within rows and 40 to 60 cm between rows. No irrigation, pesticide or herbicide was used except where indicated. The tests in Burkina Faso were fertilized (100 kg NPK/ha) at planting. Harvesting and shelling was done by hand.

A total of 546 mm of rainfall was recorded during the test period at the site in Bryan. Supplemental irrigation was provided except for the Waller and Bryan dryland tests. Leafspot and rust were controlled using Bravo, and Terrachlor was applied for southern blight control. Insect pests were controlled with Lorsban. Treflan and Pursuit herbicides and fertilizer were applied preplant. Calcium amendment was made at the site in Brazos County. All cutural operations were mechanized. Between row spacing was 0.9 m.

The objectives of this CRSP project overlap those of other projects in Texas and the host countries of West Africa. Expenses associated with research supporting total programs, such as labor, fuel, maintenance, and supplies are funded with both CRSP and non-CRSP funds. This report emphasizes research which clearly addresses the objectives of this project and does not attempt to include all research conducted at any participating institute.

MAJOR ACCOMPLISHMENTS

- Approval for release of Fleur 11 as a peanut cultivar in Senegal was given based upon documentation of pod yield increase in excess of 30% during 5 years of on- and off-station research.

- In response to grower concerns regarding relative performance of Tamspan 90 and Starr under non-irrigated production, replicated tests were conducted at eight locations in Central and Southeast Texas. Pod yields for the two cultivars in Central Texas were equal while in the Southeast Texas tests Tamspan 90 yielded significantly more. Earlier results have shown its superiority over Starr under irrigated production, especially in soils infested with Sclerotinia minor, Pythium myriotylum, and Rhizoctonia solani.

- A multi-year soil amendment x variety study was initiated at the Farakoba Research Station in Southwest Burkina Faso where yields consistently have been low compared to other sites within the country where rainfall is much lower. The study, in collaboration with TROPSOILS, follows collaborative research in which it was determined that soil acidity and aluminum toxicity might be constraints to the performance of some or all cultivars.

- Significant differences in response to water applications were found among breeding lines and cultivars grown under a source line gradient irrigation system at Yoakum, TX. Such interpretation was made after construction of a variety performance indices (VPI) comprised of normalized values for yield and coefficients of regression.

- Decision was made in Mali to increase seed of four breeding lines (73-28, M 13, HYQ (CG)S-49, EH 310-9) for on-farm tests in prospect of release to farmers as a result of good performance in three years of variety tests.

- Another 250 peanut accessions, bringing to a total of 2260, were field-screened for leafspot reaction at Yoakum, TX. About 1% of the 2260 accessions have been considered worthy of further testing.

  More than 1800 populations were field-screened for reaction to Sclerotinia minor at Stephenville. The populations derived from crosses of Tamspan 90 and select runner cultivars and breeding lines made for the purpose of developing adapted and acceptable runner cultivars with resistance to the pathogen.

- Populations with selected parentage were developed and are under agronomic selection and generation advance for selection for resistance to rosette virus or termites in Africa, and sclerotinia blight, spotted wilt virus, leafspot, rust, and/or Aspergillus flavus in Texas.

  Eight refereed journal articles, one book chapter, and one miscellaneous publication were published.

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, soilborne 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/or 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

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

Principal Investigator Dr. Olin D. Smith, Department of Soil and Crop Sciences (S & CS), TAMU, College Station (CS)

Co-Investigators Dr. Charles E. Simpson, TAMU Research

	and Extension Center, Stephenville
	Dr. A. Michael Schubert, TAMU Agri. Research Station, Yoakum
Cooperators	Dr. Marian Beremand, Department of Plant Pathology and Microbiology, TAMU, CS
Research Scientist	Mr. W.J. Grichar, TAMU Agri. Research Station, Yoakum
Research Associates	Dr. Glen E. Aiken, Dept. of S & CS, TAMU, CS
	Mrs. Monique Wells, TAMU Agri. Research Station, Yoakum
	Mr. A.J. Jaks, TAMU Agri. Research Station, Yoakum
Research Assistants	Mr. Mahama Ouedraogo, Dept. of S & CS, TAMU, CS
	Mr. Gary Meyerdirk, Dept. of S & CS, TAMU, CS
	Mr. Michael Baring, Dept. of S & CS, TAMU, CS
Technician	Mr. John Scherlen, TAMU Research Station, Yoakum
Budget Analyst	Ms. Marcia Walker, TAMU Research Foundation, CS
Secretary	Mrs. Cynthia Tanner, Dept. of S & CS, TAMU, CS
Institutional Representatives	Dr. Dudley T. Smith, Associate Director, Texas Agriculture Experiment Station, TAMU, CS
	Dr. E.C.A. Runge, Head, Dept. of S&CS, TAMU, CS

Senegal: Institut Senegalais de Recherches Agricoles (ISRA)

Directeur General	Dr. Mahamodou Ly, ISRA, Dakar
Directeur du Departement	de la Production Vegetales
	Dr. Limamoulaye Cisse, ISRA, Dakar
Collaborators	Mr. J.C. Mortreuil, IRHO/CNRA/ISRA
	Mr. Ousmane Ndoye, SUD/ISRA, Nioro
	Dr. Daniel Annerose, IRHO/CNRA/ISRA, Bambey
	Dr. Jean L. Khalfoui, IRHO/CNRA/ISRA, Bambey

Burkina Faso: Universite de Ouagadougou Institut du Developmente Rurale (IDR)

Directeur IDR	Dr. Tamini Zoumboisse, Univ. of Ouagadougou, Ouagadougou
Collaborator	Dr. Philippe Sankara, IDR, Univ. of Ouagadougou, Ouagadougou

Niger: Institut Nationale de Recherches Agonomiques du Niger (INRAN)

Directeur General	Dr. Mamadou Ouattara,INRAN, Niamey
Collaborator	Mr. Amadou Mounkaila, INRAN, Maradi

Mali: Institut d'Economie Rurale (IER)

Directeur General	Dr. Mamadou Goita, IER, Bamako
Collaborator	Mr. Dielimoussa Soumano, IER, Bamako

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 Location trials

Burkina Faso. Twenty-six Texas breeding lines, 3 ICRISAT lines, 1 US cultivar (Florunner), and a local check (TS32-1) were evaluated at five locations. Two locations, Niangoloko and Bobo, are located in the higher rainfall, southwestern region of the country, and the other three locations, Gampela, Kombissiri, and Saria are in the central and eastern region.

Pod yields in the central and eastern locations were good (Table 1). In Gampela and Tenkodogo, Florunner and Tx874263 were the highest yielding entries with respective pod yields in Gampela of 3567 and 3315 kg/ha and 3167 and 2829 kg/ha in Tenkodogo. The Texas line, Tx874263, was 34 and 27% higher in yield than the check, TS32-1, at Gampela and Tenkodogo, respectively. Stands for these entries were above 50% (percentage of planted seeds producing harvestable plants) at both locations but neither ranked the highest in stand percentage.

Table 1. Mean yield and grade for all entries per location in Burkina Faso.

	Rainfall mm	Pods ---- kg/ha ----	Seed (TK)	Stand* %
Southwest:				
Niangoloko	1304	321	198	32
Bobo	707	416	236	36
North Central:				
Gampela	752	2538	1806	39
Saria	663	1542	1019	38
Tenkodogo	538	2089	1549	43

* Percentage of planted seeds producing harvestable plants.

In Saria, TS32-1 produced yields equal or higher ($P<0.05$) than all entries. Excellent plant survival (87%) was a factor contributing to the good performance of TS32-1. Tx874737 ranked third and did not differ significantly from the check.

PI 1174, recently approved for release in Senegal under the name "Fleur 11", had the highest yield in Bobo and the second highest yield in Niangoloko (Table 2), but was only average in Gampela and Tenkodogo. In Saria, PI 1174 produced pod yields of 1465 kg/ha, which was less than the test mean and about 41% lower than the check. The poor performance of PI 1174 at this site can be attributed to a low stand percentage (23%).

At Bobo and Niangoloko, pod yields were highest for PI 1174, Florunner, TS32-1, and Tx874737 (Table 2). However, as in previous years, yields were lower for the two southwestern locations than the three north central locations. Stand percentages, although low for Bobo and Niangoloko (Table 2), do not fully explain the poor performance. Florunner with only 20% of the highest attainable stand ranked the highest in yield for Niangoloko. Leafspot and rust were present but not in severities adequate to explain the low yields. A collaborative TROPSOILS

and Peanut CRSP soil profile and chemical analyses of the Bobo (Farakoba Research Station) site in 1990 revealed low pH and high Al in the 43 to 120 cm "b" soil horizon. Thus, precipitation of an aluminum toxicity by low soil pH is a possibility.

Table 2. Mean yield and stand percentage for highest performing entries at Bobo and Niangoloko in Burkina Faso.

	Bobo Dioulasso			Niangoloko		
	Pod	Seed (TK)	Stand*	Pod	Seed (TK)	Stand
	--- kg/ha ---		%	---kg/ha---		%
PI 1174	1124	732	58	499	315	36
Florunner	767	490	55	654	458	20
Tx874737	688	427	60	451	311	44
TS32-1	721	439	46	467	305	72

* Percentage of planted seeds producing harvestable plants.

Mali. Four late-maturing peanut lines, one each from ICRISAT and India and two from Senegal, were compared with the U.S. cultivar GH 119-20 (GA 119-20) in four replicate RCB tests at Sotuba and Kita. Planting dates for the tests with 12m^2 plots were 6 and 20 July, respectively. Leafspots and rust were prevalent at Kita but plant survival was good and pod yield ranged from 2542 to 3146 kg/ha. Breeding lines M-13 and EH 310-9 were 23.8 and 13.9%, respectively, better (p=.05) than the GH 119-20 check. Haulm yields did not differ (P=.05) among entries although the yield of EH 310-9 was 26% less than that of GH 119-20. At Sotuba, substantial plant loss occurred for some entries but yields ranged from 1808 to 2521 kg/ha. The differences among entries were not significant although M-13 averaged 37.5% higher in pod yield than GH 119-20. Multi-year average pod yields of the four entries and the check are shown in Table 3.

Table 3. Yields of entries in peanut varietal trials at Sotuba and Kita Agricultural Research Stations, 1989-1991.

Entry	Mean Yield (kg/ha)							
	1989		1990		1991		Average	
			Sotuba					
73-28	2104		2650		2471		2408	
M 13		2640		2383		2521		2514
HYQ(CG)S-49	2421		2292		1808		2173	
EH 310-9		2786		3025		2042		2617
GH 119-20		1417		2208		1843		1822
			Kita					
73-28			2470		2687		2578	
M 13				2865		3146		3005
HYQ(CG)S-49			2708		2562		2635	
EH 310-9				3051		2896		2973
GH 119-20				2401		2542		2260

Four early maturing lines and cultivars were compared with 55-437 and 47-40 at Cinzana in a 4-replicate test with 8.0 m^2 plots arranged in a RCB design. Pod yields ranged from 1902 kg/ha for 47-10 to 2775 kg/ha for JL 24, but were not different (p=.05). Haulm yields were not different among entries and were within the range of the checks. This was the third consecutive year in which the four lines under tests performed satisfactorily. Conclusions were made that seed of these entries should be increased, beginning in 1992, for on-farm trials in

prospect of possible future release to farmers.

Thirty lines from Texas were compared with checks 47-10 and 55-437 at Cinzana ARS. Yields were low, in general. Two Texas lines, Tx 892666 and 892609, yielded more than the checks.

Senegal. Tests were conducted at Bambey and Nioro, and at various farms to compare yields between Fleur 11 and 55-437, a local check. Leafspot and rust appeared late in the season, but did not affect yields severely. Clump virus incidence was high; close to levels observed in 1987.

Fleur 11 pod yields were 41% and 54% higher than 55-437, in station and on-farm tests, respectively (Table 4). The difference between the varieties in haulm yield was not signigicant. Seed weight of Fleur 11 was higher than 55-437 at the stations (61%) and farms (68%). Fleur 11 was approved for release and seed increase is in progress.

Table 4. Mean yield and seed weight for Fleur 11 and 55-437 grown at Bambey and Nioro, and on farms in Senegal.

Entry	Vine	Pod	wt/100 seed	Vine	Pod	wt/100 seed
	---kg/ha---		qms	---kg/ha---		qms
Fleur 11	970	550	50	430	790	62
55-437	1030	390	31	635	515	37

At the Nioro station, confectionery and edible peanut were tested in 3 and 2 sites, respectively. At harvest, stand percentage and pod yield were higher in the confectionery peanut tests than in the edible peanut tests.

Niger. Program inactive awaiting MOU approval.

Texas. Tests were conducted at eight locations in Southeast and Central Texas to compare the performance of Tamspan 90 relative to that of Starr in the absence of irrigation. Data averaged over the eight locations are shown in Table 5. Tamspan 90 yielded significantly higher than Starr at three locations in the Southeast region (data not shown), but was not different in the Central Region. The grades of Tamspan 90 averaged lower than Starr, although this was not consistent in all tests. These data will alleviate concerns of Texas growers over the adaptability of Tamspan 90 for dryland culture in Texas. Previous results have shown Tamspan 90 superior in Texas to other spanish varieties in irrigated tests and in situations where either sclerotinia blight or pod rot is present.

Table 5. Average yields and grades for two spanish cultivars at eight locations in Southeast and Central Texas in 1991.

	Val/ac	Pods/ac	TK	SMK	OK	Wt/100 SD
	$	kgs.	-------%-------			qms
Tamspan 90	687	1029	72	65	6	40
Starr	638	964	74	68	5	39

Fourteen lines, half of which derived from a cross of a drought tolerant African line and a short-growth duration cultivar with large pods and the other seven with pod disease resistant parentage, were evaluated in an irrigated, four-replicate test near Bryan. Yields were high, ranging from 4733 to 6927 kg/ha. Shelling percentages and grades averaged 78 and 71%, respectively. Although all lines performed well, six of the large seeded lines excelled in yield. Seed

weights ranged from 76 to 98 gms/100 seed.

Soil Amendment Test - Burkina Faso

- Recent field and laboratory studies conducted by Peanut CRSP and TROPSOILS suggested that low pH and Al toxicity might be affecting yield at the Bobo Dioulasso site on the Farakoba Research Station. In 1991, the first of a planned multiple year, collaborative TROPSOILS - Peanut CRSP test was conducted at this location to ascertain the effect of five soil amendment treatments on soil pH and peanut yields of three locally grown cultivars: RMP-12, TS32-1, and QH243C. The soil amendment treatments were applications of either $CaCO_3$, P_2O_5, CaCO3 + P_2O_5, ash, or no amendment (control). Stand percentage at harvest for RMP-12 (36%) was lower ($P<0.05$) than for TS32-1 (74%) and QH243C (72%), but the average yield per plant was highest for RMP-12. The effect of soil treatment on stand and yield per unit area over varieties was not significant. However, a variety X soil amendment interaction on yield per hectare was apparent ($P<.05$).

Leafsize

Texas. Thirty-four runner and 20 spanish $F_{3:4}$ lines, derived from crosses of the small-leaved PI 341269 and Florunner or Tamnut 74, were compared at Bryan in irrigated, replicated tests with checks to determine associations among leaflet size and important agronomic traits. The breeding lines tested were selected for uniformity of leaflet size and plant form in the F_3. PI 341269 and several of the spanish cross progenies sustained considerable damage by soilborne disease, symptomatic of stem rot and pythium pod rot. Yields in the "spanish" test ranged from 1503 to 3453 kg/ha, and in the "runner" test from 1731 to 5427 kg/ha. The shelling percentage varied from 59 to 73% in the spanish test, and from 55 to 76% in the runner test. No associations were detected between leafsize and yield or grade in the spanish test. Entries in the runner test with higher yields and shelling percentages had large leafsizes, but moderate and low yields and shelling percentages were also observed for other entries with large leafsizes. Entries with small leafsizes were generally low in yield and shelling percentage.

Fatty Acid Composition

Texas. Oleic and linoleic acid are important components of peanut. Furthermore, the oleic:linoleic ratio has been associated with oil stability and shelf-life in peanut. F_1, F_2, and F_3 generation seed from crosses of lines with high O:L vs U. S. and West African spanish and bunch cultivars were produced for plant row and single plant selection in 1992.

Drought Tolerance and Escape

Texas. Identification of traits that impart drought resistance or avoidance under field conditions is difficult when all germplasm is subjected to the same water level. Comparisons under a range of soil water levels might help to identify desirable trends in performance to water supply. Performance of selected peanut germplasm was examined at different water levels at Yoakum in 1989, 1990, and 1991. A source line irrigation gradient was used to provide different water levels across entries in each of the three years. The 48 entries included cultivars from USA and Senegal, and germplasm among which some differences in drought resistance were expected.

The selected entries were subdivided into maturity groups and one test each of medium and short growth duration entries was planted north (downwind) of the sprinkler line; and one test of each maturity group was planted South (upwind) of the line. Each test had 12 entries replicated four times. Row directions were perpendicular to the sprinkler line. Water application rates, soil moisture, and various plant responses were measured at several predetermined

distances from the irrigation lines. Yield will be the only response discussed in this report.

Yield data for each entry combination was subjected to linear regression against water level. The slopes (water response; yield/ha/cm) indicated some variation in response to water levels among entries. Inasmuch as both mean yield and slope are important considerations in the evaluation of entries for varied water regimes, variety performance indices (VPI) were calculated. For this calculation, slopes for each entry were normalized by dividing by the mean slope for all entries, and mean yield for each entry was normalized by dividing by the mean yield for all entries. The two calculations were then summed to provide VPI. Thus, a high VPI indicates that the mean yield and response of a variety to increasing water, within the range tested, performed either near average or above in both traits or else superior in one or both measures.

Yield data combined over the three years for late-north entries are shown in table 6. Over the three years, the highest yielding lines tended to have the highest VPI's and slopes. A comparison of VPI and average yielding ability for all water levels indicate that entry performance is significantly related to VPI value.

Table 6. Pod yields, slopes, and variety performance indices for late-maturing peanut entries planted downwind from irrigation lines.[1]

Entry	Yield kg/ha	Slope (kg/ha)/cm	VPI
Tx833841	2906 a[2]	68.4 a	2.27 a
Sn57-422	2904 a	68.1 a	2.27 a
NC-343	2839 ab	66.9 ab	2.22 ab
Southern Runner	2703 abc	63.4 abc	2.11 abc
Florunner	2644abc	62.3 abc	2.07 abc
Tamrun 88	2566 abcd	59.4 bcd	1.99 abcd
Tx855143	2496 bcd	58.4 cd	1.95 bcd
GK7	2487 bcd	57.8 cd	1.93 cd
Okrun	2453 cd	57.8 cd	1.93 cd
Sn73-33	2453 cd	57.9 cd	1.92 cd
ICGS-11	2207 de	51.5 de	1.72 de
Tx855515	2046 e	48.2 e	1.60 e

[1] Data combined for 1989, 1990, and 1991 crop years.
[2] Values in each column followed by the same letter are not significantly different at the 5% level of significance according to Duncan's Multiple Range Test.

In another test, ten lines with drought tolerance, early maturity and large seed size were compared agronomically under irrigation in prospect of subsequent testing in Senegal. Three lines had yields that ranged from 4309 to 4743 kg/ha, but were not significantly better (P>0.05) than the U.S. runner cultivar check Tamrun 88 (3873 kg/ha). Shelling percentages and grades for the three lines, which averaged 78 and 69%, respectively, also were not different from that of Tamrun 88. Seed weights ranged from 69 to 81 gms/100 seed compared to 52 gms/100 seed for Tamrun 88.

Thirty-two lines from Burkina Faso, with characteristics of interest, were planted in replicate near Bryan for observation and increase. Plant development was reasonable but pod production was restricted by soilborne disease and excess moisture which resulted from lateral water movement and poor soil drainage.

Ten of 33 lines of Chinese origin that were observed in 1990 were evaluated for adaptation in a replicated yield test at Bryan. None of the introductions appeared to have potential use in Texas.

Twenty-five lines, including three checks, derived from crosses of early maturing and drought resistant traits were evaluated agronomically in duplicate, non-irrigated, three-replicate tests at Bryan and Waller. Yields at Bryan ranged to 2829 kg/ha for one test, and 2935 kg/ha for the other test. These were 27 and 18% higher than the average for the checks, respectively; however, the differences among entries were not significantly different (P>.05). Shelling percentages ranged from 68 to 77%, and grades ranged from 64 to 72%. Maximum yields and the ranges in shelling percentages and grades at Waller were similar to those at Bryan; however, the rankings of entries were dissimilar between the two locations. Such interaction indicates strongly the necessity of multiple location testing.

Fourteen cultivars and candivars were grown in a replicated yield test at Waller under rainfed culture. Yields ranged from 1455 to 3440 kg/ha with grades ranging from 69 to 75%. Tamspan 90 produced the highest average pod yield followed closely by Fleur 11 which had a superior grade and total value per acre based on the 1991 USDA loan schedule. Fleur 11 did not compare well with Texas cultivars in a duplicate irrigated test conducted at Bryan.

Seventy-two F_5 plant rows from selected F_4 plants having parents with short growth duration and dormancy were grown in duplicate in prospect of selecting adapted, short season dormant lines that would avoid seed germination loss at digging. Fifty-nine had little or no sprouting at digging (146 days after planting). Post-harvest germination on blotter paper was tested approximately 30 days after drying. Eleven lines were selected for evaluation in 1992.

Sterility was encountered following pollinations of one each of a spanish, runner, and virginia cultivar by plants of an un-named, very short growth duration, wild species (VSGr-6416). Hybridizations with the wild species, which matures in less than 50 days in its native habitat, were intended for transfer of earliness characteristics to adapted cultivated plants. Crosses with the runner and virginia cultivars were not successful, but two pods were harvested from crosses with the spanish. Indications are that crosses with the other market types will entail use of a bridge cross technique, similar to that which is being used by project personnel for leafspot and rootknot nematode resistance.

Disease Screening and Evaluation

Leafspot

Texas. Another 250 germplasms were evaluated for leafspot resistance at Yoakum, bringing the total number of entries evaluated to 2,260. Of the total lines tested, 27 lines were determined to possess enough resistance to warrant additional evaluation. The lines tested in 1991 included 45 runner-type entries of South American origin, 13 entries from the ICRISAT program, 46 entries collected in the Rurrenabaque region of the North Beni, Bolivia, and 108 entries from other diverse origins with varied plant types.

Introgression of early and late leafspot resistance from wild peanut species was carried to the BC_2F_2. Laboratory screening was accomplished on about one-half of the 6400 F_2 seed produced. Disease component examinations, in addition to general disease reaction assessment, are being made. Intercrosses were made among six lines from the BC_2F_2 introgression materials that differ in disease components in an attempt to produce and recover a leafspot resistant type which had the resistant alleles for all components of resistance. Plants were selected that had one or more desirable components (e.g., few lesions, small lesions, long latent period, low sporulation of lesions) and then crossed with selected plants

that had different desirable components. These crosses will be evaluated and tested in the future to determine if some of the components of resistance were combined.

F_0, F_1, and F_2 generation seeds from a first cycle in a recurrent selection program using introgressed and cultivated parents were produced and planted for field leafspot analysis and selection. Whole plant and disease component data are being collected for use as selection criteria. DNA extractions were made on selected backcross generation plants for RAPD analyses.

Forty eight germplasm lines, Chinese and recent U.S. introductions from South America, were evaluated for leafspot resistance at Yoakum. None of the 48 entries exhibited complete resistance, but seven entries had low to moderately low infection levels at digging. Thirty ICGV lines were evaluated for adaptability and potential for use as parents. Survival was rather poor, due in part to the wet condition of the test site. Potential for use in the program appears limited.

F_0, F_1, and F_2 seed of Southern Runner x earlier maturing runner varieties were produced with the goal of producing early maturing breeding lines that incorporates resistance to spotted wilt virus (SWV), late leafspot, and rust into a cultivar that will gain more acceptability by South Texas peanut growers. Seventy-four F_2 derived families were planted south of San Antonio in 1992 for repeated inspection of SWV symptoms throughout the growing season. F_2, F_4, and F_5 generation populations are under production at Bryan in the absence of the disease. In addition, 37 F_4 and F_5 families from crosses including Southern Runner as a parent are planted in replicate at the same South Texas site for SWV evaluationa.

Leafspot disease severity has often been associated with heavy fruit load. Fruit production by the leafspot resistant wild Arachis is generally low when grown in Texas. Thus, question arises whether a fruit load/disease reaction association exists in wild species germplasm. Plants of chacoensis, cardenasii, and batizocoi were grown with Southern Runner and Florunner in replicate under spaced plantings at Yoakum where natural infections by leafspot persists. Treatments consisted of fruiting restrictions of none, 50%, and 100% imposed by frequent clipping of newly formed pegs. Unfortunately, serious southern blight development occurred which could not be controlled adequately with available pesticides. No differences among treatments in leafspot reaction were observed among the wild species, although some indications of differences were apparent in the cultivated. Plant loss was so severe that the test had to be abandoned.

Burkina Faso. Biweekly ratings of leafspot symptoms were taken at Niangoloko and Bobo using the ICRISAT scale for AUDPC (area under disease progress curve) calculation and comparison. Fifty-one entries were evaluated in the tests. Disease pressures were similiar at the two locations. Few entries at the last measurement had scores of less than 6, most ranged from 7 to 9. Average percent defoliation at digging was 71% at each location. Pod yields were low.

Sclerotinia Blight

Texas. A program of breeding for sclerotinia blight (Sclerotinia minor) resistance has concentrated on transfering the genes for resistance from Tamspan 90 into runner types. Even though a large number of new introductions and other germplasm have been evaluated, no source of resistance has been found to be better than Tamspan 90. Included with the lines under field test at Stephenville were a large number of check plots which consisted of Tamspan 90, Florunner, and Langley. Averaged over 43 check plots for each variety, and under heavy sclerotinia pressure, the average percentage infection was 8.5% for Tamspan 90, 48% for Florunner, and 68% for Langley.

The 1991 tests included 147 lines of hybrid origin that were selected for low

sclerotinia incidence in each of the three previous years. Fifty-six lines were selected from this group for additional evaluation. Five of the lines showed no infection throughout the season. An additional 1621 lines of hybrid origin in various generations of advance and development from $F_{2:3}$ to $F_{4:5}$ were tested for the first time. Of these, 310 lines were selected for additional testing. Seed of 120 of the lines were subsequently evaluated in vivo for sclerotinia reaction with artificial inoculation in the greenhouse through the cooperation of Dr. H.A. Melouk, USDA/ARS Pathologist at Stillwater, OK. Additional crosses and backcrosses were made with selections from four of the better families (E-28, E-38, E-9, and 6401) for additional line development. F_2 populations were planted for seed increase and selection in 1992. In addition, selections were made at Bryan from an BC_1F_2 Tamspan 90/Tamrun 88 spaced-plant population for plant row disease evaluations in 1992.

Southern Blight

Texas. Advanced lines with southern blight and leafspot resistant parentage are being evaluated for southern blight reaction, yield, and grade in 1992.

Additional crosses with a select advanced line that has shown good yield potential and southern blight resistance were made with Tamrun 88 with intent to develop lines with improved grade that are high-yielding and resist southern blight. Current advanced lines in program that show significant southern blight resistance normally grade 2 to 3% lower than best U.S. commercial cultivars. The F_2 seed were produced for spaced planting and selection.

Aspergillus flavus and aflatoxin

Texas. Aflatoxin analyses were made on four replicates of 52 early and medium maturing entries grown at Yoakum on soil infested and supplemented with A. flavus under dryland culture at Yoakum. The test was duplicated at Waller at a site with natural fungal infestation. In addition, replicates of 60 additional breeding lines under evaluation for agronomic evaluation at Waller were analyzed. Low fungal invasion at both Yoakum and Waller, presumably a result of unusually plentiful rainfall, resulted in very low aflatoxin production so that the slight differences among entries were not significant.

Senegal. Breeding lines were evaluated for Aspergillus flavus resistance and dormancy. The dormancy of 73-30 is being transferred using the pedigree method. Advanced lines were more productive than the checks, 57-422, 73-33, 73-30 and 55-437, but were less productive than Fleur 11.

Burkina Faso. Seed samples for aflatoxin analyses were provided to HC collaborators on the AL/FT/BF project from three locations of the multiple location trials. Aflatoxin contamination varied among locations and among entries within locations. Although no entry was aflatoxin free, comparatively less contamination was apparent in some lines than in others at all locations. Evaluation of candivars for aflatoxin production to avoid release of highly susceptible lines as cultivars might be an important aspect in variety development.

Rust

Texas. Six lines that had been screened for rust resistance were grown for the purposes of increasing seed and examining uniformity and growth habit. Growth was adequately uniform for most of the lines with spreading and erect growth habits being observed. Seed was sent to West Africa for evaluation in locations infested with Puccinia sp.

Burkina Faso. Evaluations of rust incidence and severity were made on 51 entries at Niangoloko and Bobo using the ICRISAT scale. Rust infection was very low in Bobo, with no entries receiving a score greater than one. Scores at Niangoloka

ranged from 2 to 6. Forty-one percent of the entries had scores between 4 and 6.

Rosette Virus

Texas. Rosette virus is an important disease in West Africa that causes significant yield losses. Previous program evaluations have indicated the need for strengthening HC programs in developing adapted varieties resistant to this disease. Crosses were made between rosette resistant RMP and KH lines, and adapted short and medium growth duration varieties and lines. F_1 generation plants were grown to produce F_2 seed. Small populations from two crosses were transported to Burkina Faso for preliminary observation. Screening in collaboration with the Ga/PV/N project is anticipated.

Spotted Wilt Virus

Selected cultivars and breeding lines were crossed with Southern Runner with intent to produce a more acceptable and earlier maturing cultivar with SWV and disease resistance. Southern Runner was also crossed with NC 343 to ascertain whether the traits for insect and disease resistance in the parents can be favorably combined. F_0 to F_3 generation seed were produced and plantings were made for preliminary screening for SWV reaction on a plant row basis.

Termites

Texas. F_0, F_1, and F_2 generation plants of NC 343/West African germplasm were made for experimentation in selecting for termite resistance. NC 343 has been identified as among the most termite resistant genotypes found by the GA/IM/BF project. A limited number of $F_{2:3}$ families were sent to Burkina Faso for preliminary observations. Other populations have been planted in Texas for seed increase and agronomic observations. Screening and selection in collaboration with the GA/IM/BF project is anticitpated.

Germplasm Collection and Conservation

Collection was made in Brazil of 122 wild and 82 cultivated accessions as seed, five wild accessions as cuttings, and 22 nodule collections by a team of scientists including Dr. C.E. Simpson. Funding for the trip was provided by IBPGR, USDA, EMBRAPA/CENARGEN, CIAT, and TEXAS A&M UNIVERSTIY. CRSP funded TAMU researchers participated in processing accessions, and will assist in increase and classification of the collections.

A total of 124 accessions of local varieties were increased in spaced plots for seed maintenance at Sotuba, Mali.

HYBRIDIZATION

The first attempts to hybridize peanut in the country were made using locally adapted varieties and introduced germplams in a total of 7 combinations plus reciprocals. Crosses were made in the field without irrigation. Pod and seed set were low as a result of physical conditions and operator skills. Not all crosses were accomplished.

PRESENTATIONS AND CONFERENCE PARTICIPATION

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Philippe Sankara participated in the Annual Meeting of APRES, Suffolk VA, and the International Congress on Crop Science, Ames IA.

Mahama Ouedraogo participated in the Annual Meeting of APRES, Suffolk VA, and the International Congress on Crop Science, Ames IA.

TRAVEL - OVERSEAS

Mahama Ouedraogo conferred with faculty at the University of Ouagadougou and USAID Mission officials, visited peanut research plots in Burkina Faso, and reviewed Texas/Burkina Faso collaborative research with HC collaborators.

PUBLICATIONS

Smith, O.D., C.E. Simpson, W.J. Grichar and H.A. Melouk. 1991. Registration of Tamspan 90 peanut. Crop Sci. 31:1711.

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Wildman, L.G., O.D. Smith, C.E. Simpson, and R.A. Taber. 1992. Inheritance of resistance to Sclerotinia minor in selected spanish peanut crosses. Peanut Sci. 19:31-35.

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Simpson, C.E. 1991. Global collaborations find and conserve the irreplaceable genetic resources of wild peanut in South America. Diversity 7: 59-61.

Simpson, C.E., D.L. Higgins, G.D. Thomas, and E.R. Howard. 1992. Catalog of passport data and minimum descriptors of Arachis hypogaea L. germplasm collected in South America. 1977-1986. Texas Agric. Exp. Stn. Texas A&M Univ.System. College Station, TX 77843. Misc. Publ. #1737.

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. Oleagineu 47: 119-133.

Subrahmanyam, P., and D.H. Smith. 1991. Variability in pathogenicity and symptomatology of Leptosphaerulina crassiasca on peanut. Plant Disease 75: 1266-1269.

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 1992/1993

Training - degree oriented

- PhD training:
  Mahama Ouedraogo, Burkina Faso. Level 2, Univesity of Ouagodougou, 1987; M.S. Texas A&M Univerisity, 1990.

- M.S. training:
  Yolanda López, Colombia. Biologist (Genetics), Universidad del Valle, 1975.

- Jason Goldman. B.S. Rutgers University. 1992.

Training - Short term

Ousmane Ndoye, Dielimoussa Soumano, Philippe Sankara, Amadou Mounkaila, A.M. Schubert, and O.D. Smith to participate in West African Groundnut Conference at Ouagadougou, Burkina Faso.

Research

Host Countries

- Single and multiple location advanced line and variety trials will be conducted in Senegal (2 locations), Burkina Faso (6 locations), and Mali (3 locations). Multiple location test entries will not be the same in all tests as HC collaborators select entries based upon performance in preliminary tests in their specific countries.

- A drought-tolerant variety trial of early maturing entries procurred from ICRISAT-SC and Hyderabad will be conducted at Same. - On-farm peanut varietal tests with early spanish varieties JL 24, QH 243C and a local check will be conducted in farmers fields of villages around Same.

- Analyses for aflatoxin contamination will be made on selected entries at selected locations of the Burkina Faso multiple location trial in collaboration with the AL/FT/BF project.

- Study at Farakoba, Burkina Faso will be continued to determine the effect of soil amendments on three peanut cultivars on soil found to have low pH and high Al, especially in the rooting zone. Soil treatments will consist of lime, ash, gypsum and phosphorus. Cultivars consist of check varieties of different growth durations. Attempts are being made to obtain and increase a line/cultivar with tolerance to low pH/high Al for use as an entry in the study.

- Soil profile and chemical analyses will be made at peanut test sites at Saria, Niangoloka, and Gampela in collaboration with TROPSOILS.

- 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.

- F_2 populations produced in 1991 will be studied and advanced in Mali.

- Early generation populations segregating for resistance to leafspot resistance will be grown and evaluated in Senegal.

- Preliminary tests with early generation populations with rosette virus or termite resistant parentage will be evaluated in Burkina Faso. Increase and selection will be imposed on larger and additional populations in Texas for more extensive tests in Burkina Faso in 1993.

- Basic seed increase will be made of Fleur 11 in Senegal.

- Fleur 11 and Tamspan 90 will be evaluated in the ICRISAT/PEANUT CRSP Regional variety test.

- Seed multiplication for large scale on-farm tests will be made in Mali.

- Release of an early maturing variety will be considered in Senegal.

Texas

- Field evaluations of about 1500 F_3 to F_5 families will be made for Sclerotinia reaction at Stephenville. Yield and agronomic assessments will be made on about 20 of the entries at three locations. F_5 plant selection will be imposed upon F_2 derived families with favorable sclerotinia reaction and plant form. F_2 populations of different parental combinations will be grown for selection and F_3 seed increase.

- Germplasm lines selected for moisture response will be studied further for moisture response under a source line irrigation system at Yoakum. Plot sizes will be sufficiently large for collection of data useful in crop growth and farming system models.

- Another 250 germplasms will be evaluated for leafspot reaction at Yoakum.

- Evaluations of leafspot reactions on F_2 plants from a diallel among 8 genotypes (6 of interspecific origin) will be made at Yoakum.

- RAPD analyses will be made among leafspot resistant backcross progenies from amphiploids for improved techniques in breeding for leafspot resistance.

- Selection for a second cycle of recurrent selection will be based on disease components and whole plant assessments.

- Southern Runner cross derived F_3, F_4, and F_5 families will be evaluated for resistance to spotted wilt virus in South Texas.

- Peanut lines grown in Waller for replicated agronomic trials at Waller and replicated trials for toxin analysis at Yoakum will be evaluated for *Aspergillus flavus* infection and aflatoxin production.

- Leafspot evaluation and selection for another backcross will be made in the introgression of leafspot resistance and nematode resistance of wild into cultivated species.

- Single plant progenies combined in the development of Tamspan 90 will be grown in fungal infested soil under dryland culture and analyzed for *Aspergillus flavus* infection and aflatoxin production.

- Selection will be imposed upon spanish and bunch-type populations segregating for fatty acid composition.

- Forty-four introductions from Bolivia will be evaluated for A. flavus infection and aflatoxin production in cooperation with the TX/MM/S project. Separate seed increase and agronomic comparisons will be made under irrigation.

- Compositional quality factors will be examined on selected germplasms grown in Texas and Burkina Faso in collaboration with the AL/FT/BF project.

- Plant and plant row selection will be imposed on populations from parents differing in resistance to rosette virus, termites, spotted wilt virus, leafspot, or southern stem rot; and or populations with varied fatty acid composition.

- Yield, grade, and other factors will be evaluated at multiple locations in Honduras on U.S. and HC varieties in collaboration with INSORMIL and LUPE.

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.

MAJOR ACCOMPLISHMENTS

In Thailand, (Taiwan 2 x UF 71513-1) was identified as high yielding, boiling type peanut in Farm Trials by the DOA and is being considered for recommendation. Its yield is significantly higher than check cultivar Khon Kaen 60-2. Three peanut cultivars [(MGS-9 x Robut 33-1)-5-2-2-4, 69-PYS 107 (C-124) and Roi-et] were identified as superior when evaluated in the before-rice growing conditions by the KKU. Thai groundnut researchers provided technical training on groundnut seed production for three agricultural officers from Myanmar during 1 February-30 April 1992.

In the Philippines, JL-24 was approved as a Philippine seedboard variety in May 1992. It was released as UPL Pn 10. It is high yielding (11% seed yield increase over the national check cultivar, BPI Pn 2) with good seed qualities (large seeded, oblong seed shape, light colored seed coat, thin and smooth shells), resistant to defoliators and leafhoppers, moderately resistant to *Aspergillus flavus* invasion and high storability/viability. It is susceptible to rust and late Cercospora leafspot. Resistance to both foliar diseases seems to be

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associated with small seededness. This is true with recommended varieties like UPL Pn 4, UPL Pn 6 and UPL Pn 8 with resistance to both diseases but small seeded. All large-seeded recommended varieties like BPI P9, UPL Pn 2, BPI Pn 2 and UPL Pn 10 (which are preferred by large consumers) are susceptible to both foliar fungal diseases.

IPB Pn 85 10-68, an IPB advanced line, was recommended for seed increase and on-farm trials across major peanut-growing areas. It was the highest yielder with mean seed yield of 2.02 tons/ha during the 1991 wet cropping season at two testing sites. Also, it ranked third among the 14 entries tested in the national cooperative yield trials at seven locations during the 1991-92 dry cropping season with a mean seed yield of 1.90 tons/ha.

On-farm trials of promising shade-tolerant lines as intercrops under coconut at four locations (Davao City, North Cotabato, Quezon and Bicol) showed that IPB Pn 82 82-25 had consistently the highest mean pod and seed yields of 1.26 and 0.77 ton/ha, respectively. However, in terms of 100-seed weight, IPB Pn 82 82-25 (41.1 g) is significantly lighter than UPL Pn 2 (53.1 g).

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

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 insects 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.

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.

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. William V. Campbell, Dept. of Entomology
	Dr. Barbara Shew, Dept. of Crop Science
Technicians:	Ms. Joyce Hollowell, Dept. of Plant Pathology
	Ms. Tracy Jones, Dept. of Crop Science
	Ms. Gerry Phillips, Dept. of Crop Science
	Mr. Philip Rice, Dept. of Crop Science
Institutional Representative:	Dr. J.C. Wynne, Dept. of Crop Science
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):	Dr. Vichitr Benjasil, DOA, Thailand
Assistant Coordinator (Thailand):	Dr. Paisan Supangkasen, DOA, Thailand
Principal Investigator (Philippines) :	Dr. Remedios M. Abilay, UPLB,
Principal Investigator (Thailand):	Dr. Aran Patanothai, KKU
Co-Investigators (Philippines):	Dr. Marina P. Natural, UPLB
	Dr. Henry P. Samonte, UPLB
	Ms. Leonila A. Lantican, UPLB
	Ms. Maria H. Magpantay, UPLB
	Mr. Rudy S. Navarro, UPLB
	Mr. Apolonio M. Ocampo, UPLB
	Dr. Pablito P. Pamplona, University of Southern Mindanao
	Ms. Gloria L. Pantican, UPLB
	Mr. Valentino C. Perdido, Ilagan Experiment Station
	Mr. Onofre V. Cavite, Bicol Experiment Station
Co-Principal Investigators: (Thailand)	Mr. Wootisuk Butranu, DOA
	Dr. Surapong Charoenrath, DOA
	Dr. Duangchai Choopanya, DOA
	Dr. Sanun Jogloy, KKU
	Mr. Sopone Kittisin, DOA
	Ms. Tuksina Sansayavichai, DOA
	Mr. Preecha Surin, DOA
	Dr. Banyong Toomsan, KKU
	Ms. Soomjintana Toomsan, DOA
	Dr. Sopone Wongkaew, KKU
	Dr. Thammasak Sommartya, KU
C. USAID Project Officers:	Mr. Kevin Rushing, USAID, Manila
	Ms. T. Hiranraks, USAID, Bangkok

APPROACH

Peanut germplasm is being introduced 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 being 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. 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 the cultivated germplasm, interspecific hybridizations will be utilized to introgress desirable characters from the wild species into *A. hypogaea*. As 40-chromosome populations are developed, they are incorporated into the *A. hypogaea* breeding programs.

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.

ACCOMPLISHMENTS IN DETAIL--RESEARCH

Thailand

A. **Breeding**

1. **Department of Agriculture.** The peanut breeding work of the DOA aims to develop cultivars with high yield, early maturity, resistances to rust and leafspots, and to develop large-seeded and boiling-type peanut. Work in 1991 was 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, well performed lines in the previous year standard yield trials were further tested in the regional yield trials, and outstanding lines were evaluated in the preliminary yield trial stage. The lines were grouped according to the individual breeding objectives. 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 testings were done at the research stations of the Field Crops Research Institute, both in the rainy season and in the dry season with irrigation.

a. **Preliminary yield trials**

1) **High yield.** Work on breeding for high yield in 1991 included selection in segregation materials and four sets of preliminary yield trials. The segregation materials were progenies of seven crosses of F_2 and F_4 generations. These materials were evaluated at Khon Kaen, 215 plants and 56 lines were selected from the F_2 and F_4 generations,

respectively. The test entries in the first and second sets (27 each) were lines selected at Khon Kaen Field Crops Research Center. The first set was evaluated at Khon Kaen in dry season, and it was found that (NC 7 x Tainan 9)-21-10-9 gave the highest yield. Seventeen lines were selected for testing in coordinated preliminary yield trial in the rainy season. The second set was evaluated at Mahasarakam in the rainy season, and it was found that [(MGS 9 x Chico)-12-16- 5 x NC 7]-117 gave the highest yield. This set was repeated in the dry season of 1992.

The third and fourth sets of preliminary yield trials were the coordinated trials. The test entries were selected lines from DOA and KKU. The third set was evaluated at Khon Kaen in the dry season, while the fourth set was evaluated at Roi-et and KKU in the rainy season. (Tainan 9 x UPL Pn4)-12-4-22 was the top yielding line in the third set yield trial, and nine lines were selected for testing in standard yield trial in the 1992 rainy season. In the fourth set yield trial, (Moket x NC 7)-65-6- 13 was the top yielding line at Roi-et, while (Moket x NC 7)-66-6-29 was the top yielding line at KKU.

2) **Early maturity.** The aim of this breeding objective is to develop high yielding lines with early maturity, preferably 80-85 days, for certain cropping systems. Activity on this objective was only a preliminary yield trial. This trial was tested at Kalasin in the dry season and at Loie and Roi-et in the rainy season. [(MGS 9 x Chico)-12-16-5 x NC 7]-19-3-21, (TMV3 x NC 7)-5 and (TMV3 x NC 7)-37-1-46 were the top yielding lines at Kalasin, Loie and Roi-et, respectively. These three lines gave the average yields higher than those of the checks. Well performed lines from this trial were selected for subsequent yield testing.

3) **Foliar disease resistance.** Materials carried under this breeding objective were F_3 progenies from KKU. The 50 crosses were grown in the rainy season at Khon Kaen and 35 lines were selected for subsequent yield evaluation. The criteria for selection were low rust and leafspot incidences and good agronomic performances.

4) **Insect resistance.** The 22 insect-resistant lines were identified by the DOA entomologist and handed on to the DOA breeder for evaluation of agronomic performance and adaptation. Fourteen lines were selected for further testing.

5) **Large-seed size.** Two preliminary yield trials of large- seeded lines were conducted at Khon Kaen. The first set was tested in the dry season and it was found that (NC 7 x Tainan 9)-7-32-21 gave the highest yield. Fourteen promising lines were selected for testing in the second set. In set II, lines were tested in the rainy season. [NC 7 x (MGS 9 x Chico)-12-16-1]-3-28-9 was the top yielding line. High-yielding lines with desirable characters were selected for repeat testing in 1992.

b. **Standard yield trials.** The test entries in standard yield trials 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 Kalasin, Chainat and Phitsanulok. Eleven lines were evaluated in this trial. (Moket x RCM 387)-1-1-2 gave the highest average yield. The second trial was conducted during the rainy season at Rayong, Phitsanulok, Banmai Samrong, Roi-et and KKU. Only one line, ICGS 110, gave higher yield than those of the checks.

The third standard yield trial consisted of 4 four aflatoxin-resistant lines, 7 high yielding lines, 2 crown rot-resistant lines and 3 checks. This trial was conducted at Kalasin, Chiang Mai ad Phitsanulok in the dry season, and at Rayong, Phitsanulok, Mukdaharn and Roi-et in the rainy season. (Ah 65 x NC Ac 17090) gave the highest average 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 Khon Kaen, Phitsanulok and Praputtabat in the rainy season. Yields obtained from Phitsanulok were low because of flooding. Khon Kaen 60-1 and Khon Kaen 60-2 gave the highest average yields.

Large-seeded entries in the standard yield trial Set V were carried out both in the dry and rainy season at Khon Kaen, Chiang Mai, Mahasarakam, Nakornsawan and Praputtabat. (C 7 x RCM 387)-1-1 was the top average yielding line.

Lines tested in the standard yield trial Set VI were early maturity lines. This trial was conducted both in the dry and rainy seasons at Kalasin, Khon Kaen, Loei, Mukdahar, Rayong and Mahasarakam. (Lampang x Chico)-18-6-3 gave the highest average yield.

c. **Regional yield trial.** Well performed entries in the standard yield trials were selected and evaluated in the regional yield trial at more locations. There were three regional yield trials. The first and second set were coordinated regional yield trials. Nine entries in the first trial were evaluated at Chiang Mai, Kalasin, Philsanulok and Sakon Nakorn in the dry season. (Moket x J 11)-12-3-26 and (Panjab x PI 337394 F)-4 gave higher yield than the other lines, but their average yields were lower than the checks. Tainan 9 and Khon Kaen 60-1. At the second trial, seven lines were evaluated in the rainy season at Chiang Mai, Rayong, Nakornsawan, Songkla, Roi-et, Loei and KKU. China no. 1, (Moket x Ah 24439)-12-8-16 and [ICG(FDRS)]-11 were the well performing entries.

Entries in the third trial were 7 aflatoxin-resistant lines, 2 high yielding lines and 3 checks. The trial was conducted at Khon Kaen, Phitsanulok, Chainat in dry season and at Mahasarakam, Loei Phitsanulok, Uboratchatanee, Petchaboon in rainy season. High yielding lines were (Tainan 9 x Ah 24439)-32-5-11, (Tainan 9 x RCM 387)-12-3-11, (J11 x Ah 24439)-18-11-6 and (J11 x RCM 387)-8-6-2, but these yields were equivalent to those of the checks.

d. **Varietal farm trial.** Promising entries selected from the regional yield trial were entered in the farm trial conducted in the farmers' fields. In 1991, two boiling-type peanut lies were tested together with three checks (SK 38, Khon Kaen 60-1 and Khon Kaen 60-2) in the dry and rainy seasons. The trial was conducted in farmers' fields in Khon Kaen, Ubonratchatanee, Roi-et, Chiang Mai, Kalasin, Mahasarakam, Nakornsawa, Rayong, Loei, Banmai Samrong and Songkla. One of the new lines, (Taiwan 2 x UF 71513- 1), gave slightly higher shelling percentage, fresh and dry pod yields than the boiling-type check, Khon Kaen 60-2. This particular line had larger seed size than Khon Kaen 60-2.

2. **Khon Kaen University.** Peanut breeding work at Khon Kaen University includes breeding for high yield, early maturity, resistances to rust, leafspot and insects, improvement of large-seeded virginia and boiling types, increasing biological nitrogen fixation and improved cultivars for before- and after-rice without irrigation. Work done in 1991 included

generation of new segregation materials for selection, introduction of breeding material from NCSU and ICRISAT, evaluation and selection of segregating material in various breeding objective materials, and yield evaluation of different groups of materials. Promising lines were selected from yield trials and handed on to the DOA for adaptability and stability evaluation on diverse environments. Coordinated yield trials were also conducted, and collaboration was made with the pathologist, entomologist in screening for foliar diseases and insect resistance, respectively, and with the soil microbiologist in screening for efficient biological nitrogen fixation.

a. **New crosses made and new material received.** In 1991, two sets of local crosses were made. The first set were 20 crosses between four adapted lines (Tainan 9, Lampang, Khon Kaen 60-1 and Khon Kaen 60-2) and five late leafspot- and rust-resistant lines [ICG(FDRS) 17, PI 259747, NC Ac 17090 ad DHT 200]. The second set, 5 adapted lines (Tainan 9, Khon Kaen 60-1, Lampang, Khon Kaen 60-2 and Khon Kaen 60-3) were crossed to four high nitrogen fixation lines [Virginia Branch, PI 240574, A3-1-1 (BC164) and 42-G-105]. The two sets of segregating material were generated by using MxN mating design. The material will be used for genetic studies for rust and leafspot resistance and for increasing biological nitrogen fixation of material set I and set II, respectively.

b. **Breeding for the after-rice unirrigated conditions.** In 1990-91 after-rice unirrigated growing season, 20 F_4 population of crosses involving well performed lines under the after-rice unirrigated conditions were grown for advance generation. Four yield trials were conducted in the 1990-91 after-rice season. These included a farm trial, an advanced yield trial, a intermediate yield trial and a preliminary yield trial. The tested entries, totaling more than 40 lines, were selected from the 1989-90 after-rice trials. All trials were conducted in paddy fields with high residual soil moisture during dry season. The farm trial was conducted on 10 testing sites in Khon Kaen, Surin and Korat. The advanced yield trial and the intermediate yield trial were conducted at Khon Kaen University and Kranuan, Khon Kaen. The preliminary yield trial was conducted in a location at Khon Kaen University.

   In the farm trial, Tainan 9 gave the highest yield among the tested entries and (GA 207-3 x Robut 33-1)-11-4-2 gave higher yield than check cultivar Khon Kaen 60-1. Ten entries were evaluated in the advanced yield trial. Only ICGS 11 gave higher yield than check cultivar Khon Kaen 60-1, about 5%; however, it has a smaller seed size than Khon Kaen 60-1. In the intermediate yield trial, 10 entries with four replications were tested at two locations. (MGS x Robut 33-1)-5-3-1-6 was the top yielding cultivar in the trial. Its yield was 21% higher than Khon Kaen 60-1. Several tested entries performed better than check Khon Kaen 60-1 in the preliminary yield trial. Among them, [ICGS 20 x (MGS x Robut 33-1)-4-2]-1 gave the highest yield in this trial.

c. **Breeding for the before-rice growing conditions.** Six yield trials of selected lines tested in 1990 were conducted. These included a farm trial, an advanced yield trial, an intermediate yield trial and three sets of preliminary yield trials. The farm trial was conducted at five testing sites. Six tested entries with a replication were evaluated in each site. All tested entries performed better than check Khon Kaen 60-1; however, those entries have smaller seed than Khon Kaen 60-1. In the advanced yield trial, six tested entries and two checks were evaluated with four replications at two locations. Tested entries ICGS (E)-173 and ICGS (E)-166 are among the top

yielding entries in this trial. Six tested entries and two checks were evaluated at Khon Kaen University. No tested entries performed better than check Khon Kaen 60-1 in the intermediate yield trial. Three sets of the preliminary yield trials were conducted at Khon Kaen University. Several entries in the preliminary yield trials performed well, giving yield higher than Tainan 9. [(Tainan 9 x Robut 33-1)-5-2] F_7-2, (Lampang x ICG 2375 NC Ac 2938) F_7-1 and (ICGS 4 x RCM 387) F_7-1 gave the highest yield in the preliminary yield trial Sets I, II and III, respectively.

d. **Breeding for high yield.** Work under this breeding objective in 1991 included generation advanced selection of segregating material and yield trials. Twenty F_3 populations of material received from NCSU, 11 F_3 populations of crosses made locally and 21 F_6 populations of material received from ICRISAT were grown for advanced generation in the 1990-91 dry season. In the rainy season of 1991, all segregating material was grown and single plant selection was performed based on agronomic yield and pod quality.

Twelve yield trials of breeding lines in this breeding objective were conducted at Khon Kaen University in the 1991 rainy season. The trials included two sets of intermediate yield trials and 10 sets of preliminary yield trials. The tested entries, totaling more than 370 lines, were selected from the 1990 rainy season trials. All trials were conducted at KKU. In the intermediate yield trial set I, several lines performed better than check cultivar Khon Kaen 60-1. The promising lines in this trial are Schwarz 21, (UPL Pn4 x SK 38) F5-9, (SK 38 x Robut 33-1) F6-7, (UPL Pn4 x SK 38)F5-3 and (UPL Pn4 x SK 38) F6-10. Among the top entries in the intermediate yield trial set II, (UPL Pn4 x Lampang) F6-41, (UPL Pn4 x Lampang) F6-34, (UPL Pn4 x Lampang) F6-39 performed better than check Khon Kaen 60-1. Several of the tested entries performed well, giving higher yield than Khon Kaen 60-1 in the preliminary yield trials. (Lampang x UPL Pn5) F5-1 (ICGS 4 x ICG 4994 Nc Ac 2466)-6, (Lonyun 6101 x ICGS 4)-2, [ICGS 20 x (Nc Ac 2564 x Nc Ac 17090) F2-P28-B1-B1-B1]-2 gave the highest yield in the preliminary yield trial sets I, II, III and IV, respectively; while (Lonyun 6101 x NC 4) F8-1, (Tainan 9 x Argentine 8-3) F8-2 and [(Tainan 9 x (GAVG-1 x PI 259747)5-1-F5]F8-3 gave the highest yield in the preliminary yield trial Sets VII, VIII and IX, respectively. No tested entry performed better than check cultivar Khon Kaen 60-1 in the preliminary yield trial sets V, VI and X. Based on the results of these trials, the promising lines were selected for more advanced yield trials in the 1992 rainy season.

e. **Breeding for earliness.** Breeding work for early maturity was continued from the previous year. Nineteen breeding populations in F_3 generation of crosses made locally and 15 F_4 populations of material received from ICRISAT were grown for generation advance in the 1990-91 dry season. In the 1990 rainy season, 19 populations in F_4 generation of crosses made locally ad 15 F_6 populations of material received from ICRISAT were grown. All breeding material was harvested at 85 days after planting. Single plant selection based on pod maturity and agronomic yield was performed. The selected single plant will be re-evaluated in the 1992 rainy season.

Two sets of preliminary yield trials of early maturing lines were conducted at KKU in the 1991 rainy season. Tested entries in the first set included early maturing lines from ICRISAT while the tested entries in the second set were selected lines from local cross material. In the preliminary trial set I, ICGV 87055 (91176 x JL24) and (ICGV 86143) ICGS 44 x Robut 33-1 x Nc Ac 2721)] gave significantly higher yield than Khon Kaen 60-1. ICGV 87055 (91176 x

JL24) was 5 days earlier in maturity than Khon Kaen 60-1; however, those two lines have smaller seed size than Khon Kaen 60-1. No tested entries gave higher yield and earlier maturity than Khon Kaen 60-1 in the second set of the preliminary yield trial.

f. **Improvement of large-seeded type peanut.** Thirty-one F_3 populations of crosses involving large-seeded lines were grown for advanced generation in the 1990 dry season. In the 1991 rainy season, the 31 crosses were grown for evaluation and single plant selection was performed. Selected single plants will be evaluated in the 1992 rainy season.

Two preliminary yield trials of large-seeded peanut lines were conducted at KKU in the 1992 rainy season. Sixteen entries with one replication were evaluated in each trial. The entries in the first set trial were selected from natural outcrossing of RCM 387, and all of them have pink seed coat while the tested entries in set II were material received from ICRISAT. In the preliminary yield trial I, only Khon Kaen 60-1 and (RCM-Pink)-15-1-2 gave higher yield than check entry Khon Kaen 60-3; however, both of them have smaller seed size than Khon Kaen 60-3. No tested entries performed better than check in the preliminary yield trial set II. Most tested entries gave lower yield and have smaller seed size than the check.

g. **Breeding for resistances to rust and leafspots.** Work on resistances to rust and leafspots in 1991 included generation advance, selection of segregating material and yield trials. Forty-one local cross populations in F_4 generation, 7 F_4 and 15 F_7 populations of material received from NCSU were evaluated for disease resistance. Single plant selection was performed based on disease resistance and agronomic traits.

Two yield trials of foliar disease-resistant lines were also conducted at KKU in the 1991 rainy season. The trials included a set of intermediate yield trial and a set of preliminary yield trial. Twelve selected entries from KKU were evaluated in the intermediate yield trial, while 25 entries received from ICRISAT were evaluated in the preliminary yield trial. Agronomic yield and disease rating were recorded. (Chico x NC 343) and (PI 109839 x NC 343) were among the top yielding entries in the intermediate yield trial. Those two lines also showed moderately resistant to rust. In the preliminary yield trial, ICGV 86590 (x- 14-4-19-6 x PI 259747), ICGV 87237 [(53-68 x Nc Ac 17090) x (Ah 6279 x PI 259747)] and ICGV 86594 (Nc Ac 1107 x Nc Ac 17090) are among the top yielding in this trial. ICGV 86699 (S 29/1-B2-B1 gave higher yield than Khon Kaen 60-1 (about 33%) and also ICGV 86699 (S 29/1-B2-B1) showed high resistance to rust and black leafspot. The promising lines were selected for re-evaluation in the 1992 rainy season.

h. **Improvement of boiling type.** Twenty-four F_3 populations of crosses locally made in 1988 were grown for generation advance in dry season 1990. In 1991 rainy season, 24 F_4 populations of the crosses were evaluated and single plant selection was performed based on agronomic yield and pod characteristics for boiling-type peanut. The selected single plats will be re-evaluated in the 1992 rainy season.

i. **Breeding for insect resistance.** Eight F_3 populations of crosses involving insect resistance were grown for advanced generation in dry season 1990. In the 1991 rainy season, eight F_4 populations were also grown for advanced generation. This segregation material will be evaluated for insect resistance in the 1992 rainy season.

j. **Breeding for increased biological nitrogen fixation.** Breeding work for increasing biological nitrogen fixation was initiated in 1990. In 1990, 36 promiscuous lines were grown and evaluated for nitrogen fixation. Five peanut lines were selected as parents for crossing program. New crosses were made between high nitrogen fixation lines and adapted lines as described in topic 2.a.

B. **Pathology**

1. **Department of Agriculture.** The pathological research projects carried out in 1991 by the DOA comprised of various kinds of work. The first experiment aimed at evaluating the resistances of peanut lines to black spot and rust under a disease nursery condition and the second investigated the reactions of peanut varieties to colonization of *Aspergillus parasiticus* and aflatoxin production. The third examined the infection process and epidemiology of peanut stem rot caused by *Sclerotium rolfsii*. The last experiment was set to study chemical control of peanut stem rot.

a. **Screening for black spot (*Phaeosariopsis personatum*) and rust (*Puccinia arachidis*) resistances in peanut under disease nursery conditions.** Twenty-seven peanut lines from a preliminary yield trial, 20 lines from previous studies and 48 lines from a preliminary trial for foliar disease resistance obtained from KKU were evaluated for black spot (*P. personatum*) and rust (*P. arachidis*) resistances under disease nursery condition at the Khon Kaen Field Crops Research Center. The lines were planted in a 6-m row plot with two replicates. A susceptible early line (ICGS(E)-1) was planted between every two rows of the test entries to act as a disease spreader. Both ICRISAT rating system and a two- or three-character system were used in assessing the disease resistances. The evaluation was done at 50, 70 and 90 DAE. At 50 DAE, ICRISAT rust scores were 3.9 for the most susceptible line and 1.2 for the most resistant one, while those of the susceptible and resistant checks were 2.0 (Tainan 9) and 2.2 (NC Ac 17090). The differences in level of resistance were much higher at 70 and 90 DAE (Table 1.1), where 31 lines showed a moderate level of resistance having rust scores less than 5. Among them, Khon Kaen 60-3, a newly released cultivar, was included. Results obtained from the three-character scoring system were considerably similar to that of the ICRISAT system. At the early date (50 DAE), most of the pustules were observed only on the lower part of the plants, but subsequently spread upward and found on the uppermost leaves of almost every line at 90 DAE. At this date most of the pustules ruptured and were full of spores. Interesting lines that had high levels of rust resistance found in this trial were KKU-91- 209-6, KKU-91-209-10, KKU-5 and (Nc Ac 17090 x Tainan 9)-7.

Reactions to black leafspot of some resistant lines were as shown in Table 1.2. In general, the responses were similar to that against rust in that the severity increased with time. Among the lines tested, (NC Ac 17090 x RCM 387)-19P-3 outperformed others in the level of resistance. The score of this line at 90 DAE was only 1.1 compared to the parent Nc Ac 17090 which had 5.9 black spot score. On this line the infection appeared to limit itself on lower leaves only.

When considering the resistances to both black spot and rust, a number of these lines possessed those qualities. Among the released cultivars, Khon Kaen 60-3 appeared to have the highest level of multiple resistance.

b. **Reactions of peanut varieties to colonization of *Aspergillus parasiticus* and aflatoxin production.** Reactions of peanut lines to

A. parasiticus and aflatoxin production were studied using a split-split plot design. Main plots comprised of frequent watering (control) and water stress periodically imposed treatments. Sub-plot treatments were with and without inoculation of *A. parasiticus*. Sub-sub-plots were seven lines of peanut-- namely, (J11 x RCM387)-8-6-2, (J11 x RCM387)-7-1-10, (J11 x Ah 24439)-18-11-6, Lampang, Khon Kaen 60-1, J11 and Tainan 9. Results indicated that under stress conditions, average seed infection percentage (27.10) was higher than that of the control (15.42). Field-inoculated (at 50 DAE) and non-inoculated treatments showed no difference on seed infection percentage. On the average, seed infection percentage of most peanut cultivars ranged between 11.46 and 21.26, except (J11 x RCM387)-7-1-10 of which infection percentage was very high (42.82). Cultivar Khon Kaen 60-1 had the lowest seed infection percentage. Aflatoxin production in seeds indicated a similar trend to that of seed infection; the mean of aflatoxin production was 24.54 ppb under stress compared to 3.10 ppb of the control. Cultivars Khon Kaen 60-1 and J11 showed little response to stress conditions, while aflatoxin production of (J11 x Ah 24439)-18-11-6 and Tainan 9 reduced considerably from 4.54 to 1.36 and 13.92 to 6.34 ppb, respectively under drought conditions. In general, inoculation increased aflatoxin production considerably. Aflatoxin production was the highest (38.62 ppb) and lowest (2.45 ppb) in (J11 x RCM387)-8-6-2 and J11 peanut, respectively.

c. **Infection and epidemiology of peanut stem rot caused by *Sclerotium rolfsii*.** The experiments were conducted at four locations--Khon Kaen Field Crops Research Center, Kalasin Field Crops Experiment Station, Mahasarakarm FCES, and Loei FCES. Data from stratified sampling plots indicated that *S. rolfsii* distributed in clump and patchy patterns. The viability percentage of sclerotia over the summer season in four field soil series--Korat (at Mahasarakarm), Yasothon (at Khon Kaen), Roi-et (at Kalasin), and Wangsaphung (at Loei)--were 79, 86, 88, and 90%, respectively (Table 1.3). On average, stem rot incidence ranged between 0.05-0.86 at the seedling stage, 0.33-3.67% during 50-60 DAE, and 1.54-20.91% at preharvest period. The average seed infection percentage was about 0.21-12.45% (Table 1.4). However, the correlation analysis between *S. rolfsii* sclerotium numbers and disease incidences over the seasons of 1990 and 1991 were as low as 0.01-0.07 and 0.12-0.24, respectively. When the analysis of variance and the mean number of sclerotia of four different sampling patterns--e.g., parallel-shaped, X- shaped, W-shaped, and H-shaped--were compared to those of the standard stratified sampling plot, it was found that the parallel-shaped sampling pattern was the most suitable pattern for Khon Kaen, Kalasin, and Mahasarakarm, while the W-shaped was suitable for Loei location (Tables 1.5- 1.8). Moreover, at Khon Kaen, Kalasin and Mahasarakarm, by average, one sclerotium/kg of soil (collected from 15 samples in 900 m^2 area) was able to give 0.05-0.29% infected plants at seedling stage, 0.18-3.46% during 50-60 DAE, and 1.58-24.33% at harvest. At Loei, however, the same sclerotium density gave 0.08-0.22% infected plants at seedling stage, 0.17-1.21% during 50-60 DAE, and 1.37-6.50% at harvest.

d. **Chemical control of peanut stem rot.** Study of chemical control of peanut stem rot caused by *S. rolfsii* were conducted at two locations in farmer fields during the dry season and one location at Khon Kaen Field Crops Research Center during the dry season. Six fungicides which were previously tested both in the laboratory and greenhouse were used in this study compared with a fungal antagonist, i.e., *Trichoderma* sp.

The results showed that all fungicides gave a better yield compared

to that of the check at the Khon Kaen Field Crops Research Center, particularly terbutrazole 250 EC, diniconazole 8 EC, carboxin 75 WP, and metalaxyl + mancozeb 72 WP (Tables 1.9-1.10). Terbutrazole 250 EC (25.80% ai) applied at 48, 58, and 68 DAE gave the best control (disease incidence = 29.5%) and low percentage of seed and pod infection by *S. rolfsii* were observed. The mixture of carboxin and thiram 200 at the rate of 80.8 g/rai (ai) and dinionazole 8 EC at the rate of 25.8 ml/rai (ai) sprayed at the soil line three times were also effective.

2. **Khon Kaen University.** Studies on virus diseases were the main research topics for KKU in 1991-92. These viruses included peanut stripe (PStV), peanut mottle (PMV) and groundnut bud necrosis (GBNV). Collection on various peanut yellow spot virus-symptom variants (PYSV) were also attempted for further investigation. Apart from the research activities, a considerable effort has been made in re-establishing the project since the brief leave of the principal investigator during 1990 to early 1991 had brought all activities to a complete stop. The following main topics were carried out this year.

a. **Biology of the Thai isolates of groundnut bud necrosis virus: A preliminary study.** Although groundnut bud necrosis disease (GBND) has been detected in Thailand as early as 1989 (Wongkaew, 1985), very little has been done on its etiology. From the annual disease surveys carried out regularly in both wet and dry seasons, it is noted that the disease incidences have been increasing at an exponential rate, especially during the dry season. It is expected that the disease could become a major constraint to peanut production in Thailand as it has already been to some parts of the Indian sub-continent. Although proper control measures are available, they will be fully effective only if the causal agent is similar to that which is epidemic in India. This study is conducted to compare the similarity among the Thai GBNV isolates and other tomato spotted wilt virus (TSWV) isolate to the Indian isolate.

Various isolates of GBNV were collected from dry season peanut grown in Nong Kai, Kalasin, Mahasarakam, Roi-et and Khon Kaen. They were sub- divided into two groups of symptom variants, mild and severe isolates. The mild variants (GBNV-M) did not induce bud necrosis but caused oak-leaf typical of GBNV symptoms. The severe variants (GVNV-S) gave typical symptoms as described by Reddy et al. (1991). All isolates were serologically tested to have positive reaction with the antiserum against the Indian isolate (kindly contributed by D. V. R. Reddy, ICRISAT). DAC ELISA using anti-Fc phosphatase conjugate (also from D. V. R. Reddy) as a secondary antiserum was employed with the same protocol as described by Reddy et al. (1991). Two isolates representing one from each group were finally selected and propagated in peanut after passing through single lesion isolation in *Petunia hybrida*. These isolates along with TSWV isolate from pepper (*Capsicum fruitescens*) were manually inoculated to a set of host plants to compare their host reaction. The neutral 0.05 M phosphate buffer with 0.2% 2- mercaptoethanol and 1% celite was used as the inoculation buffer throughout the study. The thermal inactivation point of the isolates was also investigated using the standard method (Reddy et al., 1991).

Both mild and severe GVNV variants gave positive reaction with anti-GBNV Indian isolate but negatively reacted with anti-TSWV. Host responses to the two isolates were almost identical to those caused by the Indian isolate. In general, the host reactions to the GBNV isolates were considerably similar to those caused by TSWV-P except that the latter gave a systemic necrosis symptom on inoculated *P*

hybrida. Only local necrotic lesions were developed on petunia inoculated with GBNV. TSWV-P also failed to systemically infect peanut. Both GBNV and TSWV-P had lower than 50°C thermal inactivation point (TIP).

From the results, it could be concluded that the causal agent of BND in Thai peanut is a similar virus to that found in India. The mild variant, although, did not cause bud necrosis; its positive reaction to GBNV antiserum and some other common host reaction to those of GBNV indicate that it could be a symptom variant of GBNV. With the increasing incidence and severity observed in recent years, it could be predicted that this virus may become a threat to the peanut production in the dry season as having been experienced in India. Effective control measures are evidently needed before the epidemic can reach that scale.

b. **Preliminary trial on bud necrosis disease resistance.** In responding to the increase in bud necrosis problems and its economic importance, concentration has been made to find an effective control measure that is applicable under the Thai environment. Although chemicals and some special cultural practices are considerably effective in controlling the disease, the application either needs more input or is not fit to the local cropping system. Employing resistant cultivars is perhaps the most suitable mode that can be readily adopted by the farmers. Its success in controlling bud necrosis in peanut has been demonstrated in India. In early 1992, we set up a preliminary trial to evaluate some selected lines from ICRISAT that have been tested to be BND-resistant. Working on this trial was in cooperation with Ms. Buiel from ICRISAT.

Fifteen lines were planted at two locations, Ban toob, Mahasarakam and KKU. The BND incidences assessed in these areas were 10-15% during the past dry season. Seeds were sown double row with 20 x 60 cm spacing in a 4-m row. Between each two rows of test entries, a row of JL-24 (Ban toob) of Tainan 9 (KKU) was planted to act as a disease spreader. The experiment laid out was in randomized complete block design with four replications. Standard cultural practices were applied to the plants but with minimum insecticide spray. Bud necrosis incidences were recorded at 60 days after planting. The trial at Ban toob commenced on February 14 and the one at KKU started on February 27, 1992.

Plants in the trial at Ban toob performed very badly. They were hit by severe drought and infested heavily by leaf miners (*Aproaerema modicells*). The damage was so severe that it hindered the expression of bud necrosis and some other diseases. The trial at KKU was less affected but the drought and high temperature (39-42 C) during the first 2 weeks of growth appeared to decrease the number of BND thrips vector drastically. As a consequence, very low BND incidence was observed in all entries. However, the adverse conditions neither affected the thrips vector of peanut yellow spot virus (PYSV), a GBNV-related virus nor the aphids. It is interesting to note that under both Ban toob and KKU conditions, line ICGV 86031 was less affected by leaf miner. This performance stood clearly at Ban toob where most of the plants lost all their leaves, but line ICGV 86031 appeared almost normal. The high incidences and levels of severity of peanut yellow spot disease observed in most entries implied that the nature of PYSV resistance and GBNV may not be related except in lines INGV 86430 and 2192-6 (65) where both incidences and severities of yellow spot were rather low.

The failure of these two trials to develop bud necrosis disease probably arose from the plants being sown too late in the season. It was noted that peanut planted 1.5 month earlier had as high as 20% BND incidence. Although this failure affects the experiment, it does indicate that by adjusting planting date, BND could be avoided. We expect to repeat the study in the next dry season.

c. **Microscopic differentiation between peanut tissues affected with different viruses or some other causes.** Although by carefully examining the symptoms of diseased peanut, an experienced observer probably could tell of the causal agent(s) with great accuracy, this may not be applicable when one is examining a virus disease. From our experience in working with four different viruses--peanut mottle, peanut stripe, bud necrosis and peanut yellow spot--very often we have to look at the label to be certain of the causes of the infected plants. In the field, it is even more confusing because not only viruses that can cause chlorosis, mottling or necrosis, other agents such as insects, chemical injuries or genetic aberration can induce symptoms very similar to virus infection as well. There are various methods used for virus disease diagnosis such as indexing on differentiate hosts, serological assay or electron-microscopic examination, but these methods either are time-consuming or could be done only in well equipped labs. From our experience, microscopic examination of the affected tissue with a light microscope for inclusion bodies was equally effective in identifying the cause(s). At the early stage, the technique and stain combinations as described by Christie and Edwardson (1986) was employed. The technique, although working very well, the use of stain combination made it more troublesome. In our lab we tried toluidine blue 0 in phosphate buffer as a single stain and it worked equally well. In this report, a comparison of peanut tissues infected with different viruses was made using the single stain. Abnormal tissues by other causes were also compared. Each of four viruses was manually inoculated to 10 Tainan 9 peanut (*A. hypogaea*) at the 2- leaf stage. The four viruses were peanut mottle virus (PMV), peanut stripe virus (PStV) (chlorotic ring, blotch and necrotic isolates), peanut yellow spot and groundnut bud necrosis (mild isolate). At 20 days after inoculation, the third fully expanded quadrifoliolate with symptoms was harvested and examined for virus inclusion bodies or other cytological abnormalities using the techniques as described by Christie and Edwardson (1986), except 0.1% toluidine blue 0 in 0.5 M phosphate buffer pH 6.4 was used instead of stain combinations. Epidermal strips of the lower leaf surface were used in all cases. After 1 minute of floating on 2.5% Triton x aqueous solution, the strips were transferred onto distilled water for 1 minute. Subsequently, they were stained by floating on the stain solution for 15-30 seconds before being covered with a glass slip. Four to five strips were examined at 400 x or 1000 x for each virus isolate using a light microscope. Epidermal strips from leaves with jassid damage, thrips injuries, genetic aberration and virus field-infected plants were also examined to verify the accuracy of the technique as a diagnostic tool. All leaf tissues examined were subsequently assayed for the virus identity using direct antigen coation indirect anti Fc immunosorbant assay (DAC ELISA).

When examining with 400 x, the inclusion bodies typical of potyvirus group were seen in 50-80% of cells inoculated with PMV and all PStV isolates. The inclusion bodies stained light blue as contrasted to the adjacent nucleus which was dark blue with a prominent purplish nucleolus. Shapes of the inclusion bodies could not be differentiated at this magnification. But at 1000 x the inclusion bodies of PMV looked less granular and retained a spherical or oval

shape, while those of PStV isolates appeared very granular or needle-like. The shape of their inclusion bodies was slightly different, ranging from oval to spindle forms. No inclusion bodies were detected in healthy tissues or those infected by PYSV or GBNV, and neither were they detected in abnormal tissues by other causes. Strips from a number of samples taken as healthy by the samplers contained inclusion bodies of PStV type. These samples gave positive reaction with a PStV antiserum when assayed by DAC ELISA. In contrast, strips from leaves with virus-like symptom (as assumed by the samplers) did not contain any inclusion bodies. The serological assay of these tissues always gave a negative reaction. The strips from GBNV- and PYSV-infected leaves, although not containing inclusion bodies, showed abnormal cells. The nuclei of the cells were larger and always had a large number of plastids surrounding them.

Results from this observation indicate that the microscopic examination of the epidermal tissues for inclusion bodies or cytological abnormality can be used in differentiation of the causal agent of a certain level. With little experience, PMV and PStV can be differentiated. Four out of five students could see the difference at 1000 x. Although not yielding the contrast as good as stain combinations, the simplicity of preparation in using Toluidine blue 0 made it a better choice. Neither did its use require methyl cellusolve which is inflammable and has an offensive smell.

d. **Virus disease survey in dry season peanut.** It is a routine activity to make surveys in peanut-growing areas annually in order to monitor the epidemic of common diseases and occurrence of the new ones. In 1991,m intensive surveys could be done only for the dry season crop starting in late November 1991 and ending in May 1992. Altogether, 120 fields in seven provinces were visited. The size of each field varied from smallest (0.30 ha) to biggest (1 ha). Most crops were irrigated with a furrow system except in research stations in which the sprinkler system was used. An exception was also noted at Nongkai in which the crops were grown along the Mae Khong River bank. In this area, the crops were irrigated with water pumped out from the river. The purposes of planting varied from being used as a second crop for cash earning to being used as a seed stock for the next season. Some of the farmers were contracted members of the seed production scheme run by the DOA. In general, 10% of the plant population in each field was checked for disease incidence and severity, and within that population 5-10 samples were collected and further examined in the laboratory. Microscopic examination, assay host indexing and serological tests are the main procedures used for disease diagnosis. Among virus diseases, bud necrosis (BND) was the most prevalent, especially during late December to early February with incidences of 10-20% common in most fields and few fields showing up to 70% infected plants. Once the rain began regularly in early March, the BND started to disappear and was replaced by peanut yellow spot (PYSV) in most fields and peanut stripe (PStV) in some fields. The disease caused by peanut mottle virus (PMV) was rarely found. In fact, it was detected in only two samples among 480 showing mottling symptoms and most of those were PStV-infected. Among the mottling samples, new symptom variants were also noted, especially in the areas where tomato and sweet pepper were grown as the main crops. The mottling symptoms on peanut were so mild that they could go unnoticed on young leaves. On older leaves, the symptoms appeared as a mixture of oak-leaf type and mild mottling. The oak-leaf pattern was unusual in that only the edge of the oak leaf was darker green, whereas the remaining areas had normal green color. It is expected that this could be a new virus which has

solanaceous crops as a common host. A similar virus was isolated from to tomato showing mottling and etching symptoms. This virus reacted positively with anti-PStV and pepper mottle virus (PeMV). Infected peanut tissue by the virus also produced inclusion bodies typical of potyviruses. Apart from this virus, tomatoes and peppers grown in these areas were heavily infected by groundnut bud necrosis virus (GBNDV). In tomato, the plants were stunted and had mottled leaves which subsequently turned purple (anthocyanosis). Fruits from these plants bore no seeds. In sweet pepper, the plants were slightly stunted. Chlorotic ring spots or line patterns were the most distinctive symptoms for GBNDV- infected peppers. Seeds from these plants were few and malformed or discolored.

From the results, it indicates that BND could be a major threat for peanut production in the dry season. Its increasing trend has been noted and this year proved to be one of the worse. This may be due to the complete shortage of rain during the past dry season. Normally it should rain two or three times during that period. The dry condition is favorable for thrips, the BND vector multiplication and spread. The BND did not only affect the peanut but also the more valuable crops, tomato and sweet pepper. Farmers normally earn 10 times more from the same acreage of tomato or pepper than that from peanut. These solanaceous crops were grown to produce hybrid seeds. Therefore, the effective control of BND not only saves the peanut production but also the farmers biggest earnings from solanaceous seed production. An attempt is also needed on further characterization of the new potyvirus found on peanut. No doubt the virus is closely related to PStV, but because of its distinctive symptoms and ability to infect both tomato and sweet pepper it is less likely to be a variant of PStV.

e. **A revised study on peanut mottle virus.** Before PStV was fully characterized and reported in 1984 (Demski et al., 1984), most pathologists were likely to assume that any virus causing mosaic or mottling type symptoms on peanut were only an isolate of peanut mottle virus. There was no exception in Thailand; most of the reports before 1984 identified or called any viruses "PMV" if they caused such type of symptom on peanut (Choopunya, 1973; Poolpol, 1979). It was proposed that studies on PMV should be reconducted to obtain reliable information for future research (Wongkaew, 1990). An investigation commenced in late 1991 was aimed to reach such objectives. The project was undertaken as part of an M.Sc. thesis for a postgrad student in the Department of Plant Pathology, KKU. The work is presently underway and the results have not been fully analyzed so only a brief summary is reported.

After an extensive survey of many peanut fields starting from the end of the wet season crop of 1990 until the onset of the dry season crop, only two samples of peanut leaves out of a few hundred were indexed to contain PMV. From these samples, only one was collected from Ubon Rachathani in which PMV could be isolated. After being passed through the standard single lesion isolation in Top crop bean (*Phaseolus vulgaris* Top crop), the virus subsequently has been maintained in Tainan 9 peanut. In brief, the isolate possesses all common properties of PMV except that it is more difficult to purify than those that have been reported. Various methods of purification have been tried including the one that has been routinely used at ICRISAT (1989). The viruses yielded from these procedures were too small, and eventually one of the old procedures used by Payuio and Kuhn (1973) was tried and proved to be the most successful compared to the others. At least 0.5-1 mg of virus preparation could be obtained from 100 g of infected leaves. Full details of this study

including the virus characterization and its epidemiology will be given in the next report.

Philippines

A. **Germplasm collection and evaluation for desired genetic traits.** A total of 128 new accessions were acquired for the year. Seven accessions from France which showed shade tolerance were evaluated in preliminary yield trial under artificial partial shade condition. Two boiling types from Thailand were included in the yield trial for boiling type of peanut. The other entries were planted for initial seed increase and preliminary screening for yield and disease resistance. Fifteen accessions were identified to be resistant to late Cercospora leafspot and rust.

B. **Hybridization and selection for higher yields, large seededness and resistance to major peanut diseases (rust and late Cercospora leafspot).** Six- by-six complete diallel crosses were done to measure the magnitude of general combining ability (GCA) and specific combining ability (SCA) mean squares and effects for yield, pod number per plant, pod length and dry matter content. Both GCA and SCA mean squares were significant for pod number and dry matter yield. This finding suggests the importance of both additive and nonadditive gene action in the inheritance of these traits. Only SCA was significant for both pod and seed yields. Reciprocal effects were not significant for all the traits except dry matter yield. NC Ac 17090 had the highest GCA estimate for both pod and seed yields, suggesting it is a good parent for yield improvement. Another set of 6x6 complete diallel crosses for inheritance on shade tolerance were initiated using shade-tolerant and intolerant entries. Forty-six breeding populations (F_3, F_4 and F_5 generations) were planted. A total of 258 plant selections were planted for initial seed increase and further evaluation.

Individual plant selections of 447 breeding lines selected for large seededness, and resistance to both rust and late Cercospora leafspot foliar diseases were evaluated in observational nurseries. A total of 117 lines were reselected for large seededness and resistance to rust and late Cercospora leafspot. These were included in the preliminary yield trials across two locations.

C. **Screening and confirmatory tests for disease resistance.** Four out of 25 entries in the general yield trial were rust-resistant, including IPB Pn 85 21-25, IPB Pn 27-28, IPB Pn 85 50-51 and IPB Pn 86 20-28.

Fifteen entries were re-evaluated using dry seed resistance test. The data showed that 11 genotypes were resistant to *Aspergillus flavus* invasion, including GFA x NC 8C, AR-1 x Tainan 9, UPL Pn 4, Sunbelt Runner x NC 8C, UF 71513 x Tainan 9, IPB Pn 82 71-19, UL-24, Faizpur x Tainan 9, AH 7223 x SK-38, PI 337409 x Tainan 9 and J 11.

D. **Yield testing and seed production of promising peanut entries at three locations.** A total of 81 entries were evaluated for yield in the preliminary yield tests at three locations for both dry and wet seasons. The top 25 promising entries were selected based on seed yield and size for inclusion in the general yield trial.

Twenty-five entries including UPL Pn 8 (check variety) were evaluated in the general yield tests at three locations for both cropping seasons. Seven promising entries were selected for inclusion in the advanced yield trial, including IPB Pn 85 21-26, IPB Pn 86 20-6, IPB Pn 86 20-21, IPB Pn 86 20-40, IPB Pn 86 20-47, IPB Pn 86 34-3 and IPB Pn 86 34-28. The advanced yield trial which is composed of 16 entries conducted at

UPLB showed that six entries outyielded UPL Pn 8 (check variety).

E. Screening peanut for tolerance to acidic soil conditions. The objectives of the study are twofold: (1) to select acid-tolerant genotypes capable of producing higher yields than intolerant entries and (2) to evaluate acid-tolerant lines at increased aluminum levels in acidic soils.

The potentially acid-tolerant selections were evaluated on aluminum-treated plots at two soil types and locations in Laguna (e.g., acidic Lipa clay loam soil at Los BaÑos, Laguna and acidic Antipolo clay at Siniloan, Laguna). The problems associated with the Lipa clay loam soil treated with 540 ppm Al were: pH of 4.16, exchangeable Al of 5.60 meq/100 g and solution Al of 2.25 ppm. On the other hand, the problems associated with Antipolo clay treated with 120 ppm of Al treatment were: low pH (4.04), low amounts of K (0.29 meq/100 g), Ca (0.86 meq/100 g) and Mg (0.58 meq/100 g), high exchangeable Al (4.16 meq/100 g) and high solution Al (9.17 ppm). Problems on P and basic nutrients were corrected through fertilization based on the soil test values.

Selections on an extremely acidic Lipa clay loam treated with 540 ppm Al include IPB Pn 82 70-44 and IPB Pn 82 70-15 with seed yields of 552 and 451 kg/ha, respectively, and absolute yields of 80.05 and 79.54%, respectively. One entry (IPB Pn 82 68-77) showed high tolerance to aluminum and extreme acidity but it gave low yields under normal growing conditions or at zero level of aluminum. There was a 35% yield reduction of peanut entries grown in soils treated with 540 ppm Al.

For acidic Antipolo clay soil, IPB Pn 82 68-87 was the top yielder during the 1991 wet season on all treatments (control, 7 tons lime/ha and 120 ppm Al). It also showed a relative yield of 76% which is moderately resistant to high Al and extreme acidity. The other high yielding entries under 120 ppm Al treatment are IPB Pn 82 70-44, IPB Pn 82 70-64 and IPB Pn 82 71-50. They also showed moderate resistance to high Al and extreme acidity. Addition of 120 ppm Al resulted in the mean decrease of yield by 30% as compared to the control. Furthermore, IPB Pn 82 70-44 is the best yielder at Los BaÑos, Laguna.

F. Growth and aluminum concentration of selected peanut cultivars as affected by different levels of aluminum on Antipolo clay. Fifteen selected acid-tolerant peanut genotypes were evaluated in a greenhouse tray experiment. A general decline in the length and weight of shoots and roots were observed with increasing levels of aluminum. The concentration of aluminum in the shoots and roots of peanut genotypes grown in Al-treated soils suggests one possible mechanism for tolerance to acidity. Also, it helps in selection of acid-tolerant entries and application of appropriate soil management practices for sustained crop productivity.

The high yielders in the field tests like IPB Pn 82 70-44 and IPB Pn 82 70-15 showed high levels of Al but this did not show in the concentration of Al in the shoots. This suggests that the plant roots take high amounts of Al in the roots but does not transport Al to the shoots or upper plant parts. It seems that Al just stays in the root and it is being blocked from entering or transferring to other plant parts in the translocation system.

orth Carolina

A. Breeding

1. Intensive selection 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. Six breeding lines with high yield and/or large seed size were crossed as females to four lines resistant to CBR (NC Ac 18016, NC Ac18485, N90020, and N90021). F_1 hybrids were grown in a winter nursery at the Tropical Agriculture Research Station at Mayaguez, Puerto Rico, and F_2 populations planted at a CBR-infested site in Martin County, N.C., for selection of resistant plants.

b. 19 F_2 populations from a 1990 factorial mating of five sources of resistance to CBR (NC 3033, NC 8C, NC Ac 18469, and NC Ac 18483) with four breeding lines with superior seed attributes and high yield were screened for resistance in a naturally infested field in Martin County, NC. 112 selected $F_{2:3}$ families were sent to the winter nursery in Puerto Rico for increase. $F_{2:4}$ families were planted at the infested site in May 1992 for another cycle of selection of resistant plants.

c. Selection for resistance and pod attributes was practiced among and within $F_{2:4}$ families selected during the 1990 growing season and grown on infested soil in 1991. 188 F4:5 families were planted in a completely random design with up to 5 reps per entry at the CBR-infested site in 1992. A seed increase of all families was planted on uninfested soil at the NCDA Peanut Belt Research Station at Lewiston, N.C., to produce sufficient seed of selected families for performance testing at Lewiston and CBR resistance testing at Martin County in 1993.

d. 39 $F_{4:6}$ families were evaluated in a completely random design with up to 5 reps per entry at the CBR-infested site in 1991. 16 had significantly fewer dead and diseased plants than NC 10C, the only CBR-resistant cultivar available to peanut growers, and did not have significantly more infection than NC Ac 18016, the resistant check. An additional four lines were not significantly different from either NC 10C or NC Ac 18016. In 1992, these 20 $F_{4:7}$ were planted at Lewiston for evaluation of yield and market grade and at Martin County for a second evaluation of CBR resistance.

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

a. Eighty-seven F_5-derived lines from a diallel mating among parents resistant to early leafspot and 119 F_4-derived lines from a factorial mating of virginia cultivars and breeding lines with sources of resistance will be evaluated for defoliation. Resistant lines will be tested in a replicated test in the 1992 growing season.

b. Thirty-five F_4-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 two sites, Lewiston and the Upper Coastal Plains Research Station at Rocky Mount, N.C., in the 1991 growing season. Disease pressure was intense at Lewiston with complete defoliation and 84% reduction of yield of the susceptible check, NC 7. Seven families had significantly less defoliation than the most resistant checks, GP-NC 343 and NC 3033. Five more were better than the checks although not significantly so, and eighteen were not significantly higher. Families combining acceptable levels both of resistance and agronomic performance were planted in the greenhouse for intermating to produce the third cycle of recombination. Selections were planted in the advanced leafspot

resistance test and in the advanced yield test as a part of the normal variety development stream in 1992. Seed from these families was inadequate to allow for testing by Dr. Beute for evaluation of the mechanism of resistance in the 1992 growing season.

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

   a. F_2 populations have been developed from crosses of virginia cultivars (NC 7, NC 9, NC 10C, NC-V 11, and VA-C 92R) with F435, a spanish line with an extremely high ratio of oleic to linoleic acid in the fatty acid profile of the oil. Populations were grown by single-seed descent at the winter nursery in Puerto Rico and in the field in 1992 to increase the frequency of plants exhibiting the high O/L trait from 1/16 to 49/256.

      High O/L selections were backcrossed to their respective virginia parents in the summer of 1991, and the BC_1F_1 plants were grown in the greenhouse in the winter of 1991-92 to produce the BC_1F_2 generation for a second round of O/L screening.

   b. 156 $F_{5:6}$ families from crosses of virginia cultivars in current use with sources of high O/L ration were increased in the 1991 growing season. 61 were selected for pod and seed attributes and planted for evaluation of agronomic performance in the 1992 growing season.

   c. 35 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. 26 families were not significantly lower yielding than NC 7 at the early digging. Only five were lower yielding than Va 81B, the early check. Nine families had meat content higher than the highest check, indicating earlier maturity. On the basis of their performance when dug at a conventional date, tn families were advanced to the 1992 Advanced Yield Test as part of the normal cultivar development procedure. Twelve were retained in the Early Maturity Test for 1992, and four were sent forward to the cooperative test of early-maturing lines conducted by the Virginia Agricultural Experiment Station and the N.C. Agricultural Research Service.

      An additional 87 $F_{5:8}$ families from the cross of NC 7 / NC 9 were be tested at early and late digging dates in a preliminary test at Lewiston. This population was developed using a hierarchical selfing procedure that will allow the estimation of genetic variances. The families were planted for a second year at Lewiston to obtain information on genotype-environment interaction. Thirteen of these lines were forwarded to the Early Maturity Advanced Test and 31 to the Advanced Yield Test.

4. **Recurrent selection for resistance to *Aspergillus* species.** F_2-derived families previously identified as exhibiting one or more mechanisms of resistance to *A. parasiticus* were intermated in the summer of 1991. F_2 progeny will be produced in the greenhouse and F_2 populations are grown in the field in 1992 for evaluation of resistance to dry-seed infection and aflatoxin production.

5. **Incorporation of pest resistance from wild species into *A. hypogaea*.** Tetraploid lines developed by Dr. Stalker from crosses of *A. hypogaea* PI 261942-3 with *A. cardenasii* 10017 were crossed with six high-yielding or large-seeded lines currently in the advanced stages of performance

testing. These lines included some resistant to leafspots and some with resistance to nematodes and insect pests. F_1 plants were increased at the winter nursery in Puerto Rico during the winter of 1991-92, and F_2 populations were planted in the field at Lewiston for selection of single plants or for single-seed descent.

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

   a. $S_{1:2}$ families from the 100 crosses of the fifth cycle (C_5) of recurrent selection were increased in the 1991 growing season for evaluation of yield in replicated tests at Lewiston and Rocky Mount in the 1992 season.

   b. 63 $F_{5:7}$ families from the fourth cycle (C_4) of the recurrent selection program were evaluated in a preliminary performance test at a single site. Nine families were selected for inclusion in the 1992 Advanced Yield Test as part of the cultivar development procedure.

7. **Evaluation of insect-resistant lines from W.V. Campbell's program.** 215 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 to be 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*), and for yield and agronomic value in a field without chemical control of insects. Germination of the lines was so poor in the 1991 season that there was insufficient canopy development to attain normal insect activity. These plots were abandoned as far as data collection was concerned and used as seed increase plots. Five lines were lost entirely due to poor germination.

The 210 surviving lines were planted at Lewiston in May, 1992. Thrips and leafhopper damage were rated before the end of the 1992 CRSP fiscal year. One USDA plant introduction (PI 269099, identified as "Ndoba NCR4" from the Mount Makulu Research Station in former Rhodesia) and three lines obtained from ICRISAT (FESR 03-P13-B2-P2-B2-B1-B1-B2, Mani Pintar // Robut 33-1 / NC Ac 02232, and NC Ac 02750 / PI 259747, F2-B2-B1-B2-B1) had less than 5% thrips damage. A number of lines (including Tachimasari, NC Ac 02230, GP-NC 343, and selections from NC 6 / NC 3033) exhibited very little damage from leafhopper.

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 will be harvested from the plots at NCSU. Lines with superior resistance to one or more pests but lacking commercially acceptable yield, seed or pod characteristics will be crossed with agronomically superior lines in the 1993 growing season.

B. Disease Resistance Research

1. **Nematodes.**

   a. Single populations of *M. arenaria* race 1 (MA1) and *M. hapla* (MH) and two mixed populations of the two nematode species were used in a field microplot study to characterize the interactions on infection competition and reproductive potential on resistant and susceptible peanut genotypes (Florigiant - MA1 susceptible, MH resistant; NC 7 - MA1 resistant, MH susceptible; NC 6 - MA1, MH resistant; NC Ac 18416 - MA1, MH resistant; and NC Ac 18016 - MA1/MH susceptible). The experiment was arranged in split-plot design with nematode

populations as main plot and peanut genotypes as subplot, was six replicates. At mid-season the soil juveniles of MA1 and MH in single populations were about the same densities; and were about half of those in the mixed populations. MH induced less root galls and produced fewer eggs, whereas mixed populations produced the highest egg numbers. There was no difference in egg-mass production by each population either single or mixed using soil assay with watermelon, a differential host, on which MH does not induce root galling and reproduce; there was evidence of predominance of MA 1 to MH in soil. More nematodes penetrated peanut roots in mixed-population plots than in single-population plots. Total number of MA1 and MH in root were not different, but MA1 had more parasitic stages (parasitic juveniles and adults). Assay of single egg mass to determine the proportion of adult females of each species in root from mixed population plots indicates that MA1 was present about 56.8 to 67%. At harvest the soil juvenile populations of MH increased at the greatest rate to reach levels close to those of MA1 and the mixture, but MH did not produce as many eggs, root galling and necrosis, or penetrate root as much as other populations. However, MH produced more egg masses than the other population.

During mid-season there was almost no significant difference in response of different peanut genotypes to different nematode populations. In general, Florigiant, NC 7, and NC 6 induced more soil juveniles, root galls and root penetration than the other genotypes although MH produced the least eggs on Florigiant. NC Ac 18016 had the fewest nematodes in its roots. In mixed populations, proportions of MA1 females in root of Florigiant, NC Ac 18016, NC 7, NC 6 and NC Ac 18416 were 75.3%, 65.8%, 62.3%, 57.1% and 48.8%, respectively. At harvest the juvenile population in NC Ac 18016 had a great increase, but resulting root and pod galling and necrosis and root penetration were lower than those in Florigiant. The estimation of MA1 females in mixed population in roots of Florigiant, NC Ac 18016, NC 6, NC Ac 18416 and NC 7 were 72.3%, 70.0%, 63.3%, 59.2% and 46.7%, respectively. The ranks of NC 7, NC 6 and NC Ac 18416 differ from the mid-season estimation. This difference may reflect the prevalence of MA1 on MA1-susceptible peanut (either resistant or susceptible to MH; Florigiant or NC Ac 18016, respectively), and the decrease in prevalence of MA1 on MA1-resistant peanut (either resistant or susceptible to MH).

b. Single populations of *M. arenaria* race 1 (MA1) and race 2 (MA2) and 1:1 mixed populations of the two races were tested on peanut susceptible to MA1 (Florigiant) and two tobacco cultivars resistant (TR, McNair 373) and susceptible (TS, Coker 371-Gold) to *M. incognita* in microplots. The objective was to characterize the interactions on infection competition and reproductive potential and to elucidate the population dynamics of each population in the mixed population in peanut-tobacco rotation. Mid-season soil juvenile data show that in single population plots, population of MA1 was very low on resistant tobacco (TR) and population of MA2 was very low on peanut. In the mixed population plots population levels of mixtures on each crop were close to the greater single population (MA1 for peanut and MA2 for both tobacco cultivars). Data on numbers of galls, egg mass, eggs and nematodes in root per gram of root follow the soil nematode populations. Resistant tobacco showed resistance to MA1 only. Responses of both resistant and susceptible tobacco cultivars to MA2 and combination of MA1 and MA2 were similar. At harvest, the soil juvenile populations of the single populations increased proportionally from mid-season populations. Population of the mixture was apparently higher than those in mid-season, except for peanut. Numbers of eggs left in soil had a similar pattern to soil

juvenile populations. Mixed population caused greater damage to tobacco, but not to peanut. Interactions between both races of M. arenaria in mixed population also was investigated by bioassaying microplot soil and single egg mass from tobacco using peanut on which MA2 produces no galls. The tobacco soil assay showed the dominance of MA2 (normally inducing root necrosis on peanut) in mixed population which suppressed root-gall induction and egg mass production of MA1, and causing root necrosis greater than MA1 alone. Using single egg-mass assay to determine the proportion of adult females of each population in mixed populations, the population of MA1 was also suppressed by MA2.

c. Twelve peanut genotypes were evaluated for resistance to *M. arenaria* in microplots. The genotypes included cultivated and wild *Arachis* species, and five lines derived from interspecific crosses. Genotypes were planted in fumigated microplots and inoculated with nematode eggs. Populations of nematodes in soil were determined at mid-season and again at harvest. Pods and roots were rated for nematode damage at harvest. Roots were weighted and a 10 g sample was taken for nematode extraction. The two wild species and one of the lines from an interspecific cross appeared to segregate for nematode resistance. With these exceptions, the wild species and four of the crosses were much more resistant than the cultivated checks, although none were immune. Resistant lines had 74 to 5 .6% fewer nematode eggs/10 g roots than the mean for the susceptible checks, and 90 to 99.9% fewer eggs on a total root system basis. Soil population differences were of similar magnitude.

2. **Sclerotinia Blight (*Sclerotinia minor*).**

a. Stem extracts from 5 peanut genotypes exhibiting a range of resistance to *S. minor* were tested using cellophane-covered peanut agar media to determine their influence on hyphal size and clustering of infection hyphae. The effect of nutrient status on differential development and organization of infection hyphae was also determined using three concentrations of cellophane-covered PDA media. Extracts from the different genotypes affected terminal and secondary cell size as well as number of hyphae per organized cluster. The effect of nutrient status of the medium also produced significant differences in the number of hyphae per organized cluster and terminal hyphal cell size, but not size of secondary hyphal cells.

b. Two in vitro tests were used to evaluate different levels of resistance to *S. minor* in detached limbs of nine peanut genotypes. The first test utilized wound inoculation to assay for internal metabolic resistance. The second technique utilized non-wound inoculation and reflected the plant's ability to inhibit penetration as well as internal lesion expansion. Results of in vitro tests were then compared with field disease levels to determine if in vitro tests are predictive of in vivo results. Genotype performance in the two in vitro tests did not correlate with the disease levels in the field; several genotypes had low disease incidence in field tests even though metabolic resistance was not detected in vitro.

c. Field studies were conducted over the 1990 and 1991 growing seasons in four row plots 8.5 m in length to determine the role of plant morphology, as well as metabolic and physiological resistance, in the expression of field resistance. The first study, conducted in *S. minor* infested portions of the field involved measuring, at 14 d intervals, the intact canopy height and width, limb number and length (in a 2-cm zone above the soil surface), and number of pegs in a 0.5 m row section. The second study (destructive sampling) was

established in uninfested portion of the field to characterize total plant canopy. Canopy height and width were measured on site and a 0.5 m section of row was removed to measure leaf area, leaflet number, limb length and number, and sample dry weight. Plant morphology and field disease levels were moderately correlated (r = 0.41 to 0.52) for limb number, limb length and canopy width. Canopy height was also significant (r = -0.26) under high disease pressure in 1991. Coefficients of correlation ranged from 0.54 to 0.67 for canopy width, total limb length, limb number, leaflet number, and sample dry weight for the destructive samples. Plant height and leaf area were correlated with disease incidence under high disease pressure in 1991 (r = -.044 and 0.46, respectively). Current evidence indicates that moderate levels of metabolic and physiological resistance now available to breeders will not be adequate for disease control if environmental conditions (climate, plant growth habit) are conducive for infection and disease development. Future genotype selection procedures must consider the role of plant phenotype in addition to metabolic and physiological resistance responses.

d. Sixteen peanut genotypes were planted in disease nurseries for *Sclerotium rolfsii* and *Sclerotinia minor*. A duplicate test also was planted in a grower field infested with *Cylindrocladium crotalariae*. Counts of symptomatic plants were taken in each field. Genotypes varied significantly in response to all three pathogens. Ranks of genotypes by disease incidence were significantly correlated, with Spearman coefficients that ranged from .52 for stem rot with CBR, to .69 with CBR and Sclerotinia blight. Either similar mechanisms of resistance operate for the three pathogens or resistance to stem pathogens was inadvertently selected during selection for resistance to CBR.

3. **Leafspots (*Cercospora arachidicola* and *Phaeoisariopsis personatum*).**

a. Eleven genotypes derived from crosses between *Arachis cardenasii* and virginia peanut were evaluated in the field for resistance to Cercospora leafspots. NC 6, NC 7, Southern Runner and GP-NC 343 were included as checks. Areas under the disease progress curves for early leafspot (AUC-E), late leafspot (AUC-L), defoliation (AUC-D), and total disease (AUC-T) were used to compare genotypes. All test genotypes had smaller AUC-Es than the most resistant check, GP-NC 343 and five lines had AUCs that were less than half that of GP-NC 343. Seven of the test genotypes had AUC-Ls that were not different from the highly resistant control, Southern Runner, and all had less late leafspot than NC 6 and NC 7. All genotypes had significantly less total disease the most resistant check. Although ranks of genotype by AUC-E and AUC-L were only weakly correlated ($r=.27$, $P \leq .01$), some genotypes combined resistance to leafspots and defoliation far superior to that in commercial cultivars.

b. A phytotron experiment was conducted to determine if high daytime temperatures affect *C. arachidicola* and *P. personatum* differentially. Sporulation of both pathogens was inhibited at day/night temperatures of 36/22, and at constant 32 C. In contrast, lesions of both pathogens sporulated well at temperature cycles of 32/22 C or lower. Susceptibility in four genotypes varied somewhat with temperature. Infection by both pathogens was inhibited at constant 32 C, but not when daytime temperature only was high. Results of these experiments do not support the hypothesis that *P. personatum* is more tolerant of high temperature than *C. arachidicola* for the processes examined.

4. **Aflatoxin (*Aspergillus* spp.)**

a. Microplots were established at the Sandhills Research Station and planted with 20 peanut genotypes in 10 randomized complete blocks. Cracked corn inoculum of *A. parasiticus* was added to plots at late bloom. Drip irrigation was discontinued after inoculum was added to create conditions favorable for preharvest infection and aflatoxin production. Plots were dug on two dates, according to maturity of the peanut genotypes. All uninjured, mature pods were picked from each plot and the entire sample was shelled by hand. Twenty seeds were removed from the samples at random for evaluation of field colonization and the remaining sample was kept for aflatoxin analysis. Genotypes differed significantly in preharvest colonization, with mean rates ranging from 18.5 to 60.5%.

b. Embryonic leaflets from peanut seeds were evaluated for biolistic DNA delivery. Transgenic callus lines can be routinely derived from embryonic leaflets sub-cultured on kanamycin-amended medium. Callus lines were demonstrated transgenic by gathering protein, biological and DNA data. Production of neomycin phosphotransferase (NPT II) was detected via a commercially available ELISA kit, and co-expression of the assayable marker, ß-glucuronidase (ß-GUS) was measured fluorometrically and histochemically. Kill curve studies demonstrated that the transgenic callus lines could tolerate levels of kanamycin up to 200 mg/L without significant reduction in growth rates, while non-transgenic control callus displayed a significant reduction in growth rate at 50 mg/L kanamycin. Polymerase chain reactions (PCR) conducted on the callus lines specifically amplified the delivered foreign sequences, while genomic Southern blot analysis demonstrated integration of these sequences within the callus lines. Integration events of the foreign DNA were estimated by the frequency of recovery of stably growing callus lines. Data generated from two genotypes UPL Pn4 and Tamnut 74 revealed a ten-fold difference in callus recovery frequencies between the two genotypes. The significant difference in recovery frequencies appears to be related to the extent of phenolic compounds produced. The data suggest that increase in phenolic compounds may negatively impact the isolation of transgenic cells.

c. Eleven fertile plants have been recovered from kanamycin selection experiments. All eleven appear to have been escapes, since protein and DNA analysis on the R_0 plants, and progeny from 5 of the 11 plants were all negative for production of the foreign proteins and presence of delivered DNA sequence. This data indicates kanamycin to be a "leaky" selection agent for recovery of plants from this explant. Methotrexate is currently being evaluated as a selection agent for this target tissue. To date, seven R_0 plants have been regenerated from methotrexate selection experiments. Five of the seven plants have been screened for presence of the foreign DNA sequence by PCR analysis. Data generated suggest that these plants are carrying the delivered DNA. However, successful transformation can not be confirmed until genomic Southern blot analysis on the R_0 plants and subsequent progeny has been conducted.

d. Culture response of 70 peanut cultivars has been measured. The objective of this genotype survey was to identify genotypes that are highly culture responsive within each of the botanical types of peanut. Data generated indicates a strong genotype effect on the regeneration frequencies from embryonic leaflets. Genotypes have been identified, within each of the botanical types, that are superior in culture performance. If embryonic leaflets demonstrate to be a useful target for successful transformation of peanut, these genotypes may expedite the breeding process by allowing foreign traits to be delivered directly into each of the diverse sub-species

of the crop.

C. Germplasm Enhancement with *Arachis* Species

1. Twenty-seven advanced interspecific hybrids were evaluated in the field for resistance to *Cercospora arachidicola*. Four of these entries were released through the N.C. Agricultural Research Service as breeding lines. The entries have both reduced numbers of lesions per leaf in field tests and reduced sporulation in detached leaf studies as compared to cultivated checks. Three of the lines are also moderately resistant to *Phaeoisariopsis personatum*. They have relatively small seeds and low yields and are not acceptable for commercial production.

2. To increase the agronomic potential of leafspot-resistant lines derived from *Arachis* species, a breeding program has been conducted to hybridize the entries described above with large-seeded cultivars grown in the NC-V production region. Selection of 76 interspecific hybrid lines derived from (*Arachis hypogaea* x *A. cardenasii*) x NC 6 or NC 5 were evaluated in the F_6 generation in replicated field tests for resistance to *C. arachidicola*. Severe disease pressure was observed during 1991, and the check cultivar NC 7 was completely defoliated by the end of the growing season. Fourteen hybrids had superior disease ratings as compared to the resistant cultivated checks, and 32 will be re-evaluated during 1992. Three replications of the interspecific hybrid derivatives grown under nonsprayed conditions were harvested for yield. Yields ranged from 532 to 2507 lb/acre as compared to ca. 300 lb/acre for NC 7. Several of the genotypes had seed sizes comparable to large-seeded Virginia market types, although the most resistant entries were smaller. Ten selections were also evaluated for disease progression to both early and late leafspots in the field. Natural infection for early leafspot was sufficient for testing, but plants were inoculated with *P. personatum*. Significant differences were found among genotypes and several of the lines appear to be promising sources of resistance to both the early and late leafspot pathogens. The results also indicated that we should be able to select lines with large seeds plus resistance to both leafspot pathogens. A crossing program was conducted to backcross 11 of the best lines with several large-seeded Virginia-type cultivars.

3. Seven advanced generation interspecific hybrids were grown in microplots in the field and evaluated for *Meloidogyne arenaria* resistance. Significant differences were found among genotypes, and several had very low incidence of gulls or eggs. Two genotypes segregated for resistance, and a greenhouse evaluation indicated that the differences are due to genetic causes. The same genotypes were grown in replicated field tests in Georgia, but due to very large coefficients of variation (exceeding 400), genotypes were not significantly better than moderately resistant checks. However, the interspecific hybrids were among the best lines in experiments, and several germplasm releases are expected from the materials. Tests will be reconducted in both North Carolina and Georgia during 1992. Five of the nematode-resistant interspecific hybrid lines were hybridized to three large-seeded cultivars and to the most resistant *A. hypogaea* genotypes. F_1 seeds will be grown to evaluate the genetics of resistance, to select lines with more favorable agronomic traits (such as larger seeds and higher yields), and to determine whether the resistance isolated in the cultivated germplasm collection can be favorably combined with resistance found in wild species of peanut.

4. Evaluations for aflatoxin were carried out in microplots by the breeding and pathology components of the project and are reported elsewhere in this report. Several lines which were suspected of having

tomato spotted wilt virus resistance were tested in the field in Georgia. However, due to low incidence of the virus, no positive results were found. The same materials are to be evaluated at other locations in 1992.

5. Ten advanced generation *A. hypogaea* interspecific hybrids were evaluated in a replicated field test for resistance to thrips, corn earworm, leafhopper and southern corn rootworm. Scoring was completed on a two week schedule from early June to mid September. Several lines are highly resistant to all pests except thrip. Re-evaluations will be made next year to confirm results, and several breeding lines are expected to be released from the program. To improve agronomic performance, the insect-resistant lines were hybridized to NC 6, NC 7 and NC 9. Progenies from 85 backcrosses were grown in the field to produce F_3 lines for progeny-row testing for insect resistances. Lines with superior agronomic characteristics, along with insect resistance will be selected from these materials. In addition, 29 diploid species in section Erectoides were evaluated in the field for resistance to thrip, corn earworm and leafhopper. A range from highly susceptible to near immunity was observed, and several entries should be useful for future breeding programs if incompatibility barriers between the species and the cultivated peanut can be overcome.

6. More than 50 *A. hypogaea* genotypes and interspecific hybrids were evaluated for variation in seed storage proteins. These genotypes represented an array of cultivated botanical types, including ones reported in the literature as being resistant to aflatoxin. Several hybrid lines developed from crosses between resistant and susceptible genotypes by the peanut breeding program were also available for study. Both types of materials were analyzed in an attempt to identify protein markers which could be associated with toxin production. Although an extensive amount of variation was observed among genotypes, and many could be identified by their protein profiles, no single marker was found to be positively associated with aflatoxin resistance. However, evidence was found at the molecular level for introgression from the *A. cardenasii* to the *A. hypogaea* genome. In addition to the aflatoxin study, lines identified as resistant to a number of disease and insect pests were screened for variation to seed storage protein and amino acid profiles. A protein band at the 30-kD region was found in many of the resistant lines, and preliminary results indicated that it may be associated with genes conditioning resistance. Additional genetic analyses will be needed to determine whether the marker will benefit breeding programs. Attempts to associate disease and insect resistances with isozyme patterns were attempted but did not prove successful.

7. Interspecific hybrids between two cultivated genotypes and the species *A. batizocoi*, *A. cardenasii* and *A. stenosperma* in section *Arachis* were produced and then colchicine treated to restore fertility. First generation hybrids were analyzed meiotically and the chromosome number of progenies confirmed cytologically. More than 100 unique DNA restriction length polymorphism (RFLP) markers were identified between the three species and the cultivated peanut. The markers will be used to study introgression frequencies as different cytological pathways are used to transfer genes from *Arachis* species to *A. hypogaea*. A program to self and backcross the hexaploids is being initiated to develop materials for analyses with RFLPs.

8. As a companion study, diploid interspecific hybrids between the three species mentioned above for the hexaploids were produced. Plants were then colchicine-treated to produce amphiploids, but only one combination was successfully doubled; the others will be attempted during the coming year. RFLP markers were also identified which can differentiate the

three wild species; and the probes will be used to follow germplasm introgression from the species as crosses are made and advanced with the hybridization programs. These investigations should allow more economical transfer of germplasm to *A. hypogaea*, and potentially allow specific genes to be marked to insure incorporation into advanced generation progenies.

9. Barriers to interspecific hybridization were analyzed by making crosses between four cultivated genotypes and five *Arachis* species. Fifteen peg tips for each of 14 collection times between anthesis and 28 days after pollination were then collected, fixed in FAA, and prepared for histological analyses. The hybrids included only *A. hypogaea* females, and the reciprocals will be made next year. A second experiment was conducted using two cultivars and four other *Arachis* species, in reciprocal. Materials were collected for 21 days and analyzed histologically. Preliminary results indicate that several reasons exist for lack of hybridization between *Arachis* species, including restricted fertilization, embryo abortion within the first five to seven days after fertilization, and failure of embryos to reinitiate growth after the peg enters the soil. Plants from different sections of the genus were also grown and parental tissues collected for additional studies of incompatibility among genotypes.

D. **Development of a Gene-Transfer System for Peanut.** The primary goal of our work over the past two years has been to develop reliable protocols for the transfer of alien genes into cultivated peanut. This technology is a prerequisite for any strategy involving direct genetic manipulation at the molecular level. Criteria for a useful procedure include: suitability for manipulation of any variety of peanut, regardless of genotype; production of a sufficient number of independent transgenic plants to allow recovery of transformants which retain desirable agronomic attributes following the transformation process; normal or near-normal levels of fertility in mature transformants; the ability to recover transformants within a reasonable time after the initiation of the transformation process; and moderate cost.

Several routes by which peanut transformation might be accomplished have been evaluated in our lab. Two promising strategies were identified. The first involves delivery of genes of interest to unexpanded leaflets from mature zygotic embryos by microprojectile bombardment. The second, which also employs microprojectile bombardment for DNA delivery, uses embryogenic callus, derived from immature zygotic embryos, as the recipient tissue. Within the last year, we have made substantial progress in toward transformation by both of these routes.

1. In the first approach ("leaflet system"), unexpanded leaflets are obtained aseptically from zygotic embryos four days after imbibition. Leaflets are then plated on an MS-based medium amended with 2 mg/L NAA and 4 mg/L BAP, and held for 24 hours before bombardment. After bombardment, leaflets are transferred to selective medium. Leaflets bombarded with plasmid DNA bearing a chimeric neomycin phosphotransferase (NPT II) gene are selected on medium containing 50 mg/L kanamycin sulfate. Tissues treated with a mutant mouse dihydrofolate reductase (DHFR) are selected on medium containing 0.25 mg/L methotrexate (amethopterin). Methotrexate selection is increased to 0.30 mg/L at the first subculture (2 weeks after bombardment).

Leaflets treated with with NPT II have produced large numbers of kanamycin-resistant callus tissue following protracted selection at 50 mg/L of kanamycin. Resulting calli have been shown to be composed of stably transformed cells by their continued normal growth on high levels

of kanamycin, NPT II ELISA assay (indicating the production of the NPT gene product), polymerase chain reaction (PCR) amplification of the NPT II coding sequence, and Southern blot analysis of total genomic DNA, indicating the presence of NPT II coding sequence stably integrated into the peanut genome. No untransformed callus has been recovered by this protocol, proving that kanamycin is an appropriate selective agent for selection of transgenic peanut calli. Selection of calli treated with mutant DHFR and selected on methotrexate have produced similar results.

2. We have thus far been unable to regenerate plants from leaflet-derived callus. However, numerous fertile plants have been regenerated from treated explants, possibly from the primary explant tissue. Although plants have been regenerated under kanamycin selection, all of these have proven to be escapes from selection, rather than true transformants.

More recently, however, plants have been recovered from leaflets under methotrexate selection. Several of these regenerants have been shown to contain the introduced mutant DHFR sequence, suggesting that these plants are stably transformed. These results must be considered preliminary, however, until they can be confirmed by Southern blot analysis of genomic DNA, and by molecular analysis of progeny.

3. In collaboration with Dr. Peggy Ozias-Akins at the University of Georgia, we have also succeeded in producing stably transformed plants by microprojectile bombardment of embryogenic callus tissue. In this system, immature zygotic embryos are cultured on medium containing the growth regulator picloram. The primary explant subsequently gives rise to somatic embryos. These somatic embryos then give rise to secondary somatic embryos. If carried on medium with picloram, this system will thus produce embryos continually in a cyclical fashion. If, however, these embryos are subcultured to medium without picloram, embryo maturation and germination occur in a manner analogous to that of zygotic embryos. This process ultimately results in regeneration of mature, fertile plants.

4. We have recently succeeded in producing transgenic peanut plants by microprojectile bombardment of somatic embryos. Cultures were treated with plasmid DNA carrying a chimeric gene encoding hygromycin phosphotransferase (HPH), and subsequently subjected to selection on medium containing hygromycin. Some treated cultures were also selected in liquid medium with hygromycin. Hygromycin-resistant embryos were recovered after protracted selection. These embryos have subsequently given rise to stably-transformed plants. Analysis by Southern blot has proven that these plants carry integrated copies of the HPH coding sequence.

5. Applications

a. Although stable transformation of plants has only recently been demonstrated, we have already begun the process of producing useful transgenic germplasm. The first application is expected to be the development of genotypes with enhanced resistance to Peanut Stripe Virus (PStV). To this end, we have obtained genetic constructs encoding the PStV capsid protein from collaborators at the Samuel Roberts Noble Foundation (Dr. Richard Nelson and Dr. Brandt Cassidy). In initial experiments with this construct, it was introduced into leaflets, along with a second plasmid carrying the NPT II gene. Leaflets under selection with kanamycin gave rise to stably transformed calli which were both resistant to kanamycin, and also expressed the PStV capsid protein. As described above, however, this early system was incapable of producing stably transformed

plants.

b. The PStV construct has now been engineered into a plasmid which also carries the mutant DHFR gene, providing resistance to methotrexate. This plasmid has been introduced into leaflets of peanut cv. UPL Pn4, which are now being cultured under methotrexate selection. Based on previous results with this system, we have reasonable expectation that these tissues could give rise to plants which carry and express the alien protein.

c. Finally, the PStV constructs have been introduced into the embryogenic callus system with the intention of generating transgenics by that route. Since both the embryo culture and leaflet approaches are quite new, we feel that these experiments, while somewhat redundant, provide our best insurance that PStV-resistant transgenics will be recovered quickly. Embryos treated with the PStV construct are now under hygromycin selection.

d. We have established a collaborative relationship with Dr. John Sherwood, Oklahoma State University, who can provide the necessary expertise to test transgenic peanut resulting from PStV experiments. This interaction will augment testing anticipated with our overseas cooperators.

TRAINING

Surname	Sex	Univ.	Department	Degree	Date degree received	CRSP support
U.S. citizens						
Chappell	M	NCSU	Crop Science	MS	--	Total
McIntyre	F	NCSU	Crop Science	MS	--	Partial
Thai citizens						
Panupong Tangklang	M	KKU	--	BS	1991	--
Ratchanee Fangsrikam	F	KKU	--	MS	--	--
Somsak Idhipong	M	KKU	--	MS	1991	--
Sopitra Chatcharoantong	F	KKU	--	BS	1991	--
Tinakorn Khomsa-art	M	KKU	--	MS	--	--
Visit Treesuwanwat	M	KKU	--	MS	--	Partial
Wootisuk Butranu	M	NCSU	Plant Pathology	PhD	--	Total
Other citizens						
Bianchi (Argentina)	F	NCSU	Crop Science	PhD	--	Total
Garcia (Argentina)	M	NCSU	Crop Science	PhD	--	Total
Kyaw Hlaing (Myanmar)	M	KKU	--	Nondegree	Feb-Apr 92	Partial
Rau (India)	M	NCSU	Crop Science	MS	--	Partial
Than Suang (Myanmar)	M	KKU	--	Nondegree	Feb-Apr 92	Partial
Tin Myang Myint (Myanmar)	M	KKU	--	Nondegree	Feb-Apr 92	Partial
Utomo (Indonesia)	M	NCSU	Crop Science	PhD	--	Partial

Mr. Wootisuk Butranu, a Thai citizen, has been identified by the Thai project as a candidate for graduate training in fungal pathology at NCSU. He arrived in Raleigh, N.C., for English study in mid-June, 1992.

Ms. Geeta Menon, an Indian citizen, was identified by Dr,. Weissinger as a candidate for graduate training in molecular biology at NCSU.

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PLANS FOR 1992-93

Thailand

A. **Breeding.** All breeding objectives will be continued along the same lines as the previous year. New crosses will be made among adapted lines and identified sources of desirable traits such as earliness, rust and leafspot resistances, insect resistance, and high nitrogen fixation. Desirable germplasm and segregating materials will be introduced from ICRISAT and NCSU. The currently segregating materials will be grown for advanced generation, evaluation and selection. Yield testing in various stages of different groups of material will be conducted. KKU will emphasize on generating segregating material, basic genetic studies, evaluation and selection, and initial yield testing; while DOA will concentrate on yield testing in different environments to evaluate adaptability and stability of identified promising lines. Outlines of the work plan for individual institutes are listed below.

1. **Department of Agriculture**

a. Some new crosses will be made among high yielding lines and sources of desirable traits.
b. Segregating materials currently available will be advanced and screened for the desirable traits appropriated to the respective group of material.
c. Breeding for insect resistance will be initiated.
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 yield lines and identified sources of desirable traits.
b. Segregating materials will be introduced from NCSU and ICRISAT.
c. Different groups of segregating materials will be evaluated and selected for agronomic traits according to breeding objective.
d. Basic genetic studies will be done for various economic traits of peanut.
e. Yield trials will be conducted in the before-rice, after-rice and main rainy seasons.
f. Work on breeding for increased nitrogen fixation and for resistance to certain insects will be continued.

B. **Pathology.** For the DOA, work done in 1992 will follow the direction set in 1991--that is to assist the breeders in screening for resistance to foliar diseases. Studies on soil-borne diseases will also continue with the main emphasis on Aspergillus crown rot, Sclerotium stem rot and aflatoxin-related topics. Kasetsart pathological work will be engaged constantly on the pathogen properties which play a direct effect on host-parasite interactions enabling the breeder to produce resistant lines against three major foliar diseases. Presently work on *C. arachidicola* is

in progress. Some aspects on other fungal-peanut interactions will be initiated based on important priority to economic concerns.

Philippines

Breeding efforts in the Philippines will continue on the varietal improvement of peanut for high yields, disease resistance and tolerance to various stress/marginal environments (e.g., partial shade, highly acidic soils and drought conditions). Efforts will be focused on selection for two specific types of peanut utilization which are for table and boiling types. For the table peanuts, selection will be based on high yield, large seededness, acceptable seed shape and seed coat color. On the other hand, for the boiling type, criteria such as three seeds per pod, sweetness of seeds, high yield, resistance to foliar diseases and tolerance to stress environments will be used.

Hybridization work for high seed viability will be initiated using the three identified promising materials which have high storability. The peanut lines with high viability will be crossed with the acceptable Philippine recommended varieties (UPL Pn 2 and UPL Pn 10).

The series of yield tests and on-farm trials of new promising entries will be done at selected sites for the specific growing environments.

Specific plans for July 1992 to June 30, 1993 are outlined below.

A. Breeding for high yields and disease resistance at specific growing environments

1. Optimum sunlight and pH growing conditions
   a. Seed production and promotion of UPLB/P-CRSP-developed cultivars and promising materials
   b. On-farm trials of three promising entries and farmer's variety at selected locations (Zambales, Aurora, Isabela, Pangasinan, etc.)
   c. National cooperative yield trials at seven locations; general yield trials at three locations (UPLB, IES and USM); preliminary yield trials at two testing sites (UPLB and IES)
   d. Advancement of segregating materials and individual plant selection on F_5 breeding populations
   e. Hybridization work to improve resistance on *Aspergillus flavus* infection and rust resistance
   f. Continue screening for resistance to major peanut diseases (rust, late Cercospora leafspot, Sclerotium wilt, bacterial wilt, *Aspergillus* wilt and *Aspergillus flavus* invasion in seeds)
   g. Basic studies on effect of planting susceptible and resistant cultivars, effect of fallowing, effect of weed host (*Portulaca oleraceae*) and effect of cropping pattern
   h. Determination of minimum inoculum dose in soil for occurrence of b acterial wilt
   i. Study on survival of *P. solanacearum* peanut isolate in the soil
   j. Preparation of a pictorial guide for evaluating resistance of major peanut diseases to be used by peanut breeders, collaborators and technicians

2. Partial shaded growing environment

   a. Preliminary yield trial of 49 new peanut lines under full sun- light and partial shaded conditions using 7x7 simple lattice design.
   b. Confirmatory tests of shade tolerance using nine promising entries from the general yield trials under coconut across four locations using four shade levels and three replications
   c. General yield trials under coconut using 20 entries at Quezon, Bicol,

Aurora Province, North Cotabato and Davao

d. On-farm trials of three promising entries at various coconut testing sites
e. Seed production of promising entries which are high yielding under partial shade and have extended shelf life such as IPB Pn 82 82-25, IPB Pn 82 80-5, IPB Pn 82 68-68, IPB 82 67-30 and IPB Pn 82 68-202

3. Highly acidic soils

a. Greenhouse experiments will be conducted on acid tolerance to characterize tolerant and intolerant lines
b. Diallel crosses for acid tolerance

B. Breeding for insect pest resistance

1. Continue screening for resistance to leafhopper
2. Selection work on nine F_5 breeding populations for leafhopper resistance at two environments (full sunlight and partial shaded growing conditions)

C. Breeding for drought tolerance

1. Individual plant selection on F_5 breeding populations at Pangasinan and Ilocos Sur
2. Confirmatory tests on drought tolerance

D. Breeding for longer seed storability/viability

1. Screening of new entries for improved seed viability using both modified accelerated aging test and vigor test (soil as the germinating media)
2. Hybridization work using the three identified lines with high storability and two Philippine seedboard varieties (UPL Pn 2 and UPL Pn 10)

North Carolina

Breeding. North Carolina breeding efforts will continue for the development of early maturing lines with high yields and good seed quality. High priority continues on selection and testing of cultivars resistant to diseases and insects, particularly CBR and leafspots. 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. Screening of selected lines for early leafspot resistance will continue. Advanced lines will be evaluated for agronomic performance with and without chemical control of leafspot. Tetraploid lines developed by Dr. Stalker from crosses of *A. hypogaea* PI 261942-3 with *A. cardenasii* 10017 have been crossed with large-seeded lines currently in the advanced stages of performance testing. These lines include some resistant to leafspots and some with resistance to nematodes and insect pests. An additional study compares virginia cultivars currently used by growers in North Carolina for their resistance to *P. personatum*. Lines with high levels of resistance identified by Dr. W.V. Campbell from CRSP-supported screening will be crossed with high-yielding and/or large-seeded virginia lines to create populations suitable for exploitation in North Carolina.Hybrids among *Aspergillus*-resistant selections and backcrosses to virginia-type parents will be evaluated for dry-seed resistance and aflatoxin production levels. Seed of all material considered adaptable to Thai or Filipino growing conditions will be passed on to the countries. Current advanced material will be assayed for variation in storability for chemical and market quality as indicated by fatty acid composition.

Recurrent selection for productivity in a population derived from elite germplasm will continue with performance testing of $S_{1:3}$ families from the 88 surviving crosses of the fifth cycle (C_5) at two sites. Selection for pod and seed characteristics will be performed in S_1 populations from C_5 using single-pod

harvest. Single-seed descent will be continued in the S_2 generation at the 1991-92 winter nursery. S_3 populations will be grown in the field in the 1992 season. Nine lines selected from 63 F_6-derived families from the fourth cycle (C_4) of the recurrent selection program will be evaluated in an advanced performance test at two sites.

Two hundred ten 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 will be evaluated by Dr. W.V. Campbell for resistance to thrips, corn earworm , potato leafhopper, Southern corn rootworm, and lesser cornstalk borer in a field without chemical control of insects. Seed for NCSU, Thailand, and the Philippines will be harvested from the plots at NCSU. Lines with superior resistance to one or more pests but lacking commercially acceptable yield, seed or pod characteristics will be crossed with agronomically superior lines in the 1993 growing season.

Pathology/Molecular Biology. Studies initiated in 1991 to identify preharvest resistance to infection by *A. parasiticus* and subsequent toxin accumulation will continue in 1992. Test genotypes will be grown in microplots on a hot, drought-prone site and inoculated with the fungus. Drip irrigation will be withdrawn in August to create the drought conditions necessary for toxin accumulation. Studies are being conducted at the Sandhills Research Station, Jackson Springs, NC.

A second year of a microplot study to evaluate resistance to root-knot nematodes (*M. arenaria*) in peanut will be conducted. Peanut genotypes derived from crosses between *Arachis* spp. and cultivated peanut will be characterized for resistance to nematode reproduction and galling. Segregation for resistance observed in 1991 will be investigated. The final year of a rotation study initiated in 1989 will be completed in 1992. Effects of host and nonhost crop rotations on competition and survival among mixed-species populations of *M. arenaria* Race 1, Race 2, and *M. hapla* will be assessed in microplot studies.

Correlations among resistances to the three soilborne pathogens (*Sclerotinia* blight, *Sclerotium* wilt, and *Cylindrocladium* black root rot) will be investigated by planting test cultivars in disease nurseries. Response of high-yielding genotypes to the pathogens will be evaluated, with the goal of developing cultivars with resistance to all three pathogens. Studies have been initiated to examine the effects of surface litter resulting from nonconventional tillage on soilborne pathogens of peanut. Disease in microplots infested with *S. rolfsii*, *S. minor*, or *C. crotalariae* will be assessed in the presence or absence of wheat straw on the soil surface. Surface litter may enhance or suppress disease development through several mechanisms.

Embryonic leaves of genotypes representing all the botanical types of peanut will be evaluated for plant regeneration response under various tissue culture parameters. Histological examination of the leaflets will be conducted to determine the timing and origin of meristematic areas. Stable transformation of peanut calli has been achieved via high velocity microprojectile bombardment. Evaluation of treated leaflet cultures to identify stable transgenic shoots will continue. Integration events will be characterized by Southern blot analysis, Polymerase Chain Reaction (PCR), and by sequence analysis of peanut DNA bordering the introduced gene. A construct containing DNA for capsid protein of peanut stripe virus has been obtained from John Sherwood of Oklahoma State University and Rick Nelson of the Noble Foundation in Ardmore, OK. Another containing capsid protein gene from tomato spotted wilt virus is being obtained from D. McKenzie of Agriculture Canada. Large-scale bombardments of leaflet and embryogenic callus will be undertaken to produce numbers of plants transformed with these genes.

In the immediate future, we plan to incorporate two other potentially useful genes into the transformation program. First, we will introduce a gene encoding plant chitinase into virginia, runner and valencia cultivars, in an attempt to enhance

resistance against *Aspergillus* and other fungal pathogens. We also will introduce constructs encoding the nucleocapsid protein of TSWV in order to augment native resistance against this virus.

Wild Germplasm. Advanced-generation hybrids between cultivated lines and two *Arachis* species which were selected on the basis of low egg production will be compared to the best two *A. hypogaea* plant introductions and to wild species checks for resistance to *Meliodogyne arenaria*. The experiment will be conducted in microplots with five plants each and 12 replications. Nematode eggs will be placed into each microplot at the time of planting and plant damage, egg sac masses and egg production will be recorded prior to harvest. Because two entries in previous tests were found to segregate for nematode resistance, 50 seeds of each will be tested in the greenhouse for resistance. The experiment will indicated if prior results were caused by seed mixtures or genetic causes for the observations. First generation hybrids between large-seeded cultivated genotypes and nematode-resistant interspecific hybrid selections will be grown in the field to advance generations. Vegetative cuttings will be taken from these plants and second generation progenies will be evaluated for *M. arenaria* resistance in the greenhouse. Inheritance patterns of resistance will then be determined. Because hybrids were made with large-seeded genotypes, the materials will also have potential for used as breeding lines for improved nematode resistance. In addition, hybrid progenies with the interspecific lines and two nematode-resistant *A. hypogaea* plant introductions will be evaluated at the same time to determine whether they have the similar of different genetic systems conditioning resistance.

Fifty accessions of *Arachis* species and 7 advanced generation interspecific hybrids will be tested for resistance to tomato spotted wilt virus. The experiment will be a cooperative effort with Dr. Mark Black in Texas because incidence of the disease is greater at his location. Seeds will be harvested on resistant plants of interspecific hybrids as an initial procedure to select and preserve potentially resistant lines. Crossing programs will continue between tomato spotted wilt virus-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.

A replicated test to evaluate 10 advanced generation interspecific hybrid derivatives for resistances to corn earworm, thrips, leafhopper and southern corn rootworm will be completed for the second year in the field. Agronomic traits will also be collected for future germplasm release if favorable lines are identified. 465 progeny rows derived from 85 backcross families will be grown in the field and evaluated for thrips, corn earworm, leafhopper and southern corn rootworm resistance in a non-replicated trial. Lines which are heavily damaged will be discarded and favorable materials will be harvested for re-evaluation. 28 *Arachis* accessions in section *Erectoides* will be evaluated in the field for corn earworm, thrips and leafhopper for a second year.

A crossing program will be developed to hybridize large-seed virginia type peanuts with two accessions of *A. monticola* to select genotypes with favorable agronomic traits and cylindrocladium black rot resistance.

Investigating pathways for efficient gene transfer from wild *Arachis* species into *A. hypogaea*. Three *Arachis* species have been crossed with two cultivars belonging to different subspecies of *A. hypogaea*. The triploid hybrids have been colchicine-treated and hexaploid progenies recovered. The 6*X* hybrids will be self-pollinated and backcrossed to the respective cultivated parents to establish families for molecular analyses. DNA restriction fragment length polymorphism (RFLP) markers will be identified to separate the three species from the two cultivated lines. The parents, triploid hybrids and primary hexaploids will be analyzed to establish that molecular markers can be followed during hybrid and polyploid generations. The study will continue until the most favorable selfing

and/or backcross generation can be established for maximal recombination between the wild species and cultivated genomes.

Other pathways for introgressing *Arachis* species to the cultivated peanut include the autotetraploid or amphiploid routes whereby the chromosomes of diploid species are raised to the tetraploid level before hybridizing to *A. hypogaea*. The same species used in the hexaploid route described above will be analyzed in this project. During the coming year attempts will be made to produce autotetraploid plants of three *Arachis* species and amphidiploids hybrids of three crosses. RAPD molecular markers will be identified to separate the species. A comparison of this pathway with the one described above should lead to significantly greater numbers of interspecific hybrids with detectable amounts of wild species genes in their progenies.

Hybridization barriers continue to be a major obstacle for utilizing the potentially useful germplasm in wild *Arachis* species. To answer questions related to timing and development of aborting embryos, four cultivars representing different botanical types of *A. hypogaea* were crossed as female parents to four species in section *Arachis* last year, and the reciprocal hybrids will be attempted during the coming months. Pollinations will be made, specimens collected daily from day 1 to 7 and on days 10, 14, 21, and 28. Materials will be embedded in paraffin, sectioned and microscopically observed.

Valuable genetic resources are found in sections of the genus which are completely incompatible with the cultivated peanut. Virginia and spanish types of *A. hypogaea* will be hybridized to five species in sections which are distantly related to the cultivated peanut. Specimens will be collected during early reproductive stages as described above to help determine strategies for embryo rescue. One and five day old embryos will be cultured *in vitro* in attempts to recover very young aborting tissues. Media trials will be conducted to determine optimal concentrations for peg elongation, pod enlargement and embryo recovery. Cultivated tissues will be the experimental tissue during preliminary experiments, and if positive results are obtained, interspecific hybrid embryos will be cultured. Advanced generation interspecific hybrids between *A. hypogaea* and 14 *Arachis* species will be grown in the field to increase recombination between the genomes at a high ploidy level.

Lines derived from and *A. hypogaea* x *A. cardenasii* interspecific hybrid with disease and insect resistances will be analyzed for associations of molecular markers with agronomically useful traits. RAPD markers will be used to first differentiate the two species, and then plants with different traits analyzed to detect introgression of the wild species to *A. hypogaea*. First generation hybrids between resistant and susceptible genotypes will be planted in the field to obtain populations which will be useful for associating markers with respective traits.

Intraspecific variation among accessions of *A. duranensis*, the presumed donor of the A genome of the cultivated peanut, will be analyzed. A partial diallel crossing program will be developed to produce the progenies for this study. Hybrids will be confirmed by scoring pollen viability and then meiotic analyses will be performed to analyze evolutionary trends and, hopefully, to identify the types most closely related to the cultivated peanut. To more effectively utilize resistance genes in section *Erectoides*, species relationships will be evaluated. Hybrids from last year's crossing programs will be cytologically analyzed and missing combinations of species will be made by crossing unique accessions. A diverse group of cultivated types will be evaluated for amino acid variation in an attempt to classify varieties and to find associations between amino acids and disease resistances.

INTERNATIONAL TRAVEL

T.G. Isleib, H.T. Stalker, A.K. Weissinger, A. Patanothai, S. Jogloy, R.M Abilay, and M. attended the Second International Groundnut Workshop. 25-30 November, 1991 at ICRISAT Center in Patancheru, Andhra Pradesh, India.

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TX/MM/S,G

Mycotoxin Management in Peanut by Prevention of Contamination and Monitoring

Texas A&M University - Institut Senegalais de Recherches Agricoles Institut de Technologie Alimentaire

Principal Investigators: Marian N. Beremand, Nancy P. Keller, Timothy D. Phillips - Texas A&M University
Amadou Ba - ISRA Senegal, Amadou Kane ITA. Senegal

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 reduce levels of aflatoxins, and other mycotoxins, which may be present in peanut and peanut derived 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/or other organisms that prevent mycotoxin accumulation; 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/or peanut derived products.

IMPACTS

Host Countries - Reducing the levels of aflatoxin/mycotoxins in regionally grown 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 and/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. 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 number of Segregation III peanut marketed within the country. 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.

ACCOMPLISHMENTS

Change in US-PI project management and approval of a revised research proposal has been completed. In developing and planning new projects activities, Drs. Beremand and Keller visited locations in West Africa (ITA, Dakar, Senegal; ISRA, Bambey, Senegal; University of Science and Technology (UST), Kumasi, Ghana; Food Research Institute(FRI), Accra, Ghana; and the IITA Biological Control Center (BBC) for Africa, Cotonou, Benin. As a result, programs in Senegal were reviewed and additional collaborators/cooperators were identified in Ghana (Dr. Richard Awuah from the Department of Crop Sciences at UST and Mrs. Kafui Kpodo from the FRI) and in Benin (Dr. Kitty Cardwell at the IITA, BCC). Arrangements are underway to incorporate Dr. Awuah and Mrs. Kpodo into the program and establish linkages with the IITA,BCC. Dr. Awuah's expertise in fungal identification (especially Fusarium species) and pathogenicity will be instrumental in developing new objectives based on microbial assays while Mrs. Kpodo's current skills (HPLC and TLC identification of aflatoxins) and proposed future training in Dr. Timothy Phillip's laboratory on the identification of other key mycotoxins including Fusarium mycotoxins will provide complementary chemical support.

Studies have been initiated to evaluate the role of other mycotoxins and mycotoxigenic fungi in peanut. Assays for the detection of fumonisins (a newly recognized group of carcinogenic Fusarium mycotoxins), have been added to the program and progress towards the development of a new rapid fumonisin assay is promising.

Molecular and genetic analysis of mycotoxin production has also been incorporated as an important aspect of the project. The Aspergillus nidulans ver-1 gene homologue, which encodes a reductase activity postulated to convert versicolorin A into sterigmatocystin in the aflatoxin pathway, has been cloned. Analysis of A. nidulans developmental mutants showed delayed or absent production of sterigmatocystin. DNA fingerprints of Aspergillus spp. have been established. Novel trichothecene producing Fusarium strains have been developed by genetic crosses and utilized to obtain potential new UV-induced toxin biosynthetic mutants.

Two Ph.D students completed their degree requirements at Texas A&M University. Dr. A. Bachir Sarr, a graduate student from Senegal, received his degree in January 1992 from the Department of Veterinary Public Health and Mr. Julius E. Fajardo, a graduate student from the Philippines, will be awarded his degree in August 1992 from the Department of Plant Pathology and Microbiology.

GOALS

The goals of the mycotoxin management project are to develop and apply techniques which reduce the severity of the mycotoxin contamination problems within the Lesser Developed 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 those peanut which still contain 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

- Screen peanut cultivars and genotypes under laboratory and field conditions in Texas for tolerance to aflatoxin producing fungi and/or

aflatoxin elaboration.

- Characterize preformed and induced fungal defense mechanisms within peanut plant tissues.

- Investigate the genetic and molecular mechanisms that control mycotoxin biosynthesis in Aspergillus and Fusarium species.

- Develop new assays and studies to assess the importance of other mycotoxins and mycotoxigenic fungi in peanut.

- Assess the efficacy of production, harvesting, and curing practices to reduce the severity of aflatoxin problems in Senegal.

- Ascertain within areas of Senegal the activity of aflatoxin producing fungi in the soil, determine when plant parts are invaded by aflatoxin producing fungi, and screen for resistance to fungal invasion and aflatoxin contamination.

- Analyze and develop improved mycotoxin detection systems for identifying and diverting contaminated peanut into processing for clean-up and/or detoxification.

- Develop safe, economical and efficacious methodologies for the detoxification of aflatoxin-contaminated peanut products.

- Maintain the training programs for graduate students and technicians from the developing countries.

ORGANIZATION AND PERSONNEL

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

Principal Investigator

July 1, 1991 to September 30, 1991 - Dr. Robert E. Pettit, Department of Plant Pathology and Microbiology (PPM), Texas Ag. Exp. Station (TAES) TAMU, College Station (CS)

October 1, 1991 to June 30, 1992 - Dr. Marian N. Beremand, Dept. of PPM, TAES, TAMU, CS

Co-Principal Investigators

Dr. Timothy D. Phillips, Department of Veterinary Public Health (VPH), TAMU, CS

Dr. Nancy P. Keller, Dept. of PPM, TAES, TAMU, CS

Cooperators

Dr. Olin D. Smith, Department of Soil and Crop Sciences (S&CS), TAMU,CS
Dr. Ralph D. Waniska, Dept. of S&SC, TAMU, CS
Dr. Raul G. Cuero, Cooperative Agricultural Research Center, Prairie View A&M University, Prairie View, Texas
Dr. Thomas Adams, Department of Biology, TAMU, CS
Research Associate
Dr. Jedrzej B. Serszen, Dept. of PPM, TAES, TAMU, CS

Technician

Mr. Ted Oplinger, Dept. of PPM, TAES, TAMU, CS

Budget 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, relocated from Koalack, Senegal to Bambey, Senegal

Cooperator

Mr. Jean Claude Mortreuil, CNRA, ISRA, IRHO, Bambey, Senegal, B.P. 51

Technician

Mr. Emilien Sarr, Secteur Centre-Sud, ISRA, Koalack, Senegal, B. P. 199

Directeur

Dr. Limamoulaye Cisse, Department Des Productions Vegetales, CNRA, 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 Laboratoire, ITA, Dakar-Hann, Senegal, B.P. 2765 Technicians Mrs. Nafissatou Diop, Mr. Youssou Mane, and Mr. Souleymane Diack, ITA, Dakar-Hann, Senegal, B.P. 2765

Directeur General

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

APPROACH

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

Continue to conduct laboratory experiments to characterize preformed and induced fungal defense mechanisms in peanut tissues with emphasis on elucidating potential pathogenesis-related proteins, isozymes, and phenolic compounds in seed and evaluating their significance in the inhibition of fungal invasion and toxin elaboration.

Determine the molecular mechanisms that contol 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 this research project.

In conjunction with the partial change in the personnel in the Mycotoxin Peanut CRSP Program in October 1991, visits to Senegal, Ghana and Benin were undertaken to review the progress on existing programs, redefine the objectives, and to identify and evaluate additional research locations within West African countries.

RESEARCH ACCOMPLISHMENTS

Senegal ISRA

Effect of plant growth stage and activity of aflatoxin producing fungi in the soil on colonization of peanut with A. flavus and level of aflatoxin contamination.

Peanut seeds appear to be infested by A. flavus and A. parasiticus all along the growing cycle. In order to determine the critical growing stage at which a high level of A. flavus soil propagules induces a high degree of seed colonization by the aflatoxinogenic fungus, an experiment involving 3 peanut cultivars (55-437, 73-30, and 73-33) was conducted at Nioro in 1990 and 1991. A total of 4 soil inoculations with an A. flavus conidial suspension were applied at 15 day intervals, starting one month following the sowing date and continuing up to the harvest date. Evolution of the soil fungal populations was determined by using the soil dilution technique to count the A. flavus soil propagules present at 15 day intervals from the inoculation date up to the harvest date. The percent of A. flavus seed infection and aflatoxin contamination was determined at harvest time.

As shown in Table 1, row spraying treatments performed at 60 and 75 days after the sowing date in 1990 and at 45 and 60 days after the sowing date in 1991 resulted in increased levels of soil propagules at harvest time. At harvest, soils grown with 55-437 and 73-30 appeared to be less infested than those grown with 73-33. In accordance with previous results, 55-437 and 73-30 also had lower levels of pod colonization (and in some cases seed colonization) and aflatoxin contamination at harvest than 73-33 (Tables 2,3,4,5 and 6). These data suggest that there may be a relationship between the susceptibility of the peanut varieties and the level of infestation of the soils on which they are grown. The data from these experiments also show that artificial row spraying with the conidial suspension of A. flavus at 30 and 45 days after sowing resulted in higher fungal contamination levels of pods and seeds. This stage corresponds to the penetration of pegs within the soil. The aflatoxin content of seed at harvest time also appeared highest for soil inoculation treatments performed at 30, 45 and 60 days after the sowing date than for the control and soil treatment at 75 days after the sowing date. Thus the pegging period is likely the most decisive stage for peanut preharvest contamination by aflatoxins.

Table 1. Evolution of soil contamination level (S.103 A. flavus propagules/gofsoil) 15, 30, 45 days after the treatment and at harvest time as a function of plant soil spraying with *A. flavus* conidial suspension 30, 45, 60 and 75 days following the sowing date (1990 and 1991).

Variety	Days after treatment / Treatment period	15		30		45		At harvest time	
		1990	1991	1990	1991	1990	1991	1990	1991
	5.10^3 A. Flavus Propagules/g of Soil								
55-437	Control	1.09	1.80	1.46	2.40	1.15	3.78	1.18	1.21
	30 days after sowing	18.40	24.90	8.43	14.50	9.71	6.75	7.12	5.56
	45 days after sowing	10.28	16.30	5.62	10.10	---	---	9.90	4.78
	60 days after sowing	22.90	13.50	---	---	---	---	22.80	4.60
	75 days after sowing	---	---	---	---	---	---	17.30	4.21
73-30	Control	0.46	1.80	0.50	1.75	2.78	1.71	0.56	4.72
	30 days after sowing	22.30	20.40	8.75	17.00	10.09	5.43	11.70	10.75
	45 days after sowing	8.62	13.30	6.90	25.00	---	---	8.28	19.80
	60 days after sowing	19.40	28.75	---	---	---	---	21.25	8.68
	75 days after sowing	---	---	---	---	---	---	14.06	7.25
73-33	Control	0.72	0.60	0.81	3.34	0.56	1.80	1.68	21.0
	30 days after sowing	22.12	24.20	7.75	26.06	8.40	6.43	14.53	37.75
	45 days after sowing	9.53	10.18	7.43	19.30	---	---	10.00	36.20
	60 days after sowing	18.18	13.25	---	---	---	---	26.56	33.50
	75 days after sowing	---	---	---	---	---	---	28.65	41.60

Table 2. Natural pod contamination (%) of 55-437, 73-30, and 73;.33 at harvest time in MSA medium and humidity chamber as a function of row spraying periodlg with A. *flavus* conidial suspension (1990).

Variety Treatment	55-437 MSA	 HC	73-30 MSA	 HC	73-33 MSA	 HC
	Pod Contamination with A. flavus, %					
Control	5.0	2.5	5.0	7.5	2.5	10.0
30 days after sowing	12.5	2.5	7.5	10.0	27.5	35.0
45 days after sowing	10.0	17.5	12.5	10.0	20.0	57.5
60 days after sowing	5.0	0.0	2.5	12.5	5.0	22.5
75 days after sowing	15.0	2.5	2.5	15.0	7.5	45.0

Table 3. Natural seed contamination (%) of 55-437, 73-30, and 73-33 at harvest time in MSA medium and humidity chamber as a function of row spraying periods with A. *flavus* conidial suspension (1 990).

Variety Treatment	55-437 MSA	 HC	73-30 MSA	 HC	73-33 MSA	 HC
	Seed Contamination with A. flavus, %					
Control	7.5	2.5	2.5	5.0	2.5	0.0
30 days after sowing	2.5	17.5	0.0	0.0	5.0	2.5
45 days after sowing	17.5	0.0	15.0	7.5	10.0	12.5
60 days after sowing	12.5	5.0	0.0	2.5	5.0	5.0
75 days after sowing	15.0	25.0	0.0	0.0	0.0	0.0

Table 4. Natural pod contamination (%) of 55-437, 73-30, and 73-33 at harvest time in MSA medium and humidity chamber as a function of row spraying periods with *A. flavus* conidial suspension (1 991).

Variety	55-437		73-30		73-33	
Treatment	MSA	HC	MSA	HC	MSA	HC
	Pod Contamination with A. flavus, %					
Control	0.0	10.0	5.0	13.5	60.0	50.0
30 days after sowing	20.0	10.0	25.0	25.0	30.0	40.0
45 days after sowing	20.0	10.0	16.0	16.0	60.0	40.0
60 days after sowing	10.0	10.0	12.5	16.0	50.0	60.0
75 days after sowing	10.0	10.0	12.5	12.5	40.0	60.0

Table 5. Natural seed contamination (%) of 55-437, 73-30, and 73-33 at harvest time in MSA medium and humidity chamber as a function of row spraying periods with *A. flavus* conidial suspension (i 991).

Variety	55-437		73-30		73-33	
Treatment	MSA	HC	MSA	HC	MSA	HC
	Seed Contamination with A. flavus, %					
Control	10.0	0.0	10.0	10.0	10.0	30.0
30 days after sowing	10.0	10.0	20.0	10.0	30.0	40.0
45 days after sowing	20.0	20.0	10.0	10.0	10.0	20.0
60 days after sowing	0.0	0.0	0.0	10.0	10.0	30.0
75 days after sowing	10.0	10.0	0.0	0.0	10.0	30.0

Table 6. Aflatoxin content (gg kg-1 seed) of seeds of 3 groundnut cultivars at harvest time as a function of plant soil spraying date with *A. flavus* conidial suspension (1990 and 1991).

Variety	55-437		73-30		73-33	
Treatment	1990	1991	1990	1991	1990	1991
	Aflatoxin, ug kg^{-1} seed					
Control	1.25	9.00	1.00	152.50	40.75	5655.00
30 days after sowing	1.50	231.00	0.70	240.0	187.50	5576.00
45 days after sowing	23.00	33.25	1.50	173.25	3150.00	6017.00
60 days after sowing	1.25	151.25	1.25	21.75	112.5	5682.00
75 days after sowing	1.00	77.50	1.25	153.75	143.5	5532.00

Screening peanut genotypes for resistance to fungal invasion and aflatoxin formation.

A trial carried out at Nioro in 1990 and 1991 in collaboration with the ICRISAT Sahelian Center (Niamey) evaluated 25 peanut genotypes to determine their levels of resistance to A. flavus seed colonization. Experiments were conducted following a lattice design and each plot included 4 rows, 4 M long. At harvest, 60 pods were sampled from each plot for natural fungal infestation of pods and seeds. Artificial inoculation with A. flavus was also performed on seeds previously sterilized with mercuric chloride. Genotypic differences occurred for both natural pod infection and for in vitro inoculation. During both years, several genotypes ranked in good position with regard to 55-U37 and PI33739UF which are known to have good resistance to A. flavus infection.

Senegal ITA

Occurrence of Aflatoxin B1 in unrefined rural peanut oil and its removal by Kaolin

Samples (50) of crude peanut oil from producing areas in the Kaolack district were analyzed to determine the profile of contamination by aflatoxin. Ninety-six percent of the samples contained detectable levels of aflatoxin B1, in the range of 5-254 ppb with an average value of 54 ppb. Previous studies has shown that Kaolin ("Kew"clay) was less efficient than attapulgite and Nova SilTM for aflatoxin removal. Experiments conducted to determine if the efficiency of aflatoxin B1 removal by Kaolin could be improved showed that increasing either the ratio of clay/oil, the treatment time, or both had no effect. In related experiments, exposure of aflatoxin-contaminated crude oil to sunlight for 12-to-48 hours appeared to degrade the aflatoxins.

Occurrence of Aflatoxin B1 in peanut products: peanut cakes and roasted peanut.

Peanut cakes from village squeezers were bought from the same locations as the unrefined peanut oil. Roasted peanut were bought from various sites in the peanut areas and in Dakar; each sample was hand picked and only the apparently good seed were analyzed for toxins. All 20 samples of peanut cake contained aflatoxin B1 in the range of 49-160 ppb with an average of 67 ppb. None of the 20 samples of roasted peanut contained detectable amounts of aflatoxin B1.

Texas

Evaluation of peanut cultivars and genotypes for A. flavus colonization and aflatoxin production.

Thirty-eight cultivars were examined for the occurrence of Aspergillus flavus and aflatoxins following growth under rain-fed field conditions in a plot near Waller, Texas. At maturity, the plants were dug and then dried for 3 to 4 weeks in windrows. The Spanish peanut cultivars were tested for A. flavus at digging, 17 days post digging and 31 days post digging and for aflatoxins at 10 days post digging. The runner peanut cultivars were tested for A. flavus at digging, 14 days post digging and 21 days post digging and for aflatoxins at 21 days post digging.

As shown in Tables 7 and 8, the occurrence of A. flavus was very low. Twelve of the 38 cultivars (8 spanish and 4 runner) were free of A. flavus at all three test periods; twenty-four cultivars displayed less less than 1% occurrence averaged over the three test periods; and only 2 cultivars (Toalson at 1.2% and SN-73-33 at 3.5%) were >1%. Under these conditions, Toalson and SN-73-33 were the most susceptible to infestation by A. flavus. Three samples for each cultivar were tested for aflatoxins using the SAM assay technique where the limit of detection was set at 10 ppb. Only one sample of one cultivar, Starr, tested positive with a value of approximately 40 ppb. However, a retest of 3

additional samples of this cultivar proved negative. The low rate of A. flavus infestation and aflatoxin contamination observed in this test reflects in part the apparent lack of environmental conditions required for Aspergillus growth and/or toxin production.

Control of aflatoxin production by peanut defense mechanisms.

Previous studies conducted under controlled environmental conditions to determine if chitosan and A. flavus induced phytoalexin (phenolic) production in peanut cotyledons identified p-coumaric, ferulic and vanillic acid as major or elevated phenolic acids in peanut seed treated with chitosan, A. flavus , or chitosan + A. flavus (see 1990-1991 Annual CRSP report for details). The objective of the present study was to determine the effect of these phenolic acids on the growth of A. flavus and on aflatoxin biosynthesis. P-coumaric, ferulic and vanillic acids alone and combined in a single mixture were slightly inhibitory to mycelial growth of A. flavus, especially at a 0.1M concentration (Table 9). These three compounds alone, and combined, also reduced the production of aflatoxin B1 by A. flavus with the mixture showing the most inhibition (Table 10).

Table 7. Isolation frequency of *Aspergillus flavus* in Spanish peanut cultivars grown in a field plot near Waller, Texas in 1991.

Cultivar	Isolation frequency of *A. flavus* (%)[a] windrow curing period at digging	17 days	31 days	Average
TX811956	0	0	0	0
TX813922	0	0	0	0
TX872551	0	0	0	0
TX883662	0	0	0	0
TX883722	0	0	0	0
TXAG-5	0	0	0	0
Marc-1	0	0	0	0
TX77108	0.7	0	0	0.2
TX883702	0.7	0	0	0.2
Tamnut-74	0.7	0	0	0.2
J-11	0.7	0	0	0.2
SN-55-437	0	0.7	0	0.2
TX883602	1.4	0	0	0.4
Tamspan	1.4	0	0	0.4
ICGS(E)-46	0.7	0.7	0	0.4
AT-127	0.7	0.7	0	0.4
Starr	2.1	0	0	0.6
TX8721618	0	2.1	0	0.6
TX86579	0	2.9	0	0.8
Toalson	4.3	0	0	1.2

[a]Isolation frequency is a mean of 4 replication, 35 kernels/replication.

Table 8. Isolation frequency of *Aspergillus flavus* in runner peanut cultivars grown in a field plot near Waller, Texas in 1991.

Cultivar	Isolation frequency of *A. flavus* (%)[a] windrow curing period at digging	14 days	21 days	Average
TX813973	0	0	0	0
TX874266	0	0	0	0
TX893617	0	0	0	0
TP-172#2-2	0	0	0	0
TX813964	0.7	0	0	0.2
TX855101	0.7	0	0	0.2
TX874367	0	0	0.7	0.2
RMP-40	0	0	0.7	0.2
Florunner	0	0	1.4	0.4
TX855122	1.4	0	0	0.4
TX893620	1.4	0	0	0.4
TP175-3	0.7	0	0.7	0.4
Southern runner	1.4	0	0.7	0.6
GK-7	0.7	0	1.4	0.6
FA-6	2.9	0	0	0.8
SN-73-33	12.9	0	0	3.5

[a]Isolation frequency is a mean of 4 replication, 35 kernels/replication.

TABLE 9 . Effect of phenolic acids on mycelial growth of *A. flavus* Link (NRRL 3357) in yeast extract- sucrose amended medium.

Phenolic Acid	Molarity[b]	Days of Incubation[a] Day 4	Day 7	Day 11
p-coumaric	1.0	91.7 ± 1.6	92.0 ± 5.8	93.8 ± 2.6
	0.1	98.3 ± 2.1	88.1 ± 2.8	100.5 ± 9.6
	0.01	103.0 ± 6.9	96.5 ± 0.9	99.5 ± 2.7
ferulic	1.0	88.7 ± 3.7	91.9 ± 4.6	91.3 ± 1.4
	0.1	87.6 ± 2.7	88.8 ± 1.6	94.3 ± 0.1
	0.01	86.5 ± 3.1	96.9 ± 2.7	100.3 ± 5.8
vanillic	1.0	94.8 ± 2.8	95.7 ± 4.5	104.1 ± 7.4
	0.1	96.0 ± 4.3	88.4 ± 0.6	96.4 ± 3.9
	0.01	89.2 ± 6.4	90.4 ± 3.6	102.9 ± 11.0
mixture	1.0	90.9 ± 2.3	95.2 ± 5.4	107.0 ± 6.7
	0.1	80.9 ± 3.6	91.5 ± 3.1	92.5 ± 1.3
	0.01	99.3 ± 4.0	110.4 ± 7.9	103.5 ± 8.9
control[c]	0.00	1.3 ± 3.7	0.9 ± 5.6	0.7 ± 5.7

[a]Value (± standard deviation) shown is a mean of three replicates.
[b]p-coumaric acid=0.1942 g ml^{-1}; ferulic acid=0.1642 g ml^{-1}; vanillic acid=0.1681 g ml^{-1}; mixture=1:1:1 ratio of p-coumaric, ferulic and vanillic acids. Each phenolic acid and the combined mixture contained 0.1% ethanol in the final solution.
[c]Value (± standard deviation) shown is the actual dry mycelial weight in g.

TABLE 10 . Effect of phenolic acids on aflatoxin B_1 production by *A. flavus* Link (NRRL 3357) in yeast extract- sucrose amended medium.

Phenolic Acid	Molarity[b]	Days of Incubation[a] Day 4	Day 7	Day 11
p-coumaric	1.0	- ± -	3.3 ± 1.8	49.2 ± 6.6
	0.1	- ± -	5.0 ± 4.9	17.9 ± 10.0
	0.01	79.3 ± 10.7	6.1 ± 4.5	7.4 ± 0.9
ferulic	1.0	- ± -	3.8 ± 0.1	84.1 ± 29.4
	0.1	- ± -	4.5 ± 5.0	97.7 ± 24.0
	0.01	15.5 ± 7.0	3.3 ± 0.9	70.3 ± 12.2
vanillic	1.0	- ± -	3.8 ± 2.4	99.8 ± 25.6
	0.1	- ± -	4.1 ± 1.8	6.5 ± 3.3
	0.01	9.6 ± 3.5	2.2 ± 0.4	36.0 ± 6.7
mixture	1.0	- ± -	4.8 ± 4.0	32.4 ± 11.9
	0.1	- ± -	3.3 ± 2.6	49.2 ± 12.0
	0.01	- ± -	2.9 ± 2.2	71.3 ± 14.7
control[c]	0.00	286.8 ± 51.9	1335.7 ± 30.9	350.1 ± 73.0

[a]Concentration of aflatoxin B_1 in control liquid culture amended with ethanol only=100%. Value shown is expressed as percentage of control ± standard deviation (n=3). (-) indicates no detectable levels of aflatoxin B_1.
[b]p-coumaric acid=0.1942 g ml^{-1}; ferulic acid=0.1642 g ml^{-1}; vanillic acid=0.1681 g ml^{-1}; mixture=1:1:1 ratio of p-coumaric, ferulic and vanillic acids. Each phenolic acid and the combined mixture contained 0.1% ethanol in the final solution.
[c]Value shown is the actual concentration of aflatoxin B1 in parts per billion (ppb).

Polyacrylamide gel electrophoretic (PAGE) analysis was used to study the effect of chitosan, A. flavus, and chitosan + A. flavus treatments on the activity of enzymes (CAD, GDH, G6PDH, PPO, PRX, and SKD) involved in the biosynthesis of phenolic compounds in peanut cotyledons. CAD, GDH, G6PDH and PPO were resolved by native-PAGE and the PRX and SKD enzymes were resolved using IEF-PAGE with a pI range of 4.0 - 6.5 (Table 11). The data showed (1) that chitosan elicited an increase in the enzymatic activity of PPO (Rf = 0.34) and SKD (pI = 5.22; pI = 4.27), (2) that A. flavus induced changes in the enzyme activities of G6PDH (Rf = 0.44), GDH (Rf = 0.14), PRX (pI = 4.00), PPO (Rf = 0.27), and SKD (pI = 4.56; pI = 4.04) and (3) that the combined treatment of chitosan + A. flavus markedly increased the activity of GDH (Rf = 0.14; Rf = 0.20; Rf = 0.25) and SKD (pI = 4.56, pI = 4.04) (Figures 1 and 2). Since SKD isozymes were differentially activated by chitosan, A. flavus, and chitosan + A. flavus, they might be excellent markers to differentiate between the effect of elicitors on the induction of phenolic compounds.

Studies were conducted to determine the concentration of ellagic acid in various peanut tissues. Ellagic acid is a potential inhibitor of aflatoxin carcinogenesis. Ellagic acid was effectively separated from other phenolic constituents in peanut and quantified by a reverse-phase HPLC method that uses a three-step solvent gradient system (Figure 3). The average amounts of ellagic acid in peanut tissues were 80 mg/g of testa, 68 mg/g of cotyledons, and 42 mg/g of pod tissue. Ellagic acid content could be a breeding objective for cultivar development. Breeding for high ellagic acid content, especially in cotyledonary tissues, could help reduce or prevent the harmful effects of aflatoxins in peanut used for human consumption or animal feeds.

Molecular biology and genetics of mycotoxin production.

Aspergillus flavus, A. parasiticus, and A. nidulans are being used to dissect the molecular mechanisms of genetic control of aflatoxin biosynthesis. Three putative genes involved in aflatoxin biosynthesis have been isolated. One gene (an A. nidulans gene isolated by homology to an A. parasiticus gene) has been subcloned and sequenced. This gene is thought to encode for a reductase activity necessary to convert one aflatoxin precursor, VerA, to another precursor, sterigmatocystin (sterigmatocystin in itself is a mycotoxin commonly found in peanut). PCR technologies have been used to develop DNA fingerprints of several Aspergillus spp. Current studies are aimed at (1) detecting differences at an isolate level and (2) comparing the relative strengths of using molecular or traditional methodologies to distinguish Aspergillus strains.

TABLE 11. Number and color of bands detected after isoelectric focusing and native-PAGE for some enzyme systems.

Enzyme Systems[a]	Number of Bands IEF-PAGE 4.0-6.5	IEF-PAGE 3.0-9.0	Native-PAGE 10-15 %	Native-PAGE 8-25 %	Color of Bands
CAD	0	0	0	1[b]	blue
G6PDH	0	1	0	1[b]	blue
GDH	0	0	0	4[b]	blue
PRX	1[b]	3	0	0	from blue to green into brown
PPO	1	2	2[b]	2	reddish brown
SKD	5[b]	3	2	4	blue

[a]CAD=cinnamyl alcohol dehydrogenase, G6PDH=glucose-6-phosphate dehydrogenase, GDH=glutamate dehydrogenase, PRX=peroxidase, PPO=polyphenoloxidase, and SKD=shikimate dehydrogenase.
[b]Best separation and resolution for detecting enzyme activity.

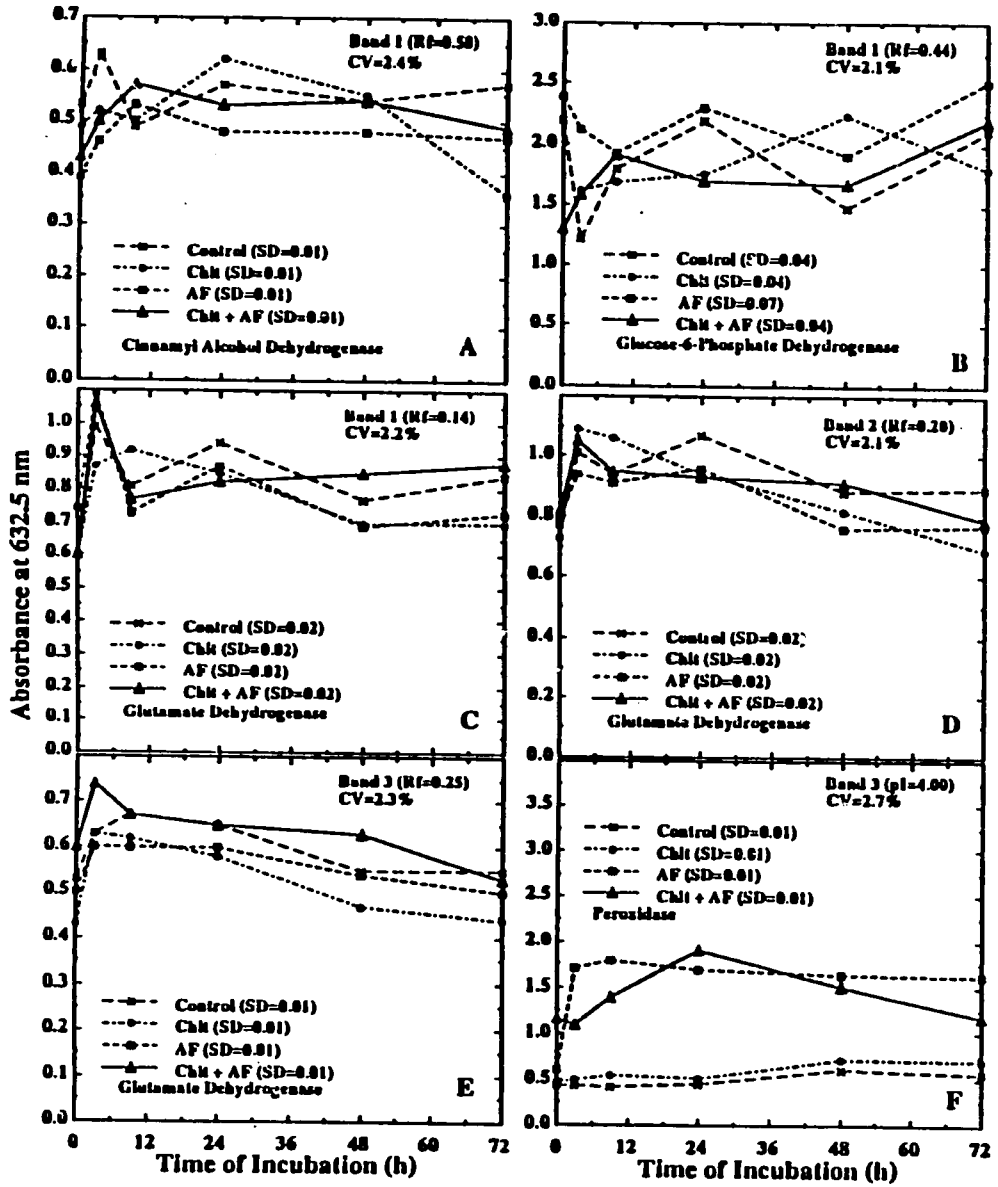


Fig. 1. Optical density for cinnamyl alcohol dehydrogenase (A), glucose-6-phosphate dehydrogenase (B), glutamate dehydrogenase (C to E), and peroxidase (F) activities in seeds of cv. Starr at Aw .85. Chitosan (Chit) was applied at 0.5% (w/v), *A. flavus* (AF) spore inoculum was applied, and chitosan + *A. flavus* (Chit + AF) were applied simultaneously. Data points are mean values of four readings. Standard deviation (SD) and coefficient of variation (CV) are indicated.

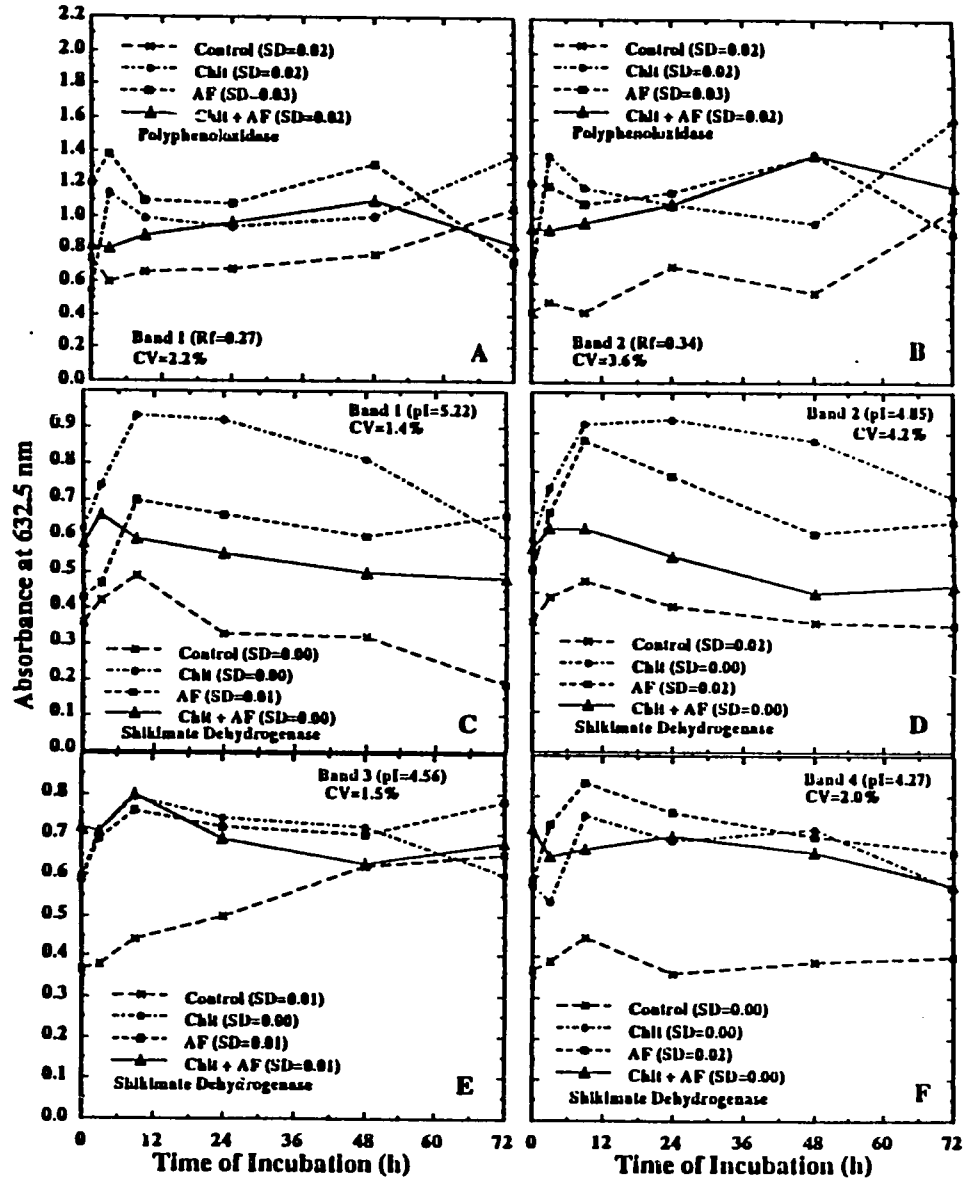


Fig. 2. Optical density for polyphenoloxidase (A,B) and shikimate dehydrogenase (C,D,E,F) activities in seeds of cv. Starr at Aw .85. Chitosan (Chit) was applied at 0.5% (w/v), *A. flavus* (AF) spore inoculum was applied, and chitosan + *A. flavus* (Chit + AF) were applied simultaneously. Data points are mean values of four readings. Standard deviation (SD) and coefficient of variation (CV) are indicated.

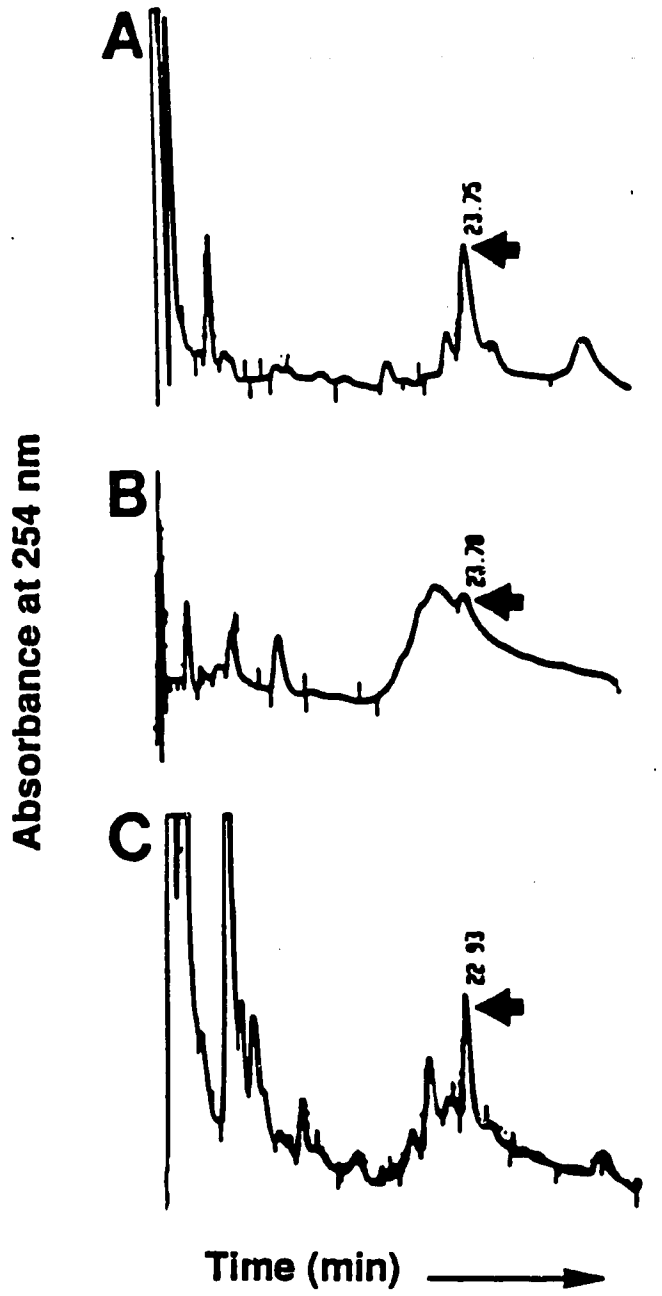
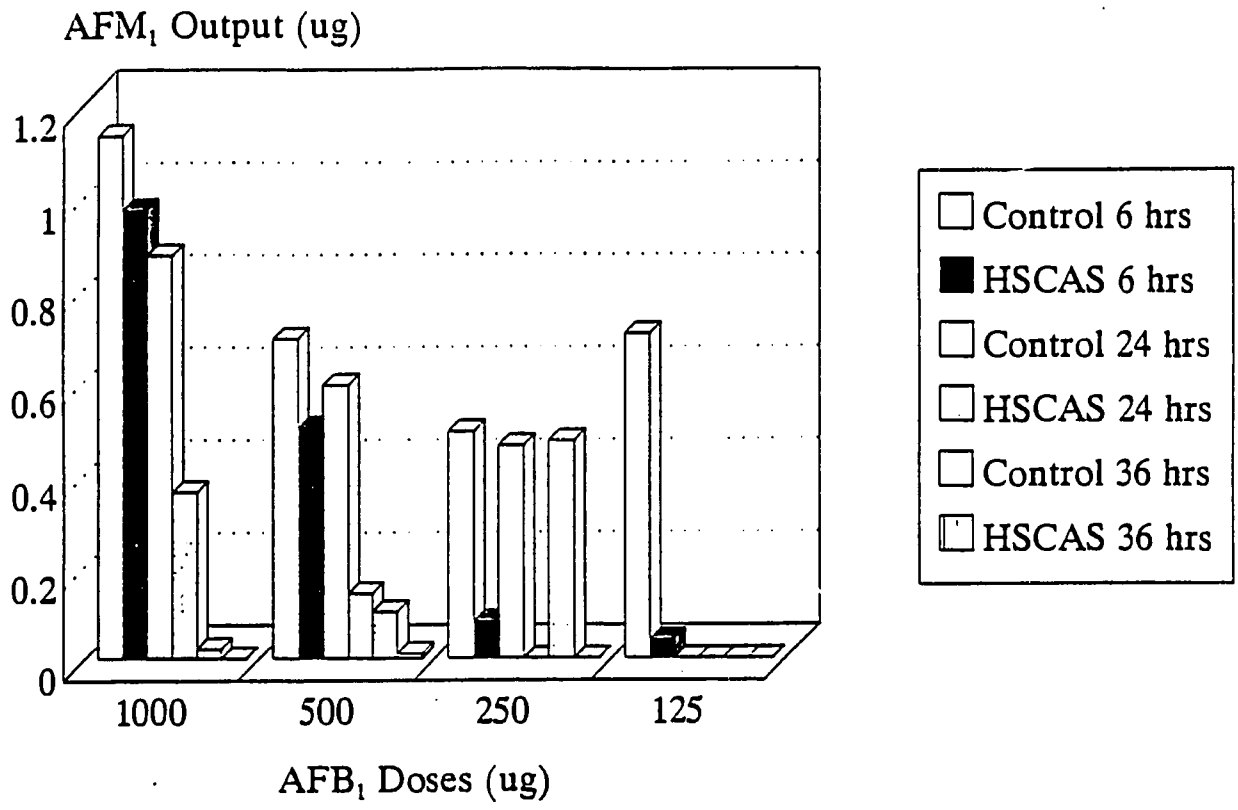


Fig. 3. Reverse-phase HPLC elution profiles of fractions from cotyledonary (A), testa (B), and pod (C) tissues in a three-step gradient solvent system. Flow rate was 1.7 ml min^{-1}. UV detection was at 254 nm. Peak of ellagic acid at a retention time of about 23 licated by an arrow.

EFFECTS OF HSCAS ON AFB_1 METABOLISM BY F-344 RATS
AFM_1 Output in Urine



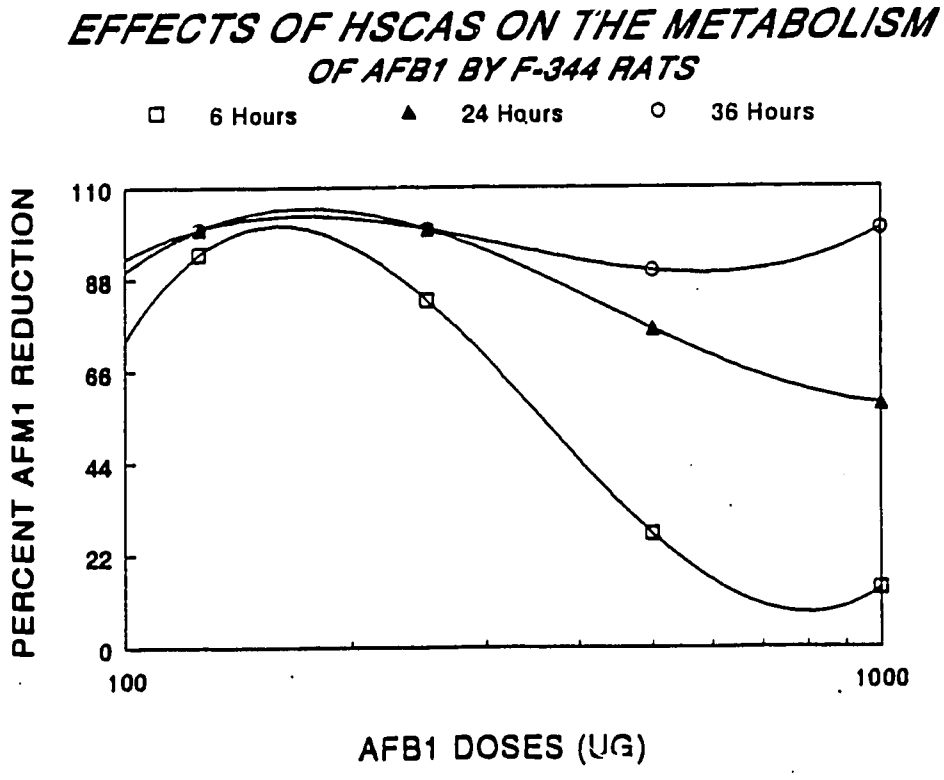


Figure 4

EFFECTS OF HSCAS ON AFB_1 METABOLISM BY F-344 RATS

PERCENT PROTECTION

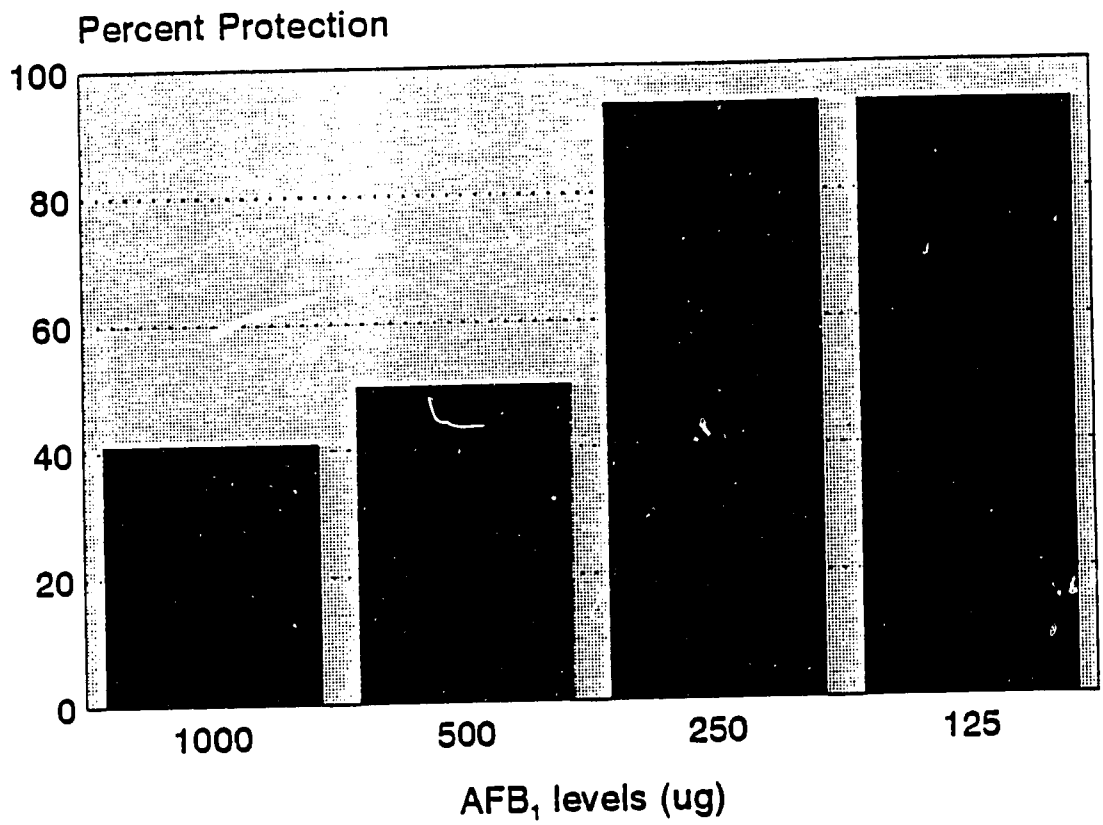


Figure 5.

Genetic and molecular systems are being used to study the regulation and function of mycotoxin (trichothecene) production by agronomically important Fusarium species pathogenic to plants. Novel T-2 toxin synthesizing strains of F. sambucinum were produced by genetic crosses. These strains were used to generate and isolate induced mutants blocked in toxin production. Characterization of these mutants is underway to determine if they represent new complementation groups and therefore identify new gene loci required for mycotoxin biosynthesis.

Phyllosilicates and clays

Previous studies have shown that the addition of HSCAS in the diet of farm animals prevented the deleterious effects of aflatoxins. Our later studies showed that the mechanism of action involves the chelation of incompletely coordinated metal ions of HSCAS by the B-dicarbonyl moiety of alfatoxins with the resulting s-p- like bond being further stabilized by resonance. In vitro extractions at various pHs and with nonpolar and polar solvents did not dissociate the bond. The objective of the following study was to determine the efficacy of HSCAS in animal models (rats) with oxidative metabolism of the aflatoxin B1 similar to that of humans. The most sensitive rat species was selected for the study. Male Fisher 344 rats (10) were divided in to two groups. One group was put on a diet containing 0.5% HSCAS and the other group was put on a regular diet. After acclimatization for one week, the rats were treated with 1000, 500, 250, and 125 mg aflatoxin B1 per kg of body weight (equivalent to 9, 5, 2.7, and 1.5 ppm in the diet, respectively). The rats were placed in metabolic cages and urine was collected after 6, 24, and 36 hours. The samples were analyzed with antibody columns followed by HPLC.

The results from these analyses showed that HSCAS significantly reduced the bioavailability of aflatoxin B1 in Fisher 344 rats resulting in lower metabolite output and that the addition of HSCAS in the diet did not produce any new metabolites of aflatoxin B1. Total aflatoxin metabolite output was comparable to those published in the literature with aflatoxin M1 being the major metabolite (Fig. 4). Protection factors of 94% were obtained with HSCAS at levels of 1.5 and 2.7 ppm, and 40 and 50% at levels of 5 and 9 ppm; the capacity of HSCAS was approached at the level of clay used in this study (0.5%- Fig. 5). More importantly, the HPLC profiles did not show any new metabolites in HSCAS-treated rats. HSCAS did not catalyze any reaction susceptible of producing toxic reaction products.

Mycotoxin detection assays.

A new minicolumn method for the rapid detection of aflatoxin M1 in milk was developed. This new method has a detection limit below the action level of 0.5 ppb.

Another minicolumn method for the detection of fumonisins is being developed. Fumonisins have been recently isolated from peanut.

PUBLICATIONS & PRESENTATIONS

Fajardo J E, Cuero R G, Waniska R D, and Pettit R E. Effects of Chitosan and Aspergillus flavus on Isozymes Related to Phenolic Compound Synthesis and Protein Profiles of Peanut Seeds. Manuscript in Preparation.

Fajardo J E, Cuero R G, Waniska R D, and Pettit R E. Phenolic Compounds in Peanut Seeds: Enhansed Elicitation by Chitosan and Effects on Growth and Aflatoxin B1 Production by Aspergillus flavus. Manuscript in Preparation.

Fajardo J E, Waniska R D, Smith O D, and Pettit R E. Phenolic Compounds in Pods at Different Stages and Ellagic Acid in Arachis hypogaea L. Manuscript in Preparation.

Keller N P, Owen J, Bhatnagar D, Cleveland T E (1992) Utility of PCR for Diagnosis of Aspergillus Species. APS 1992 Annual Meeting, Phytopathology, abstr.

Pettit R E, Ba A, Kane A, and Sarr A B (1991) "Information Bulletin dealing with prevention of peanut infestation by A. favus" Moisissures de l'arachide et contamination par l"aflatoxine.

Phillips T D, Sarr A B, Clement B A, Kubena L F, and Harvey R B (1991) Prevention of Aflatoxicosis in Farm Animals via Selective Chemisorption of Aflatoxin. In Mycotoxins, Cancer, and Health, Volume 1. Pennington Center Nutrition Series, Louisiana State University Press, Baton Rouge.

Sarr, Ahmedoul Bachir (1992) Evaluation of Innovative Methods for the Detection and Detoxification of Aflatoxins. Ph. D. Dissertation.

TRAINING: DEGREE AND SHORT-TERM

Two Ph.D. students have successfully defended their thesis work. Dr. A Bachir Sarr (a student from Senegal) recieved his degree from the Department of Veterinary Public Health in Jan. 1992 and is currently conducting a research project through a cooperative effort between Dr. Phillip's laboratory at Texas A&M and ITA in Dakar, Senegal. Mr. Julius Fajardo (a student from the Philippines) will be awarded his degree from the Department of Plant Pathology and Microbiology in Aug. 1992.

OTHER

The ISRA Peanut CRSP-Aflatoxin laboratory was transferred from Kaolack, Senegal to Bambey, Senegal in 1991 in order to coordinate better the research on peanut at the national level in Senegal.

PLANS FOR 1992-1993

Host Countries

Continue review of programs in Senegal with completion of the current field tests and field screening of peanut genotypes/cultivars for resistance to A. flavus. Examine the potential utilization of newly developed assays to screen for aflatoxin resistant peanut cultivars.

Continue studies on the detoxification of aflatoxins with emphasis of applications of Nova SilTM in peanut meal, animal feeds and commerical processing in Senegal. Studies will include participation in programs to test small scale oil mills in villages for the efficacy of potential detoxification procedures and to develop a modified clay that will settle faster with gravity in peanut oil.

Set up contacts with Societe' Nationale de Commercialisation des Oleagineus du Senegal (SONACOS) (1) to apply the aflatoxin minicolumn test, reported earlier, to the quality control and survey of peanut products, and (2) to determine the most effective step at which HSCAS can be added in the oil extraction process to improve oil and peanut meal quality. Utilize peanut meal in feeding study in Senegal or France in collaboration with CIRAD-CA.

Continue efforts to obtain official approval to establish collaborative and cooperative research activities with identified scientists and institutions in Ghana. Upon approval, initiate studies (a) to identify fungistatic/fungi toxic compounds from West African plants which inhibit or induce the production of aflatoxins or other mycotoxins and (b) to evaluate the occurrence of mycotoxigenic Fusarium species and related mycotoxins on peanut.

Texas

Continuation of creation of microbiological assay using A . flavus, A. nidulans and A. parasiticus mutants in the aflatoxin pathway for screening for tolerance in peanut.

Continued isolation and characterization of enzymatic and regulatory genes in the aflatoxin pathway using A. flavus, A. parasiticus and A. nidulans isolates.

Examination of various components of peanut cotyledon (eg lipids, carbohydrates and proteins) for ability to induce aflatoxin at a biochemical and molecular level.

Isolation of aflatoxin precursors norsorolinic acid, averantin, averufin and versicolorin A for use in microbiological assays, detection studies and feeding experiments.

Test selected peanut genotypes and cultivars for resistance to A. flavus colonization and aflatoxin production using field tests and microbial assays.

Undertake studies to evaluate the occurrence of Fusarium mycotoxins and mycotoxigenic fungi in peanut.

Continue identification, characterization and isolation of structural and regulatory genes in the trichothecene biosynthetic pathway(s) present in Fusarium species.

Develop a minicolumn method for the detection of fumonisins.

Conduct a full feeding study with F-344 rats to evaluate the effects of HSCAS and other phyllosilicates on weight gain, histopathology and other parameters.

Continue training programs within the LDC, and in Texas to train staff and professionals in fungal identification, detection methodologeis, detoxification procedures, and overall management of the mycotoxin problem.

GA/IM/BF

IPM Strategies for Peanut Insects in SAT Africa

University of Georgia
University of Ouagadougou, Institute Superior Polytechnique

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 Sahel of West Africa continues as one of the crucial problems for the inhabitants of the region and is characterized by wide variations between years. Food production in this region is the responsibility of peasant farmers who use primitive production practices that result in subsistence farming. Using such production techniques, inadequate rainfall, poor distribution of rainfall during the growing season, and losses from plant pests often result in tremendous fluctuations in the quantity/quality of food produced. Thus, during years with adequate rainfall, farmers increase crop production, since the food produced may have to suffice for one to several years. Successive years with inadequate rainfall or major losses due to plant pests leads to famine, as noted recently in Ethiopia and Somalia. Thus, the major goal for West Africa is stability in 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 in these countries. Equally important to direct losses caused by arthropod injury are the plant pathogens that they transmit or exacerbate. Rosette transmitted by the peanut 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. 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 peanut 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 they 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.

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MAJOR ACCOMPLISHMENTS

Research Results

Research in Burkina Faso was conducted at two locations, Gampala and Farakoba, in 1991. 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 neem for control of insect injury on peanut.

At Gampala, thrips and jassid damage to peanut declined with increase in plant population. However, this trend was not evident at Farakoba. Aphids, rosette, and termite damage were more prevalent at Farakoba. No 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 at Gampala. However, at Farakoba peanut yield increased with each increase in plant population.

Termite injury to peanut pods increased linearly with an increase in days to harvest at Gampala. This increase in pod injury was directly related to a decrease in soil moisture from an average of 6.8% at 90 days to 1.4% at 120 days. Maximum yield in both untreated and insecticide-treated plots was recorded at 100 days after planting and then declined with each delay in harvest.

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. Termite damage increased significantly with a delay in harvest. RMP 12, NCAc 2240, NCAc 2243, NCAc 2242, and NCAc 343 sustained the least damage, significantly less than the susceptible Robut 33-1. Yield of M13, NCAc 343, RMP 40, and RMP 12 were among the highest, even with a delay in harvest. At Farakoba, an interaction in termite damage was between peanut cultivar and harvest date. Termite damage to pods averaged less than 1% for NCAc 2243, NCAc 2242, NCAc 2240, NCAc 2230, and NCAc 343.

Treatment with neem produced no meaningful significant differences for reduced damage by thrips, jassids, Lepidoptera, or termites. No consistent trends for reduced damage to plants or pods were noted with the use of neem for insect control at either Gampala or Farakoba. Likewise, no significant differences in yield were noted at Gampala in the evaluation of neem for insect control. At Farakoba, several neem treatments resulted in yields that were comparable with that for the insecticide treatment, but none of the treatments produced yields significantly higher than the yield of the untreated control.

Evaluation of recommended peanut cultivars in the U.S. for insect damage showed significant differences among cultivars in thrips damage and in laboratory bioassays against the fall armyworm and velvetbean caterpillar. However, no differences were noted in potato leafhopper or velvetbean caterpillar damage ratings in the field. Significant yield and grade differences were also noted among cultivars.

Laboratory evaluation of 14 plant introductions against the velvetbean caterpillar produced significant differences in their level of susceptibility. Evaluation of another group of plant introductions in the field resulted in significant differences in thrips, leafhopper, and velvetbean caterpillar damage ratings. Similarly, evaluation of selected peanut genotypes (from the NC/IM insect project) and cultivars in the field produced significant differences in thrips, leafhopper, and velvetbean caterpillar damage ratings.

The sweetpotato whitefly, Bemisia tabaci (Gennadius), attacking peanut in Georgia was identified as Strain B, the poinsettia strain. Measurements of immatures on peanut showed that their were 4 nymphal instars and that their sizes on the upper versus lower leaf surface were comparable, with the exception that fourth instars were significantly larger on the upper leaf surface than fourth instars on the lower leaf surface. Few immatures were found on the terminal or second leaf of a lateral branch. They were most abundant on leaves 3, 4, and 5 and then their numbers declined with an increase in leaf age. Immatures were 3-5 times more abundant on Florunner than on Southern Runner. Yellow sticky traps placed in a horizontal position at ground or canopy level with the sticky surface upward were most effective in capture of sweetpotato whitefly adults.

GOALS

Major goals for the research are: 1) identify the major arthropod pests of peanut in Burkina Faso; 2) determine the economic significance of these arthropods on peanut yield; 3) develop IPM strategies and control measures to reduce losses to these pests; and 4) determine the relationship between injury to peanut pods by arthropods and the incidence of aflatoxin contamination.

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. Develop bait attractants or other control strategies for the major insect pests.

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

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. Bharat Singh, Principal Investigator, Department of Food Science, Alabama A&M University, Normal, Alabama.

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

Dr. Alfred S. Traore, Food Scientist, 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." Completed one year of classwork and research.

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.

RESEARCH ACCOMPLISHMENTS

Burkina Faso

Effect of Plant Populations on Insects

Gampala

Significant differences were recorded in thrips, jassid, Lepidoptera, and termite damage in the study on peanut plant populations (Table 1). Thrips and jassid damage were significantly greater in plots with 120,000 and 180,000 plants/ha than damage in plots with 220,000 or 330,000 plants/ha. Lepidopteran defoliation

was significantly higher with plant populations of 180,000/ha than defoliation with 120,000 or 220,000/ha, but did not differ from that at 330,000/ha. Termite damage to plants was significantly lower at 120,000 plants/ha than at 180,000 and 330,000 plants/ha, but did not differ from damage at 220,000 plants/ha.

A significant interaction was noted between plant population and harvest date in the number of plants/row at harvest (Table 2). This interaction resulted from differences in the number of plants for the 180,000 and 220,000 plants/ha treatments at normal harvest (October 4) versus the delayed harvest (October 19); number of plants was significantly greater for the 180,000 treatment than for the 220,000 treatment at the normal harvest date, but their were no significant differences in the number of plants between these two treatments at the delayed harvest. Pod damage due to termites, both scarified pods and penetrated pods, was not affected by plant population, but a significant increase in damage when harvest was delayed was noted. Increase in plant population, control of insects with insecticides, or delay in harvest did not affect peanut yield.

Farakoba

At Farakoba, plant population did not affect thrips or jassid damage, lepidopteran defoliation, or the number of plants with rosette (Table 3). Aphid numbers generally increased as plant population increased and were significantly more abundant at 330,000 plants/ha than at 120,000 or 180,000 plants/ha. However, these differences in aphid abundance did not correspond to the number of plants with rosette. The number of termite-damaged plants/plot generally increased with increase in plant population.

The number of peanut plants at harvest was significantly influenced by a plant population X harvest date interaction (Table 4). At the normal harvest date, October 26, numbers of plants/row were consistent with the expected plant populations. However, at the delayed harvest, November 10, number of plants was lower for the 220,000 treatment than for the 180,000 plants/ha treatment. Also, for all treatments except one, there was an increase in the number of plants/plot between the normal versus delayed harvest; plant numbers declined from normal to delayed harvest for the 220,000 plant/ha treatment where insecticides were applied to control insects. Both plant population and harvest date had a significant impact on the percentage of termite-scarified and undamaged pods, while only harvest date influenced the percentage of termite-penetrated pods. The percentage of scarified pods was significantly greater with 330,000 and 220,000 plants/ha than the percentage with 120,000 plants/ha. A delay in harvest significantly increased the percentage of scarified and penetrated pods. However, peanut yield did not differ between harvest dates, but showed a general increase with increased plant population. Use of insecticides to control insect damage resulted in a 44.3 percent increase in yield at 220,000 plants/ha.
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 aldicarb and chlorpyrifos 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). Furthermore, insecticides failed to significantly decrease damage to plants at any of the harvest times.

There was a general increase in externally damaged pods with increase in time until harvest, but insecticides failed to reduce damage at any of the harvest intervals compared to untreated plots harvested on the same date. No significant differences were recorded for the percentage of termite-penetrated pods among any of the treatments.

Soil moisture declined with days to harvest and was significantly correlated with total percentage pod damage (external + penetrated) from untreated plots.

Peanut yield was significantly increased by use of insecticides in only the 90-day harvest. Yields were maximum for both the insecticide-treated and untreated plots at 100 days and then declined with each delay in harvest.

Farakoba

The number of termite-damaged plants increased significantly with each increase in time to harvest at Farakoba (Table 6). With the exception of the first harvest, insecticides significantly decreased the number of plants damaged by termites compared with the number of damaged plants in the untreated counterparts. However, it was obvious that the effectiveness of chlorpyrifos applied 90 days after planting had declined by 110 and especially 120 days after planting.

External pod scarification due to termite feeding was significantly greater at 120 days than similar damage to pods at 100 days, but did not differ significantly from that recorded at 90 or 110 days after planting. Insecticides were effective in reducing this damage only at 90 and 110 days. In untreated plots, the percentage of termite-penetrated pods increased significantly at 110 and 120 days compared with the percentage at 90 days. Insecticides were effective in reducing the damage only at 110 days and then declined in effectiveness.

Soil moisture declined with increase in the time until harvest and was again significantly correlated with total pod damage (external + penetrated) for the untreated plots.

Peanut yield was significantly greater when insecticides were applied for insect control for each of the harvest times. Maximum yield for the untreated plots was recorded at 100 days and then declined with each delay in harvest. Conversely, maximum yield for the treatments with insecticide was recorded at 120 days, but was not significantly greater than yield recorded for the other harvests with insecticides. The maximum yield produced with use of insecticides was only 4.0 percent greater than the maximum yield produced without insecticides.

Termite Resistant Peanut Lines

Gampala

Peanut cultivars selected for resistance to termites in India were evaluated for resistance to termites in Burkina Faso. The number of plants/row at harvest was affected by both cultivar and harvest date (Table 7). Significantly more plants were recorded at harvest for cultivars NCAc 2230, NCAc 17888, and TMV 2 than were recorded for NCAc 2142, TS 32-1, RMP 40, NCAc 343, and M-13. Significantly more plants were also recorded for the first harvest date than were recorded for the delayed harvest.

The number of termite-damaged plants or termite-penetrated pods was not affected by either cultivar or harvest date (Table 7). However, the percentage of externally damaged and percentage undamaged pods was affected by both cultivar and harvest date. The percentage of externally damaged pods was significantly greater for the second harvest than the percentage for the first harvest. Significantly more Robut 33-1 pods were damaged externally than were damaged for any other variety. Less than 3.5% external damage to pods was recorded for RMP 12, NCAc 2240, NCAc 2243, and NCAc 2242. Likewise, Robut 33-1 had the lowest percentage of undamaged pods, significantly fewer than any other variety. Over 95% of the pods from cultivars RMP12, NCAc 2240, NCAc 2243, RMP 40, and NCAc 2242 were undamaged.

Peanut yield was affected by cultivar, harvest date, and an interaction between these factors (Table 7). For the first harvest, yield was significantly greater for M-13 than for any other cultivar. M-13 was also the highest yielding cultivar for the second harvest, but its yield was not significantly greater than several of the cultivars with relatively low levels of termite damage to pods, notably NCAc 343, RMP 12, and RMP 40.

Farakoba

Significant cultivar, harvest date, and cultivar x harvest date interactions were noted at Farakoba in the number of plants/row at harvest, number of termite-damaged plants, and percentage of externally damaged, penetrated, and undamaged pods (Table 8). Analysis by harvest date for number of plants/row at harvest showed significant differences among cultivars for both harvest dates. However, the magnitude of change varied by cultivar between the two harvest dates. This was extremely evident for cultivars J 11 and Robut 33-1. At the first harvest, both of these cultivars had plant populations that were comparable to that recorded for NCAc 17888, the cultivar with the highest number of plants/row. However, by the second harvest, plant populations for J 11 and Robut 33-1 had declined by 44.1 and 42.6 percent and both had a significantly lower number of plants/row than did NCAc 17888.

Similarly, significant differences were recorded for the number of termite-damaged plants on both harvest dates (Table 8). NCAc 343 and RMP 12 had no pod damage on the first harvest, but did not differ significantly from that recorded for RMP 40, NCAc 2243, M-13, NCAc 2230, NCAc 2242, NCAc 17888, Robut 33-1, or NCAc 10033. By the second harvest, termite damage to plants had increased substantially, and NCAc 10033, Robut 33-1, and NCAc 2242 had significantly more damaged plants than did NCAc 343.

Pod damage due to termite feeding was relatively low on both harvest dates, but significant differences were noted between cultivars in the percentage of externally damaged, penetrated, and undamaged pods on each harvest (Table 8). For the first harvest, external damage was lowest for NCAc 2240, NCAc 2243, NCAc 343, RMP 40, and NCAc 2242, but did not differ significantly from the percentage recorded for M-13, NCAc 2142, NCAc 2230, NCAc 17888, or RMP 12. On the second harvest, external damage for RMP 12 and NCAc 2142 was significantly greater than that recorded for NCAc 2243.

The percentage of pods penetrated by termites was lowest for cultivars NCAc 2243, NCAc 343, RMP 12, NCAc 2230, and NCAc 10033 on the first harvest date. By the second harvest, damage had increased in NCAc 10033 so that it was significantly more damaged than the least damaged cultivar, NCAc 2243. Also, pod penetration for NCAc 2242 increased only slightly between the first and second harvest so that damage on the second harvest was not significantly higher than that recorded for NCAc 2243.

On the first harvest, the highest percentage of undamaged pods was recorded for NCAc 2243, but was not significantly higher than values recorded for NCAc 343, NCAc 2230, or RMP 12 (Table 8). NCAc 2243 also had the least amount of damage on the second harvest. NCAc 343 and NCAc 2230 continued to have damage comparable with that recorded for NCAc 2243, but RMP 12 sustained slightly more pod damage than did NCAc 2243. Also, NCAc 2242 showed only a slight increase in pod damage from the initial harvest until the last harvest and was comparable to NCAc 2243 in the percentage of undamaged pods on the second harvest date.

Peanut yield at Farakoba was extremely low and was influenced only by cultivar (Table 8). Yield was greatest for RMP 12, a variety with resistance to rosette and adapted to the growing region, but not significantly greater than the yield for TS 32-1, RMP 40, NCAc 10033, or Robut 33-1.

Arthropod Control with Neem

Gampala

Pulverized neem seed mixed with corncob granules were compared with Margosan-O, a commercial preparation of neem, for insect control in Burkina Faso. These preparations were applied at a low and high rate and at 60 or 80 days after planting. Margosan was also applied at 60 days at the high rate twice per week for 3 successive weeks. These treatments were compared with control obtained with a combination of two applications of aldicarb plus two applications of chlorpyrifos. At Gampala, significant differences were noted among treatments in thrips damage, jassid damage, lepidopteran defoliation, and number of termite-damaged plants (Table 9). However, the real biological significance of these differences is questionable; thrips damage and termite damaged plants in the untreated control were comparable with those recorded for the insecticide treatment, and even the highest reduction in jassid damage or lepidopteran defoliation obtained with neem was not significantly different from that recorded for the untreated control.

The percentage of externally damaged pods, percentage undamaged pods, and peanut yield were affected only by harvest date at Gampala (Table 10). Conversely, the percentage of termite-penetrated pods was affected only by treatment. The percentage of externally damaged pods increased slightly while the percentage of undamaged pods and peanut yield decreased slightly with a delay in harvest. The percentage of penetrated pods was lowest for the treatments with insecticide and low rate of Margosan applied at 60 days, but neither were significantly lower than the number of penetrated pods recorded for the untreated control.

Farakoba

Significant differences among treatments were noted in thrips damage, jassid damage, lepidopteran damage, aphid abundance ratings, and number of plants with rosette (Table 11). Differences noted in thrips, jassid, and lepidopteran damage were primarily due to the insecticide treatment which sustained the lowest level of damage for each of these insects. Several of the neem or Margosan treatments reduced thrips or lepidopteran damage comparable to that obtained with the use of insecticides, but none of these treatments reduced damage significantly below that recorded for the untreated control. Aphid abundance was significantly reduced by application of Margosan twice a week for three weeks, neem at a low rate applied at 60 days, Margosan at a high rate applied at 60 days, Margosan at a high rate applied at 80 days, and the insecticide treatments. A significant reduction in the number of plants with rosette was also noted for the Margosan 2X for three weeks, neem at low rate at 60 days, neem at a high rate at 60 days, Margosan at a low rate at 60 days, Margosan at a low rate at 80 days, Margosan at a high rate at 80 days, and insecticide treatments compared with the number of plants with rosette for the untreated control.

The percentage of externally damaged, penetrated, and undamaged pods was not influenced by neem treatment, but was affected by harvest date (Table 12). The percentage of externally damaged and penetrated pods as a result of termite feeding increased significantly with a delay in harvest, resulting in a corresponding decrease in the percentage of undamaged pods with a delay in harvest.

Peanut yield was significantly greater for the insecticide treatment than yield for the treatment with Margosan applied at a low rate at 80 days (Table 12). However, yield for the insecticide treatment did not differ significantly from yield for the untreated control or the remainder of the neem treatments.

Georgia

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 NC 9 than damage for GK-7, Southern Runner, and Georgia Runner (Table 13). No significant differences were noted in the ratings for potato leafhopper or velvetbean caterpillar damage in the field. Laboratory bioassays of leaf tissue collected from the field plots failed to show differences among cultivars in their host suitability index for the fall armyworm, but did show significant differences in host suitability for the velvetbean caterpillar. A high host suitability index would indicate that the cultivar was more susceptible to damage by the test insect, while a lower rating would suggest that the cultivar was less susceptible to damage. GK-7, Southern Runner, and NC 7 had significantly lower host suitability ratings than Sunrunner for velvetbean caterpillar.

Peanut yield was significantly greater for Sunrunner than for any other cultivar (Table 13). Similarly, yield for Georgia Runner was significantly greater than that of all cultivars except Sunrunner, GK-3, and Southern Runner. Total sound mature kernels were significantly higher for Florunner, GK-7, Southern Runner, and Georgia Runner than those for the other cultivars.

Evaluation of Plant Introductions for Resistance to Insects

Fourteen peanut plant introductions that had been selected in previous tests for their resistance to insect damage in the field were evaluated in a laboratory bioassay against the velvetbean caterpillar. Plants for these lines were grown in replicated plots in the field and leaves were collected and brought to the laboratory for assay. Significant differences were noted among lines in the weights of larvae at 10 days, days to pupation, weights of pupae, days to adults, and survival to adults (Table 14). Expressing these differences in a host suitability index showed that PI 471985 and PI 259714 were significantly more susceptible to velvetbean caterpillar feeding than most other lines. Conversely, PI 196619 had the lowest rating and was significantly more resistant than PI's 259714, 270828, 275498, 336963, 431457, and 471985.

An additional 16 lines were evaluated in the field for insect damage in comparison to a standard cultivar, Florunner. Tobacco thrips damage ratings were lowest for PI's 196665 and 279627, and were significantly lower for eleven of the PI's than the rating for Florunner (Table 15). PI 196665 also had the lowest potato leafhopper damage rating and was the only line with a lower rating than the rating for Florunner. Damage ratings for the velvetbean caterpillar were lowest for PI's 196612 and 196627, and all sixteen lines were rated significantly lower than Florunner. Peanut yield was greatest for PI 186482. Several of the PI's produced yields that were comparable to the yield of Florunner, but none had percentages of sound mature kernels comparable to that for Florunner.

Resistant Peanut Genotype Evaluation

Twelve of the original 54 peanut genotypes evaluated in cooperation with the NC/IM Project were selected for further evaluation. Four genotypes from Georgia, NC 6, NC 7, and Florunner were also included in the test. Tobacco thrips damage ratings were lowest for NC 7 x NC 343 (4-91) and NC 6, significantly lower than the rating for Florunner (Table 16). Leafhopper damage ratings were lowest for NC 7 x NC 10247 (12-91) and NC 7 x NC 343 (6-91), significantly lower than the ratings for Florunner. Five of the entries [NC 7 x NC 343 (3-91), NC 7 x NC 343 (4-91), NC 7 x NC 15745 (11-91), GAT-2845, and GAT-2736] had significantly lower damage ratings for the velvetbean caterpillar than did Florunner.

Sweetpotato Whitefly on Peanut

Studies on the sweetpotato whitefly as a pest of peanut showed that there were four instars for the insect on Florunner peanut with mean length and width (μm) as follows: 1st instar 207.8 ± 5.4, 120.9 ± 4.4; 2nd instar 314.9 ± 8.8, 194.0 ± 6.4; 3rd instar 442.6 ± 11.2, 289.1 ± 8.0; and 4th instar 619.3 ± 9.2, 428.7 ± 4,4 (Table 17). Few immatures were found on the terminal and second leaf of a lateral branch of Florunner peanut (Table 18). They were most abundant on leaves 3, 4, and 5 and then their numbers declined with an increase in leaf age. Immatures were found on both the upper and lower surfaces of peanut leaves, but were equally distributed among the tetrafoliates of a peanut leaf.

A comparison of the distribution and populations of sweetpotato whitefly immatures on Florunner and Southern Runner showed similar distributions on the two cultivars, but with considerably higher numbers on the leaves of Florunner than on the leaves of Southern Runner (Figure 1). A comparison of these cultivars over time showed that 3-5 times as many immatures were found on Florunner as were found on Southern Runner (Figure 2).

Evaluation of yellow sticky traps for monitoring populations of sweetpotato whitefly adults in Florunner peanut showed that traps placed in a horizontal position at ground or at canopy level with their sticky surface up were most effective in the capture of adults (Figure 3).

PUBLICATIONS AND PRESENTATIONS

Publications:

Idrissa, I. O. 1991. Evaluation de la resistance des gousses de quelques varieties d'Arachide aux attaques des termites (Isopteres: Termitidae) et des iules (Myriapodes: Diplopodes). Rev. Res. Amelior. Prod. Agr. Milieu Aride 3:63-72.

Lynch, R. E., and D. M. Wilson. 1991. Enhanced infection of peanut, Arachis hypogaea L., seeds with Aspergillus flavus group fungi due to external scarification of peanut pods by the lesser cornstalk borer, Elasmopalpus lignosellus (Zeller). Peanut Science 18:110-116.

Mack, T. P., D. P. Davis, and R. E. Lynch. 1992. Development of a model to time scouting for the lesser cornstalk borer (Lepidoptera: Pyralidae) attacking peanut in the Southeastern U.S. J. Econ. Entomol. (In press)

Lynch, R. E., and G. K. Douce. 1992. Implementation of integrated pest management program in peanut: Current status and future direction. Proc. Second International Peanut Workshop, Patancheru, A. P., India. 25-29 Nov. 1991, ICRISAT Pub. No. (In press).

Lynch, R. E., I. O. Dicko., S. A. Some, and A. P. Ouedraogo. 1991. Effect of harvest date on termite damage, yield, and aflatoxin contamination in peanut in Burkina Faso. International Arachis Newsletter 10:24-25.

Lynch, R. E., and A. S. Simmons. 1993. Distribution of immatures and monitoring of adult sweetpotato whitefly, Bemisia tabaci (Gennadius) (Homoptera: Aleyrodidae), in peanut, Arachis hypogaea L. Environmental Entomology (In press).

Presentations:

Lynch, R. E., and G. K. Douce. 1991. Implementation of integrated pest management program in peanut: Current status and future direction. Proc. Second International Peanut Workshop, Patancheru, A. P., India. 25-29 Nov. 1991.

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.

Lynch, R. E. 1992. Impact of insects in less developed countries. Entomology 773, Entomology for Teachers, Cooperative Extension Service, University of Georgia, Tifton, GA. May 12, 1992.

TRAINING

Research conducted by the Peanut CRSP in Burkina Faso was used to train the following students at the University of Ouagadougou:

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 Some, former assistant collaborator on the Peanut CRSP Entomology Project, returned to the University of Georgia to obtain his Ph.D. in agronomy, working under the direction of Dr. Bill Hargrove. Dr. Lynch is serving on the graduate committee for Mr. Some.

INTERNATIONAL TRAVEL

U.S. Participants

Dr. Robert E. Lynch was invited to make a presentation and participated in the Second International Peanut Workshop at the ICRISAT Center, Patancheru, A. P., India, Nov. 25-30, 1991.

Host Country Participants

Dr. Idrissa Dicko attended the Second International Peanut Workshop at the ICRISAT Center, Patancheru, A. P., India, Nov. 25-30, 1991.

PLANS FOR 1992/93

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.

5. Evaluate the efficacy and placement of yellow sticky traps for monitoring populations of aphids and jassids in peanut.

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 LCB feeding.

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

4. Evaluate Group II Plant Introductions (runner plant types) for resistance/susceptibility to insects.

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

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

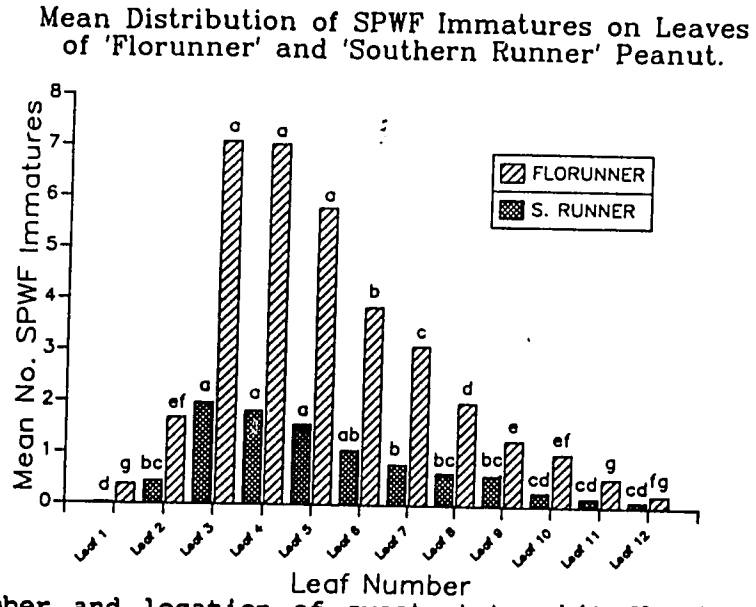

Figure 1. Mean number and location of sweetpotato whitefly immatures on the leaves of Florunner and Southern Runner peanuts.

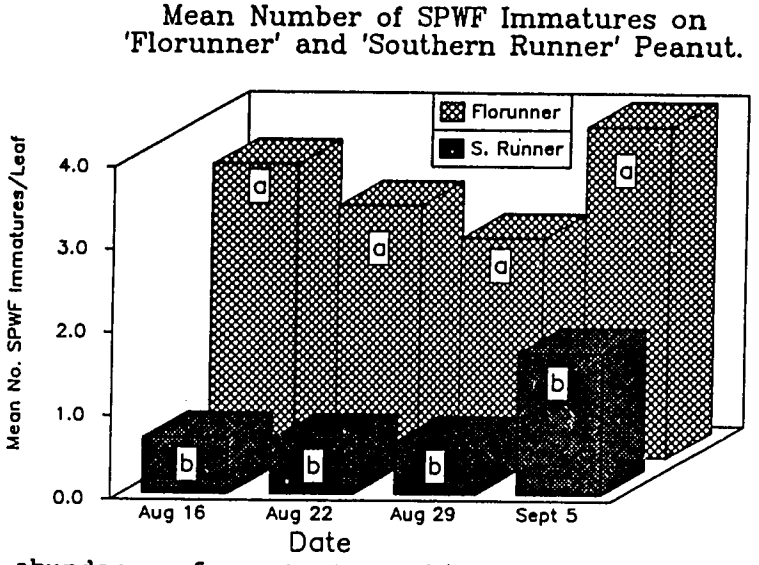

Figure 2. Relative abundance of sweetpotato whitefly immatures on Florunner and Southern Runner peanuts over time.

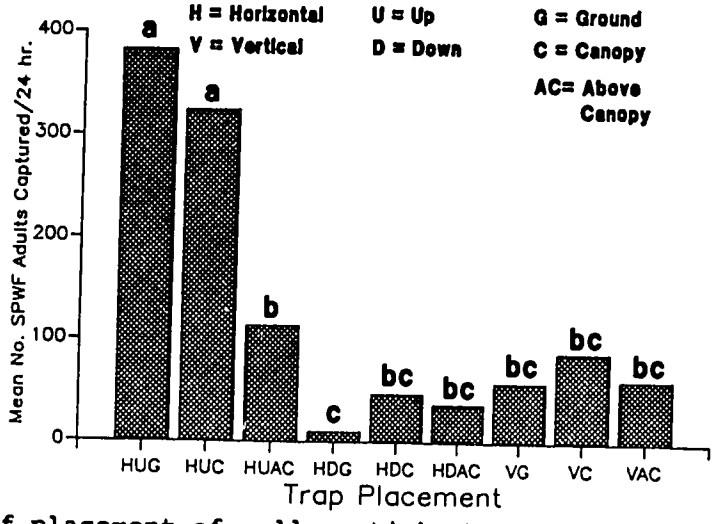

Figure 3. Effect of placement of yellow sticky traps on capture of sweetpotato whitefly adults in Florunner peanuts.

Table 1. Effect of plant populations on insect damage to peanut, Gampala, 1991[a].

Treatment (Plants/ha)	No. Plants/m	Thrips Damage	Jassid Damage	Lepidoptera Defoliation	Aphid Abundance	No. Plants With Rosette	No. Termite-Damaged Plants
120,000	4.2 c	3.2 a	3.4 a	1.5 b	0.0 a	0.0 a	2.8 b
180,000	4.3 c	3.3 a	3.0 a	2.5 a	0.0 a	0.0 a	9.4 a
220,000	9.3 ab	2.1 bc	1.6 bc	1.6 b	0.0 a	0.0 a	7.0 ab
330,000	9.5 a	2.4 b	2.1 b	1.9 ab	0.0 a	0.0 a	9.4 a
220,000-Chem. Cont.	8.8 b	1.6 c	1.3 c	0.8 c	0.0 a	0.0 a	4.0 ab

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 2. Effect of plant population on pod damage by termites and yield of peanut, Gampala, B.F., 1991[a].

Plant Population (No./ha)	No. Plants at Harvest			Pod Damage (%)									Yield (kg/ha)		
				Scarified			Penetrated			Undamaged					
Treatment	***			NS			NS			NS			NS		
Harvest Date	***			***			*			*			NS		
T. x H.D.	*			NS			NS			NS			NS		
	Oct. 4	Oct. 19	Mean	Oct. 4	Oct. 19	Mean	Oct. 4	Oct. 19	Mean	Oct. 4	Oct. 19	Mean	Oct. 4	Oct. 19	Mean
120,000	84.6 d	92.0 c	88.3	1.1	10.6	5.8 a	1.0	4.1	2.5 a	98.0	85.4	91.7 a	3253.6	2354.5	2804.0 a
180,000	181.0 b	128.4 b	154.7	2.4	9.0	5.7 a	1.6	3.8	2.7 a	96.1	87.3	91.7 a	2785.4	2528.2	2656.8 a
220,000	133.8 c	133.0 b	133.4	1.5	17.1	9.3 a	2.1	4.8	3.5 a	88.6	78.2	83.4 a	3277.4	2774.1	3025.8 a
330,000	253.4 a	206.8 a	230.1	3.7	13.7	8.7 a	2.8	4.1	3.4 a	93.6	82.6	88.1 a	3743.9	3122.0	3433.0 a
220,000 - Insecticide	156.8 bc	128.0 b	142.3	2.3	23.7	9.5 a	2.8	6.3	3.8 a	94.9	66.4	86.8 a	3695.8	4278.1	3985.0 a
Mean	161.9	137.6		2.2 b	13.9 a		2.0 b	4.4 a		94.2 a	81.8 b		3351.2 a	3011.4 a	

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 3. Effect of plant populations on insect damage to peanut, Farakoba, 1991[a].

Treatment (Plants/ha)	No. Plants/m	Thrips Damage	Jassid Damage	Lepidoptera Defoliation	Aphid Abundance	No. Plants With Rosette	No. Termite-Damaged Plants
120,000	5.0 c	1.4 a	1.4 ab	1.4 a	0.0 b	25.0 a	46.6 b
180,000	5.0 c	1.2 a	1.8 ab	1.6 a	0.4 b	27.8 a	95.6 a
220,000	7.2 ab	1.2 a	2.0 ab	2.0 a	0.6 ab	11.0 a	81.0 ab
330,000	8.4 a	1.4 a	2.4 a	2.0 a	1.2 a	22.6 a	101.6 a
220,000-Chem. Cont.	6.2 bc	0.6 a	1.0 b	1.6 a	0.0 b	34.2 a	49.4 b

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 4. Effect of plant population on pod damage by termites and yield of peanut, Farakoba, B.F., 1991[a].

Plant Population (No./ha)	No. Plants at Harvest			Pod Damage (%)									Yield (kg/ha)		
				Scarified			Penetrated			Undamaged					
Treatment	***			**			NS			**			**		
Harvest Date	*			**			*			***			NS		
T. x H.D.	*			NS			NS			NS			NS		
	Oct. 26	Nov. 10	Mean	Oct. 26	Nov. 10	Mean	Oct. 26	Nov. 10	Mean	Oct. 26	Nov. 10	Mean	Oct. 26	Nov. 10	Mean
120,000	67.0 d	69.6 d	68.3	9.7	22.0	15.8 b	8.9	8.2	8.5 a	81.5	69.9	75.7 a	1067.6	704.6	886.1 c
180,000	85.6 cd	122.8 b	104.2	19.0	34.7	26.8 ab	7.0	15.2	11.1 a	74.0	50.2	62.1 bc	1432.5	1410.9	1421.7 bc
220,000	94.2 bc	105.0 bc	99.6	26.1	42.5	34.3 a	9.7	18.2	13.9 a	64.2	39.3	51.8 c	1224.8	1459.2	1342.0 c
330,000	128.0 a	143.2 a	135.6	25.0	38.4	31.7 a	10.4	21.1	15.7 a	64.7	40.6	52.6 c	2718.8	1727.3	2223.0 ab
220,000 - Insecticide	108.4 ab	97.2 c	102.8	12.6	22.8	17.7 b	4.4	13.9	9.2 a	83.0	63.4	73.2 ab	2122.4	2696.6	2409.5 a
Mean	96.6	107.6		18.5 b	32.1 a		8.1 b	15.3 a		73.5 a	52.7 b		1713.2 a	1599.7 a	

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 5. Effect of peanut harvest date on termite damage to peanut, Gampala, 1991[a].

Treatment (Days After Planting)	No. Termite-Damaged Plants	Postharvest Pod Damage (%)			Soil weight (mg)		Soil moisture (%)	Yield (kg/ha)
		External	Penetrated	Undamaged	Wet	Dry		
90	3.4 bc	4.6 bc	1.3 a	94.2 a	69.9 a	65.1 a	6.7 ab	2304.8 b
90-Insecticide	2.6 bc	2.2 c	0.5 a	97.3 a	66.0 a	61.4 a	6.9 a	2840.7 a
100	8.2 a	1.9 c	1.0 a	97.2 a	38.7 b	37.7 b	2.7 c	2525.4 ab
100-Insecticide	5.0 ab	2.0 c	0.5 a	97.6 a	41.8 b	38.9 b	3.9 abc	2961.4 a
115	0.2 c	7.4 bc	3.0 a	89.2 ab	38.6 b	37.7 b	2.4 c	2294.5 b
115-Insecticide	1.2 bc	6.7 bc	2.6 a	90.9 ab	36.9 b	34.8 b	2.4 c	2519.1 ab
120	0.2 c	19.4 ab	2.5 a	78.1 bc	38.2 b	37.7 b	1.3 c	2176.0 b
120-Insecticide	1.2 bc	33.6 a	1.6 a	64.8 c	38.6 b	38.0 b	1.5 c	2038.6 b

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 6. Effect of peanut harvest date on termite damage to peanut, Farakoba, 1991[a].

Treatment (Days After Planting)	No. Termite-Damaged Plants	Postharvest Pod Damage (%)			Soil weight (mg)		Soil moisture (%)	Yield (kg/ha)
		External	Penetrated	Undamaged	Wet	Dry		
95	4.4 d	18.8 ab	1.7 c	79.6 bc	83.9 a	79.5 a	5.2 a	1118.9 b
95-Insecticide	0.6 d	4.5 c	1.7 c	93.9 a	82.6 a	78.5 a	5.0 a	1678.0 a
100	17.8 c	13.4 bc	3.3 bc	83.4 ab	73.4 b	70.0 b	4.7 a	1239.4 b
100-Insecticide	3.2 d	5.5 c	0.7 c	93.9 a	70.5 b	67.0 b	5.0 a	1660.8 a
110	60.0 b	22.6 ab	6.8 ab	70.6 cd	72.8 b	70.1 b	3.7 b	1052.1 b
110-Insecticide	24.6 c	6.8 c	2.1 c	91.1 a	70.3 b	68.1 b	3.2 b	1543.8 a
120	99.0 a	26.1 a	7.1 a	66.8 d	59.9 c	58.5 c	2.4 c	975.4 b
120-Insecticide	69.0 b	19.6 ab	6.7 ab	73.8 bcd	63.5 c	62.4 c	1.8 c	1748.5 a

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 7. Evaluation of peanut germplasm for resistance to termites, Gampala, 1991[a].

	No. Plants at Harvest			No. Termite-damaged Plants			Pod Damage (%) External			Pod Damage (%) Penetrated			Pod Damage (%) Undamaged			Yield (kg/ha)		
Treatment	*			NS			*			NS			**			***		
Harvest Date	**			NS			**			NS			**			**		
T. x H.D.	NS			NS			NS			NS			NS			*		
	Harvest Date																	
Peanut Line	9/29	10/14	Mean	9/29	10/14	Mean	9/29	10/14	Mean	9/29	10/14	Mean	9/29	10/14	Mean	9/29	10/14	Mean
M-13	134.5	123.5	129.0bcde	1.3	1.0	1.1a	4.7	5.8	5.3bcde	2.2	2.3	2.3a	93.3	91.9	92.6abc	3477.0a	3883.0a	3680.0
TMV-2	160.3	141.3	150.8a	2.3	2.0	2.1a	7.3	6.8	7.0bcd	2.0	0.7	1.3a	90.6	92.6	91.6bc	1684.0cde	1690.3def	1687.2
Robut 33-1	132.3	157.0	144.6abc	2.5	3.8	3.1a	5.8	35.8	20.8a	0.6	1.3	0.9a	93.6	63.0	78.3d	2464.7b	1879.0de	2171.8
NCAc 343	127.5	123.5	125.5bcde	0.0	2.0	1.0a	4.7	6.4	5.5bcde	1.3	0.6	0.9a	94.0	93.1	93.5abc	2574.6b	3504.6a	3039.6
NCAc 2142	138.3	101.0	119.6e	1.8	2.0	1.9a	6.7	11.8	9.2b	1.8	1.9	1.8a	91.6	86.4	89.0c	1217.7ef	1793.4def	1505.5
NCAc 2230	156.3	148.8	152.5a	1.5	0.8	1.1a	2.2	9.0	5.6bcde	1.2	0.9	1.0a	96.6	90.1	93.4abc	1362.3def	1421.8ef	1392.1
NCAc 2240	133.0	131.3	132.1abcde	0.0	2.5	1.3a	1.2	1.4	1.3e	1.5	1.4	1.4a	96.6	97.3	97.0ab	775.3f	965.0f	870.2
NCAc 2242	158.5	127.5	143.0abc	1.3	0.3	0.8a	3.2	1.9	2.6cde	2.0	2.7	2.3a	94.9	95.5	95.2abc	1177.3ef	1391.7ef	1284.5
NCAc 2243	149.0	134.3	141.6abcd	1.0	0.8	0.9a	1.2	2.3	1.7cde	1.6	1.8	1.6a	96.6	96.3	96.4ab	790.0f	1306.3ef	1048.1
NCAc 10033	148.0	122.0	135.0abcd	2.8	2.0	2.4a	2.1	10.7	6.4bcde	0.2	0.9	0.6a	97.8	88.4	93.1abc	2418.1b	2505.6bcd	2461.8
NCAc 17888	148.5	155.8	152.1a	1.3	1.0	1.1a	2.1	8.5	5.3bcde	1.3	1.3	1.3a	96.6	90.2	93.4abc	2080.6bc	1803.7def	1942.2
RMP 40	142.3	104.5	123.4cde	2.3	2.3	2.3a	2.3	4.6	3.4bcde	0.4	0.7	0.6a	97.3	94.8	96.0ab	2091.1bc	3293.8ab	2692.4
TS 32-1	136.3	106.3	121.3de	2.5	2.5	2.5a	4.1	11.6	7.8bc	0.7	1.3	1.0a	95.3	87.1	91.2bc	1709.4cde	2308.5cd	2009.0
RMP 12	131.5	119.8	125.6bcde	0.5	1.3	0.9a	0.3	0.4	0.3e	0.9	0.7	0.8a	98.9	98.9	98.9a	1966.9bcd	3136.3abc	2551.6
J 11	139.5	151.5	145.5ab	2.5	3.5	3.0a	1.9	10.4	6.2bcde	1.1	2.3	1.7a	96.9	87.1	92.0bc	2285.9bc	1818.8def	2052.4
Mean	142.4a	129.9b		1.6a	1.8a		3.3b	8.5a		1.2a	1.4a		95.4a	90.2b		1871.7	2180.1	

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 8. Evaluation of peanut germplasm for resistance to termites, Farakoba, 1991[a].

	No. Plants at Harvest			No. Termite-damaged Plants			Pod Damage (%)									Yield (kg/ha)		
							External			Penetrated*			Undamaged					
Treatment	***			***			***			***			***			***		
Harvest Date	***			***			***			***			***			NS		
T. x H.D.	*			***			**			**			***			NS		
	Harvest Date																	
Peanut Line	11/7	11/21	Mean	11/7	11/21	Mean	11/7	11/21	Mean	11/7	11/21	Mean	11/7	11/21	Mean	11/7	11/21	Mean
M-13	103.8bcd	98.3ab	101.0	0.8cde	4.0fgh	2.4	0.5ef	1.3def	0.9	2.4fgh	5.6de	4.0	97.1bc	93.1de	95.1	448.2	525.8	487.0abc
TMV-2	93.8d	77.3bc	85.5	4.0ab	34.0a	19.0	4.2a	8.3a	6.3	8.2b	16.4b	12.3	87.6f	75.3h	81.5	313.1	284.4	298.8bcd
Robut 33-1	129.0ab	74.0bc	101.5	1.8bcde	16.3cde	9.0	3.1b	6.0b	4.5	4.4d	9.1c	6.8	92.6e	84.9g	88.7	347.1	398.4	372.7abcd
NCAc 343	65.3e	60.0cd	62.6	0.0e	0.5h	0.3	0.2f	0.2ef	0.2	1.3hi	2.4hi	1.9	98.5ab	97.4ab	97.9	214.7	268.9	241.8bcd
NCAc 2142	104.0bcd	79.5bc	91.8	6.0a	20.0bc	13.0	0.8def	1.9d	1.3	2.4fgh	5.4def	3.9	96.8c	92.6de	94.7	68.5	146.4	107.5d
NCAc 2230	123.5ab	111.8a	117.6	1.3cde	8.0efgh	4.6	0.5ef	0.4ef	0.4	1.4ghi	2.1hi	1.7	98.1abc	97.6ab	97.8	207.8	164.8	186.3cd
NCAc 2240	95.8cd	78.5bc	87.1	3.0bc	10.5defg	6.8	0.1f	0.7def	0.4	3.1ef	4.1efgh	3.6	96.9c	95.3bcd	96.1	155.7	159.1	157.4cd
NCAc 2242	130.5a	110.5a	120.5	1.5bcde	10.0defg	5.8	0.3f	0.1ef	0.2	2.4fgh	3.3ghi	2.8	97.4bc	96.6abc	97.0	80.9	66.4	73.7d
NCAc 2243	107.3abcd	109.5a	108.4	0.8cde	6.8fgh	3.8	0.1f	0.0f	0.0	0.9i	1.4i	1.2	99.1a	98.6a	98.8	229.4	217.7	223.6bcd
NCAc 10033	119.3abcd	113.8a	116.5	2.3bcde	16.5cde	9.4	1.1de	1.9d	1.5	1.9fghi	3.6efgh	2.8	96.9c	94.4cde	95.7	378.5	370.0	374.2abcd
NCAc 17888	131.5a	117.8a	124.6	1.5bcde	12.3cdef	6.9	0.9def	1.3def	1.1	4.4d	6.3d	5.4	94.7d	92.4e	93.6	296.2	273.7	285.0bcd
RMP 40	114.0abcd	113.3a	113.6	0.3de	8.8efgh	4.5	0.2f	1.1def	0.6	2.7fg	4.6defg	3.6	97.1bc	94.3cde	95.7	325.0	451.1	388.0abcd
TS 32-1	120.8abc	92.0ab	106.4	2.8bcd	18.0cd	10.4	1.6cd	3.9c	2.8	6.3c	8.4c	7.3	92.2e	87.7f	89.9	511.9	564.7	538.3ab
RMP 12	44.0e	44.0d	44.0	0.0e	3.3gh	1.6	0.8def	1.4de	1.1	1.3hi	3.4fghi	2.3	97.9abc	95.1bcd	96.5	356.8	1053.8	705.3a
J 11	127.5ab	71.3bcd	99.4	4.0ab	27.3ab	15.6	2.4bc	7.1ab	4.8	9.6a	19.6a	14.6	88.0f	73.3h	80.6	350.0	387.4	368.7bcd
Mean	107.3	90.1		2.0	13.1		1.1	2.4		3.5	6.4		91.2	95.4		285.6a	355.5a	

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 9. Effect of neem on insect damage to peanut, Gampala, 1991[a].

Treatment	Thrips Damage	Jassid Damage	Lepidoptera Defoliation	Aphid Abundance	No. Plants With Rosette	No. Termite-damaged Plants
Untreated	4.1 a	2.1 bc	2.6 abc	0.0 a	0.0 a	2.6 bcd
Margosan-High-3 wk x 2X/wk	3.3 ab	1.8 cd	2.4 bcd	0.0 a	0.0 a	3.2 bcd
Neem-Low-60d	4.1 a	2.3 ab	2.6 abc	0.0 a	0.0 a	2.2 cd
Neem-High-60d	3.9 ab	2.3 ab	2.3 cd	0.0 a	0.0 a	5.0 abc
Margosan-Low-60d	3.8 ab	2.2 bc	3.0 a	0.0 a	0.0 a	5.2 ab
Margosan-High-60d	3.5 ab	2.2 bc	2.2 cd	0.0 a	0.0 a	6.6 a
Neem-Low-80d	3.6 ab	2.7 a	2.2 cd	0.0 a	0.0 a	5.0 abc
Neem-High-80d	3.1 b	2.3 ab	2.2 cd	0.0 a	0.0 a	2.2 cd
Margosan-Low-80d	3.8 ab	1.8 cd	2.9 ab	0.0 a	0.0 a	1.4 d
Margosan-High-80d	4.1 a	2.0 bcd	2.4 bcd	0.0 a	0.0 a	3.6 bcd
Insecticide	3.6 ab	1.6 d	2.0 d	0.0 a	0.0 a	2.0 d

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 10. Effect of neem on pod damage and yield of peanut, Gampala, 1991[a].

	No. Plants at Harvest			Pod Damage									Yield (kg/ha)		
				Externally			Penetrated			Undamaged					
Treatment	NS			NS			*			**			NS		
Harvest Date	***			***			NS			***			***		
Treat. X H.D.	NS			NS			NS			NS			NS		
	10/3	10/18	Mean	10/3	10/18	Mean	10/3	10/18	Mean	10/3	10/18	Mean	10/3	10/18	Mean
Untreated	125.8	155.6	140.7 a	1.7	3.9	2.8 a	0.5	1.2	0.8 ab	97.9	95.0	96.4 a	2003.4	1692.2	1847.8 a
Margosan-High-3 wk x 2X/wk	124.4	153.8	139.1 a	0.9	2.6	1.8 a	1.2	1.7	1.4 ab	97.9	95.8	96.8 a	2217.4	2023.6	2120.5 a
Neem-Low-60d	128.2	156.6	142.4 a	1.0	2.3	1.6 a	1.9	1.2	1.5 ab	97.2	96.5	96.9 a	1795.2	1542.2	1668.7 a
Neem-High-60d	125.4	157.2	139.3 a	2.8	1.8	2.3 a	1.1	2.5	1.8 ab	96.2	95.8	96.0 a	1942.0	1741.5	1841.8 a
Margosan-Low-60d	128.8	145.4	137.1 a	1.2	4.8	3.0 a	0.5	0.3	0.4 b	98.4	95.0	96.7 a	2157.4	2056.8	2107.1 a
Margosan-High-60d	128.8	168.6	148.7 a	1.0	3.1	2.0 a	0.9	1.4	1.2 ab	98.2	95.6	96.9 a	2252.9	1761.7	2007.3 a
Neem-Low-80d	130.8	145.0	137.9 a	2.4	5.3	3.8 a	1.8	2.0	1.9 a	95.3	92.8	94.1 a	2053.6	1784.4	1919.0 a
Neem-High-80d	108.4	157.8	133.1 a	1.4	3.6	2.5 a	0.8	0.8	0.8 ab	97.9	95.7	96.8 a	2375.5	1669.0	2022.2 a
Margosan-Low-80d	138.0	158.0	148.0 a	1.9	2.7	2.3 a	0.8	0.8	0.8 ab	97.0	96.6	96.7 a	1811.8	1551.3	1681.5 a
Margosan-High-80d	121.6	143.2	132.4 a	2.5	1.9	2.2 a	1.1	0.9	1.0 ab	96.4	97.3	96.9 a	1990.0	1725.0	1857.5 a
Insecticide	115.6	153.8	134.7 a	1.2	1.2	1.2 a	0.4	0.3	0.4 b	98.5	98.5	98.5 a	2481.0	1995.6	2238.3 a
Mean	125.1 b	153.7 a		1.6 b	3.0 a		1.0 a	1.2 a		97.3 a	95.9 b		2098.2 a	1776.7 b	

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 11. Effect of neem on insect damage to peanut, Farakoba, 1991[a].

Treatment	Thrips Damage	Jassid Damage	Lepidoptera Defoliation	Aphid Abundance	No. Plants With Rosette	No. Termite-damaged plants
Untreated	1.6 ab	3.2 a	1.0 ab	2.0 ab	8.6 a	44.0 a
Margosan-High-3 wk x 2X/wk	1.2 abc	2.4 a	1.2 ab	0.4 d	1.4 c	40.0 a
Neem-Low-60d	1.0 bc	2.6 a	1.2 ab	0.2 d	3.6 bc	43.6 a
Neem-High-60d	1.6 ab	3.2 a	1.0 ab	1.0 bcd	3.8 bc	40.0 a
Margosan-Low-60d	1.8 a	3.2 a	1.8 a	1.6 abc	3.4 bc	36.6 a
Margosan-High-60d	1.6 ab	3.4 a	1.4 a	0.8 cd	5.8 abc	38.0 a
Neem-Low-80d	1.6 ab	3.4 a	1.4 a	1.0 bcd	6.2 ab	42.2 a
Neem-High-80d	1.8 a	3.6 a	1.8 a	2.2 a	4.6 abc	48.8 a
Margosan-Low-80d	1.4 ab	2.6 a	1.8 a	2.2 a	3.0 bc	41.2 a
Margosan-High-80d	1.6 ab	3.6 a	1.2 ab	0.8 cd	2.8 bc	31.2 a
Insecticide	0.6 c	0.6 b	0.2 b	0.8 cd	3.0 bc	43.0 a

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 12. Effect of neem on pod damage and yield of peanut, Farakoba, 1991[a].

	No. Plants at Harvest			Pod Damage (%)									Yield (kg/ha)		
				External			Penetrated			Undamaged					
Treatment	NS			NS			NS			NS			**		
Harvest Date	NS			***			***			***			NS		
T. x H.D.	NS			NS			NS			NS			NS		
	10/27	11/11	Mean	10/27	11/11	Mean	10/27	11/11	Mean	10/27	11/11	Mean	10/27	11/11	Mean
Untreated	90.8	82.6	86.7 a	14.4	23.4	18.9 a	10.5	8.9	9.7 a	75.2	67.8	71.5 a	985.7	1132.4	1059.1 ab
Margosan-High-3 wk x 2X/wk	81.0	78.6	79.8 a	14.3	25.3	19.8 a	7.8	11.5	9.6 a	78.0	63.2	70.6 a	1234.7	1180.9	1207.8 ab
Neem-Low-60d	82.6	76.4	79.5 a	22.2	25.8	24.0 a	8.8	11.9	10.3 a	69.1	62.4	65.7 a	1156.7	1238.3	1197.5 ab
Neem-High-60d	79.6	85.2	82.4 a	18.9	25.2	22.0 a	8.7	13.5	11.1 a	72.5	61.4	66.9 a	832.5	975.0	903.7 ab
Margosan-Low-60d	85.6	83.2	84.4 a	18.8	27.7	23.2 a	5.9	16.1	11.0 a	75.4	56.2	65.8 a	940.6	973.5	957.1 ab
Margosan-High-60d	71.0	86.8	78.9 a	13.9	25.7	19.9 a	6.9	11.6	9.3 a	79.2	62.7	70.7 a	1005.9	1416.1	1192.4 ab
Neem-Low-80d	70.2	81.4	75.8 a	13.1	22.2	17.6 a	11.4	8.9	10.1 a	74.6	68.9	71.7 a	1074.2	822.6	948.4 ab
Neem-High-80d	89.6	76.8	83.2 a	22.0	15.3	18.6 a	8.3	15.2	11.8 a	69.7	69.5	69.6 a	1002.2	942.3	972.3 ab
Margosan-Low-80d	91.4	84.2	87.8 a	13.4	18.3	15.8 a	7.2	13.6	10.4 a	79.5	68.2	73.8 a	776.6	871.1	823.9 b
Margosan-High-80d	93.6	81.0	87.3 a	20.5	25.4	22.9 a	7.7	10.4	9.0 a	71.9	64.3	68.1 a	1084.4	1215.1	1149.8 ab
Insecticide	94.0	96.6	95.3 a	5.9	15.4	10.6 a	3.7	10.5	7.1 a	82.5	72.4	77.4 a	1651.3	1511.6	1581.5 a
Mean	84.5 a	83.0 a		16.1 b	22.7 a		7.9 b	12.0 a		75.2 a	65.2 b		1066.6 a	1116.3 a	

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

Table 13. Evaluation of recommended peanut cultivars for resistance/susceptibility to insect damage[a].

Cultivar	Tobacco Thrips Damage[b]	Potato Leafhopper Damage[b]	Velvetbean Caterpillar Damage[b]	Fall Armyworm HSI[c]	Velvetbean Caterpillar HSI[c]	Yield (lb/A)	Total Sound Mature Kernels (%)
Florunner	5.0 ab	5.2 a	3.4 a	9.6 a	7.4 abc	2490.1 d	80.6 a
Sunrunner	5.0 ab	4.8 a	4.2 a	10.0 a	8.2 a	3850.9 a	78.5 b
GK-7	4.8 b	5.6 a	3.8 a	9.0 a	6.5 c	2634.6 d	80.3 a
Southern Runner	4.8 b	5.2 a	3.6 a	9.8 a	6.7 c	3124.0 bc	80.0 a
Florigiant	5.2 ab	5.2 a	2.8 a	9.4 a	7.3 abc	2848.8 cd	75.6 d
GK-3	5.0 ab	5.0 a	3.6 a	9.2 a	7.9 ab	3235.2 b	75.4 d
NC 7	5.0 ab	5.4 a	3.2 a	10.2 a	7.0 bc	2634.6 d	76.1 cd
NC 9	5.6 a	5.4 a	3.4 a	9.6 a	7.5 abc	2846.6 cd	77.1 c
Georgia Runner	4.6 b	5.0 a	3.4 a	9.7 a	7.6 abc	3246.0 b	81.0 a

[a] Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

[b] Damage rated on a 0-9 scale, where 0 = no damage and 9 = severe damage.

[c] HSI = Host suitability index. Cultivars with high values are more susceptible to insect damage, and lines with low values are more resistant to insect damage.

Table 14. Laboratory bioassay of peanut plant introductions for resistance to the velvetbean caterpillar[a].

P.I. or Cultivar	Larval Weight (mg) at 10 days	Days to Pupation	Pupal Weight (mg)	Days to Adults	Survival to Adult (%)	Host Suitability Index[b]
196617	61.3 klm	20.3 bc	139.7 ef	28.5 ab	20.0 efg	4.1 bc
196619	25.6 m	23.0 a	171.8 b-f	32.5 a	20.0 efg	3.1 c
196704	112.3 e-i	15.0 i	170.9 b-f	23.5 b	20.0 efg	4.8 bc
196717	156.6 a-c	15.0 i	134.8 f	23.5 b	20.0 efg	4.9 bc
196725	101.4 e-i	15.0 i	134.6 f	24.0 b	10.0 fg	4.3 bc
259629	84.6 g-l	19.7 bcd	137.8 ef	24.8 b	60.0 a-d	4.9 bc
259714	119.6 b-h	15.3 hi	217.3 ab	25.8 b	60.0 a-d	10.9 a
259789	128.9 b-g	17.7 d-h	157.1 def	26.0 b	50.0 b-e	5.4 abc
270828	108.6 c-k	17.4 d-i	213.2 a-d	27.1 ab	80.0 ab	9.6 ab
275498	129.3 b-g	16.1 ghi	197.4 a-d	24.9 b	80.0 ab	9.6 ab
336963	106.3 d-k	17.0 e-i	203.1 a-d	26.7 ab	60.0 a-d	9.3 ab
378165	73.9 k-l	17.8 d-h	196.7 a-d	26.0 b	20.0 efg	5.0 bc
431457	106.5 d-k	15.7 hi	201.6 a-d	25.0 b	30.0 d-g	9.9 ab
471985	139.2 a-e	15.3 hi	220.5 ab	25.2 b	60.0 a-d	11.1 a

[a] A total of 35 plant introductions that had previously received low damage ratings in the field were bioassayed against the velvetbean caterpillar in the laboratory. Only selected entries are presented here to illustrate the range of differences. Means in a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

[b] Host suitability index = $\frac{\text{Pupal weight}}{\text{Food consumption}}$ / Days to Adults x % Survival to Adults.

Lines with high values are more susceptible to insect damage, and lines with low values are more resistant to insect damage.

Table 15. Advanced evaluation of peanut plant introductions for resistance to insects, Tifton, GA, 1991.[a]

P.I. or Cultivar	Tobacco Thrips Damage Rating[b]	Potato Leafhopper Damage Rating[b]	Velvetbean Caterpillar Damage Rating[b]	Yield (lb/A)	Total Sound Mature Kernels (%)
179630	4.5 bc	5.8 a	3.5 cd	2179.2 cde	71.8 cd
186482	4.0 cd	5.0 abcd	3.8 c	2906.0 a	73.0 cd
196612	4.3 cd	5.3 abc	2.8 e	1182.8 f	57.3 f
196627	4.3 cd	4.8 bcd	2.8 e	2065.3 e	71.6 d
196631	5.3 a	5.3 abc	3.0 de	2127.2 de	74.1 c
196636	4.5 bc	5.5 ab	3.5 cd	2571.7 abcd	73.5 cd
196665	3.8 d	4.3 d	3.0 de	2075.9 e	69.1 e
196832	4.3 cd	4.8 bcd	3.5 cd	2269.7 cde	73.5 cd
203397	3.8 d	4.5 cd	4.0 bc	2774.8 ab	76.7 b
259820	4.3 cd	4.8 bcd	4.5 b	2197.0 cde	72.3 cd
259829	4.5 bc	5.5 ab	4.0 bc	2593.8 abc	71.8 cd
279627	3.8 d	4.8 bcd	3.0 de	2213.8 cde	71.6 d
295719	4.5 bc	5.8 a	3.8 c	2641.3 abc	73.1 cd
295724	4.0 cd	4.5 cd	3.5 cd	2226.6 cde	72.6 cd
295725	4.0 cd	5.3 abc	3.8 c	2309.6 cde	72.6 cd
298867	4.0 cd	4.5 cd	3.0 de	2347.8 bcde	72.1 cd
Florunner	5.0 ab	5.3 abc	5.8 a	2564.9 abcd	79.4 a

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

[b] Insect damage rated on a 0 to 9 scale, where 0 = no damage and 9 = severe damage.

Table 16. Evaluation of peanut genotypes for resistance to insects, Tifton, GA, 1991[a].

Genotype or Cultivar		Tobacco Thrips Damage Rating[b]	Potato Leafhopper Damage Rating[b]	Velvetbean Caterpillar Damage Rating[b]
NC 7 x NC 343	(3-91)	4.5 abc	4.0 efg	3.3 ef
NC 7 x NC 343	(4-91)	3.8 c	4.5 c-f	3.3 ef
NC 7 x NC 343	(6-91)	4.5 abc	3.3 gh	3.8 c-f
NC 7 x NC 302	(7-91)	4.5 abc	4.0 efg	3.8 c-f
NC 7 x NC 15745	(10-91)	4.3 abc	3.8 fg	3.8 c-f
NC 7 x NC 15745	(11-91)	4.8 ab	4.0 efg	3.3 ef
NC 7 x NC 10247	(12-91)	4.0 bc	2.8 h	4.0 c-f
NC 7 x NC 10247	(16-91)	4.8 ab	5.5 ab	4.5 abc
NC 7 x NC 10247	(18-91)	4.5 abc	3.8 fg	3.8 c-f
NC 7 x NC 301	(19-91)	4.0 bc	3.8 fg	4.0 c-f
NC 7 x NC 301	(20-91)	5.0 a	5.3 abc	4.0 c-f
NC 7 x NC 301	(21-91)	4.8 ab	4.0 efg	4.8 ab
GAT-2845	(32-91)	4.3 abc	5.8 a	3.5 def
GAT-2842	(29-91)	4.5 abc	5.3 abc	5.0 a
GAT-2736	(25-91)	4.3 abc	4.5 c-f	3.0 f
NC 6	(23-91)	3.8 c	3.8 fg	4.0 c-f
NC 7	(24-91)	4.8 ab	4.5 c-f	4.5 abc
Florunner	(26-91)	4.8 ab	4.5 c-f	4.5 abc

[a] A total of 36 genotypes or cultivars were evaluated. Only representatives are presented to illustrate the range of differences noted in the evaluation. Means within a column followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan K-ratio t-test.

[b] Damage rated on a 0 to 9 scale, where 0 = no damage and 9 = severe damage.

Table 17. Length and width of sweetpotato whitefly immatures on the upper and lower leaf surfaces of peanut.

Developmental stage	Leaf surface	n	Mean length µm (+SE)	Mean width µm (+SE)
Nymphal Instar[a]				
First	Upper	53	208.4 (7.6)	121.3 (6.2)
	Lower	45	207.2 (2.7)	120.5 (2.3)
Second	Upper	30	321.0 (11.2)	198.0 (8.3)
	Lower	48	311.1 (7.3)	191.5 (5.2)
Third	Upper	40	448.7 (10.9)	296.0 (8.5)
	Lower	36	435.8 (11.6)	281.5 (7.4)
Fourth	Upper	61	627.3 (3.7)[b]	430.4 (3.5)
	Lower	68	612.2 (5.2)	427.2 (5.2)
Pupa	Upper	13	600.2 (8.9)	402.6 (9.4)
	Lower	3	573.2 (38.4)	392.4 (19.2)

[a] The coefficient of determination for four instars was 0.92 for length and 0.92 for width.

[b] Significant differences between measurements on the two leaf surfaces ($P < 0.05$) using Student's t-test.

Table 18. Distribution of sweetpotato whitefly immatures on leaves, leaflets, and le surfaces of a lateral branch of peanut.

	Mean no. sweetpotato whitefly immatures[a]					
Variable	9 Aug.	16 Aug.	22 Aug.	29 Aug.	5 Sept.	Mean
Leaf Number[b]						
1	0.02 e	0.00 h	0.00 g	0.15 f	1.35 ef	0.22 g
2	0.00 e	1.11 efg	0.15 fg	1.55 cd	3.92 cde	1.06 ef
3	0.19 de	8.09 ab	6.19 abc	6.85 a	7.17 ab	5.09 a
4	0.45 d	7.64 a	7.42 a	5.17 a	7.90 a	5.05 a
5	1.61 bc	5.48 bc	6.29 a	4.25 ab	7.15 ab	4.60 a
6	2.41 a	3.83 cd	4.29 ab	2.59 bc	4.67 abc	3.57 b
7	1.78 ab	3.94 cd	3.29 bc	1.92 cd	3.25 bcd	2.75 c
8	1.02 c	3.03 d	2.50 c	1.03 de	1.43 de	2.05 d
9	1.00 c	1.57 e	1.56 d	1.29 de	0.67 ef	1.31 e
10	1.22 bc	1.45 ef	1.46 de	0.38 ef	0.77 ef	1.08 ef
11	0.33 de	0.79 fg	0.67 ef	0.25 ef	0.50 ef	0.63 fg
12	0.38 d	0.46 g	0.21 g	0.25 ef	0.00 f	0.34 g
Leaflet						
1	0.92 a	3.62 a	3.09 a	2.67 a	4.11 a	2.40 a
2	0.84 a	3.52 a	3.07 a	2.49 a	4.03 a	2.30 a
3	0.95 a	3.48 a	3.09 a	2.62 a	4.13 a	2.26 a
4	0.98 a	3.41 a	2.78 a	2.69 a	3.67 a	2.25 a
Leaf Surface						
Upper	0.66 b	4.68 a	2.94 a	2.42 a	5.16 a	2.24 a
Lower	1.18 a	5.99 a	3.07 a	2.81 a	2.80 b	2.36 a

[a] Means within a column and category followed by the same letter are not significantly different ($P < 0.05$) using Waller-Duncan (leaves and leaflets) or LSD (leaf surfaces).

[b] Leaves were numbered from the terminal (leaf 1) toward the base of a lateral branch.

NCS/IM/TP

Management of Arthropods on Peanut in Southeast Asia

North Carolina State University
Khon Kaen University
Department of Agriculture, Thailand
University of the Philippines, Los Banos

R. L. Brandenburg, Principal Investigator, NCSU
Mary Barbercheck, Co-Investigator, NCSU
Manochai Keerati-Kasikorn, Principal Investigator, KKU, Thailand
Turnjit Satayavirut, Principal Investigator, DOA, Thailand
Virginia Ocampo, Principal Investigator, UPLB, Philippines
Eliseo Cadapan, Principal Investigator, UPLB, Philippines

INTRODUCTION

The production of peanut in a manner consistent with current sustainable agricultural philosophy requires a strong understanding of the biological, economic, and social factors involved. Peanut production in the Philippines and Thailand is a complex agroecosystem subject to a wide variety of plant stresses. Two crops are grown annually and the continuous cropping as well as the warm climate render the crops available for damage by economic levels of insect pests. All parts of the plant are susceptible to attack, and the plant is exposed to insect feeding virtually the whole growing season. In order to effectively manage these pests in an economically and environmentally-sound approach lending itself toward sustainable agriculture, a sound biological base must be established. 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. The research underway is directed toward strengthening current IPM programs and achieving the goal of a more sustainable production system.

IMPACTS

One of the initial objectives of improving grower decision making for the use of insecticides is being implemented through demonstration research in both the Philippines and Thailand. Studies demonstrate that 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.

In the Philippines and Thailand, past studies of varietal tolerance and resistance of new genotype entries as well as currently recommended varieties have resulted in some change in varietal selection by growers with preference for those exhibiting higher yield under insect stress.

North Carolina peanut growers have been given additional guidelines for decision making on southern corn rootworm treatments. These will improve control, reduce pesticide use, and reduce costs. Additional work with cultural practices has demonstrated 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.

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MAJOR ACCOMPLISHMENTS

PHILIPPINES - Studies of peanut germplasm for insect resistance and/or tolerance. An excellent data base on potential resistance has been developed. 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 three locations in the Philippines.

The improved use of insecticides was continued at several locations since, in many instances, pest management must rely upon this control method. 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.

Biological control studies using *Trichogramma* sp. and a microbial insecticide *Bacillus thuringiensis* have been successful. New biological control studies show potential as do the new IPM evaluation trials. These trials evaluate the thresholds and efficacy of alternate control strategies in a realistic farm setting. They 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 was conducted at both DOA and KKU. Additional studies emphasized the 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. In addition, studies using sticky boards to investigate the migration and dispersal of thrips and the possible relationship to virus transmission are providing excellent insight into the ecology of this pest.

NORTH CAROLINA - The main focus of research efforts emphasized the development of an adequate data base to further refine the development of a sustainable agricultural system for peanuts. Extensive studies evaluating the impact of cultural 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 attractant provide information regarding rootworm treatment decisions. Current technology has limited the decision process to only those fields averaging less than 45 beetles per week and this must be improved. These additional studies to improve trap efficiency will hopefully enhance this decision-making process. Oviposition traps are also being incorporated into the program.

Wide-area studies investigating thrips overwintering, migration, and within the field dispersal were conducted in conjunction with studies on tomato spotted wilt virus in peanuts. 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.

The use of biological insecticides for pest control is currently under investigation. Initial evaluations indicate some potential with distinct ramifications for reduced secondary pest outbreaks. This is being emphasized in the area of soil pests. 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 peanuts.

ORGANIZATION

A.	U. S. Lead Institution:	North Carolina State University
	Principal Investigator:	Dr. Rick L. Brandenburg, Dept. of Entomology
	Co-Investigator:	Dr. Mary Barbercheck, Dept. of Entomology
	Post-Doctoral Assistant:	Dr. Jim Barbour, Dept. of Entomology
	Technician:	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:	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

	Mr. Dante Santiago, Dept. of Entomology
Research Associates:	Ms. Evelyn Bergonia, Dept. of Entomology Mr. Octavius Caesar P. Ebron, Dept. of Entomology Mr. Teddy de la Rosa, Dept. of Entomology
Technicians:	Mr. M. V. Navasero, Dept. of Entomology Mr. Ramir Batumalake, Dept. of Entomology
E. USAID Project Officers:	Mr. K. A. Rushing/Manila, Philippines Ms. T. Hiranraks/Bangkok, Thailand

APPROACH

Seeds of the various 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. The search for resistance to insect guilds rather than a single species is emphasized. Thus broad resistance would result in a potentially more sound release for growers since the off-target effects of host plant resistance on related pest species. 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.

Surveys of all arthropod pests, especially soil pests, will continue. Additional research on sampling and traditional management approaches 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 will be developed for incorporation into an IPM program.

Studies on thrips 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.

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 thuriengensis, 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.

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. Programs will be continually evaluated for areas requiring upgrading and/or additional data bases.

ACCOMPLISHMENTS IN DETAIL

Philippines - The evaluation of many genotypes was again hampered by damaged seed shipments and poor seed germination in most every test. Seed storage remains a problem and additional shipments arrived in poor condition.

Dr. Ocampo continues to focus more on the host plant resistance work, insecticide management and intercropping. 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, Quisino. The host plant resistance studies at UPLB and in Isabela indicate a rather wide range of insect preference or resistance among the various entries (Tables 1, 2, 3 and 4). These results from tests of peanut genotypes for the UIN, UIN(LHT), IGT, and IC as well as INT-F_7 and Philippine Seedboard recommended varieties (data not shown) indicate much promise for incorporation of some entries into an IPM program.

The survey of arthropods in the peanut system at Isabela found a wide range of species present. More importantly, this study outlined more clearly the population dynamics of thrips and leafhopper populations in this area. Such information is critical for effective management.

The study in Quirino to evaluate the intercropping of peanut and banana has produced interesting results. Performance of several varieties varied markedly from trials conducted at UPLB. PN-9 suffered the highest percent yellowing (Table 5) and is typically more susceptible to insect damage. However, this is still the preferred variety of growers in Quirino and Isabela and thus creates additional challenges for developing effective pest management programs. Significant effects of fertilizer on insect damage were also reported (Table 6).

Evaluation of pesticides included timing and threshold studies and the use of reduced rates. These studies have shown promise for improved timing and that, in some instances, insecticide rates can be reduced while maintaining yield.

The evaluation of a probational IPM package against major insect pests of peanut in Quirino indicates the use of biological control may be practical under moderate pest infestations. Results also indicate a relationship between irrigation, weeding, and fertilizer applications and insect pest infestations.

Dr. Cadapan evaluated Philippine Seedboard varieties at UPLB to determine any insect resistance or preference. The value of this work focuses on the fact that these are the varieties most commonly grown by farmers in the Philippines. Significant differences were found among the variety for certain insect pests (Table 7). Damage ratings reflected similar differences.

Studies in the southern Philippines to conduct IPM verification trials at Mandaue City were phased out due to a severe drought. Future studies will pursue these trials to compare UPLB findings with those in the more southern areas.

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 peanuts 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, as results have shown some indication that combination treatments may be best.

Thailand - Experiments at Khon Kaen and Prabuddhabat Exp. Sta. concentrated heavily on the evaluation of germplasm. At Prabuddhabat only the results from the Int-F_7 trial are available (Table 8). Leafhopper and thrips damage as well as yield appeared to be affected by variety. Resistance was also evaluated during the rainy season at Khon Kaen with some varieties exhibiting much more susceptibility to pests (data not shown).

An experiment was conducted to investigate the effectiveness of integrated control of peanut insects at Khon Kaen Field Crop Research Center during June and October 1991. The three peanut cultivars were Tainan 9, S.K. 38 and KK60-3. Time of treatment consisted of a) spray 3 times at 4, 6 and 8 wk after planting, b) spray 2 times at 4 and 6 wk after planting, and c) no application. Evaluation of insect abundance and damage as well as disease incidence were observed every other week.

Results (Table 9) indicate that fewer numbers of thrips and leafhoppers were found on Tainan 9 than that of S.K. 38 and KK60-3. There was a correlation between thrips density and incidence of peanut yellow spot virus (PYSV). Similarly, hopperburn found on each peanut cultivar corresponded positively with the number of leafhoppers. Pod yield of Tainan 9 cultivar increased about 20% and 25% when they were treated 2 and 3 times, respectively, when compared to the untreated plot.

Studies of insect migration and relationship of insect abundance to disease incidence (peanut yellow spot virus and peanut mottle virus) in a separate study at Prabuddhabat Exp. Sta. provide inconclusive results. The number of insects captured on sticky traps were relatively low, making it difficult to develop sound conclusions.

An experiment was conducted at Rayong Field Crops Research Center to verify the optimum insecticide application to reduce the unfilled pod problems of peanut. The Tainan 9 peanut cultivar was planted on June 22, 1991, in a study utilizing 3^2 factorial experiment with a check in a randomized complete block design with 4 replications. Factor A was a stage growth of plant consisting of A1 = R5, A2 = R6, and A3 = R7. Factor B was frequency of insecticide treatment consisting of B1 = 1 spray, B2 = 2 sprays, and B3 = 3 sprays. The results indicated that the number of thrips and leafhoppers there was no significant difference from insecticide treatments, but significant difference on the growth stage of the plant with more damaged leaflets at R5 than that of R6 and R7 (Table 10).

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 - Advanced work to refine the ability to predict corn rootworm outbreaks has incorporated the use of floral and feeding attractants. In addition, the use of trap crops has also been demonstrated to have some potential for enhancing a more integrated approach to rootworm management. These studies all focus on improving the predictive capabilities initially established with the pheromone trap studies from 1985-1990.

Research to improve management of early season thrips as a means of reducing the threat of tomato spotted wilt virus continued in 1992. Alternate control strategies are proving useful including the use of tillage techniques (Table 14).

Studies of thrips overwintering and migration into peanut fields have revealed much new information. Thrips do not overwinter in the soil and only a limited number appear to migrate from small grains (Tables 11 and 12). When migration into the field occurs, the number of thrips in the air is quite large and this migration occurs before peanut emerges (Figure 1). There is continued movement in the field all season long and some changes in species abundance as the season progresses (Table 12). 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 microbial insecticides and entomogenous nematodes is currently underway and data are unavailable. These control methodologies may have an integral role in future IPM programs directed closely by sustainable agriculture guidelines.

Current research on pesticide interactions helps pinpoint those current control practices that are most disruptive. The timing of preventive rootworm insecticide applications has a significant impact on the beneficial arthropod fauna as shown by current studies. This impact exacerbates secondary problems such as corn earworm and/or spider mites later in the season. In such scenarios

where there are not alternatives to the use of synthetic insecticides, the modification of application technology may be of benefit. Research on the use of Bacillus thuringiensis for caterpillar control has shown only limited potential. These studies correlate closely with research findings and needs in Thailand and the Philippines, where the potential for natural biological control is great and the impact of even a single insecticide application significant.

TRAINING OUTPUTS

Dr. Virginia Ocampo, UPLB, to spend one week in North Carolina visiting research sites with Drs. Barbercheck and Brandenburg. Dr. Ocampo attended ICRISAT groundnut workshop in November 1991.

Two students will begin working on Ph.D. programs in October 1992 at UPLB in Entomology funded by Peanut CRSP. These students will spend a semester in North Carolina for some coursework and exposure to field research.

PUBLICATIONS AND PRESENTATIONS

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Satayavirut, T. 1991. Peanut insect pests. In The Use of Technology to Improve Peanut Yield. ISBN 974-7620, 86-3. pp. 99-110. (in Thai).

Satayavirut, T., P. Sepswasdi, S. Pitak, and V. Pharpoom. 1991. Study on optimum insecticide application to reduce the unfilled pod problem of peanut. Report of the 10th Groundnut Conference, Hinsuay Namsai Resort Hotel, Rayong. 16-19 October. 6 pp.

Satayavirut, T., P. Sepswasdi, S. Pitak, and V. Pharpoom. 1991. Study on immigration of some insect vectors to peanut field by using sticky traps. Report of 10th Groundnut Conference, Hinsuay Namsai Resort Hotel, Rayong. 16-19 October. 4 pp.

Satayavirut, T., P. Sepswasdi, S. Pitak, and V. Pharpoom. 1991. Relationship of thrips density and peanut yellow spot virus and their effect on yield of selected peanut cultivars. Report of 10th Groundnut Conference, Hinsuay Namsai Resort Hotel, Rayong. 16-19 October. 6 pp.

RESEARCH PLANS FOR 1992-1993

U.S.

1. Improved early season thrips (*Frankliniella fusca*) management through biological and ecological studies and management trials.

   1.1. Studies to determine overwintering will be conducted throughout peanut production area.

   1.2. Thrips dispersal and migration into peanuts will be studied using sticky traps and foliage sampling.

   1.3. Host finding will be studied in early season trials.

   1.4. Effect of tillage will be studied as a cultural practice.

   1.5. Life history of thrips on Virginia-type peanuts will be elucidated.

2. Improved southern corn rootworm management through predictive modeling, trap cropping and cultural practices

   2.1. Use feeding attractant traps to monitor presence of ovipositing female beetles in peanuts.

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

   2.3. Conduct studies on biological control through preservation of endemic species.

3. Other endeavors

   3.1. Interact in plant breeding program for resistance selection.

   3.2. Evaluate "non-chemical" control strategies for specific peanut pests.

Philippines

4. Wet season (July-October 1992)

   4.1. Germplasm evaluation for resistance against peanut insect pest complex

   The following genotypes will be evaluated. (Only those planting materials/seeds produced from 2 consecutive dry cropping seasons in Region II, under our Seed Multiplication Experiment, will be used.)

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

   Plots will be in single rows, 5 meters long, replicated 4 times. Dr. Eliseo Cadapan will be provided with duplicate sets of the above seeds for his HPR experiments.

   4.2. 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.

Studies A and B will be conducted at Block A - Lot 5 of the UPLB Central Experiment Station covering approximately 0.8 ha. 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 population and its source around the area.

No experiment will be set up in Region II. Nobody in Quirino State College has been trained yet to monitor and sample insect pests and to assess damage. The area may become inaccessible to UPLB-based staff when typhoons (heavy rains and landslides) occur.

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

4.4 Expand host plant resistance work and pest management assessment trials into area around Cebu.

4.5. 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.

4.6. 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.

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

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

4.9. Evaluate the effectiveness and economics of hand picking as a method of controlling major insect pests of peanut for small scale production.

5. Dry season (December 1992-March 1993)

5.1. Arthropod diversities studies in peanut under different cultural management practices

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.

These studies will be done in Region II.

5.2. 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.

5.3 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.

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

5.5. Expand host plant resistance work and pest management assessment trials into area around Cebu.

5.6. 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.

5.7. 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.

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

Thailand

6. Screening of peanut lines from North Carolina collection for insect resistance. Prabuddhabat Experiment Station and Khon Kaen Field Crop Research Center.

7. Study on optimum insecticide application to reduce the unfilled pod problems of peanut. Rayong Field Crop Research Center.

   7.1. Includes ecological and management studies on subterranean ants.

8. Insect vector studies

   8.1. Study on immigration of some insect vectors to peanut field by using sticky traps. Prabuddhabat Exp. Station and Khon Kaen Field Crop Research Center.

   8.2. Relationship of thrips numbers and yellow spot virus and their effects on yield of selected peanut cultivars. Prabuddhabat Exp. Station.

9. Integrated control of major peanut insect pests using the varieties Tainan 9, KK60-4 (NC7) and Sukotai 38 (S.K.38)
   - Khon Kaen Field Crop Research Center
   - Farmer field in N.E. part of Thailand

   9.1. Develop economic injury levels for specific pests with special attention to plant phenology.

INTERNATIONAL TRAVEL

Month: January 1993
Destination: Philippines and Thailand
Duration: Two and a half weeks
Meet with collaborators and tour research plots.

Table 1. Reaction of UIN Test I peanut genotypes to common field insect pests. Cabagan, Isabela (Sept. '91-Jan. '92)[a]

Entry No.	Identity	% Yellowing	% Leaf Damage	% Thrips damage (5 WAP)	% Leafminer damage (6 WAP)	Seed Yield (g/3-m row)
1	NC 7 x NC 302	*	-	-	-	-
2	NC 7 x NC 10247	*	-	-	-	-
3	NC 6	1.0	0.17	1.0	3.0	37.0
4	GP-NC 343	3.0	1.33	8.0	3.0	13.1
5	NC 302	2.33	0.5	9.0	0	22.9
6	Florigiant	6.33	0.3	7.0	1.0	10.4
7	Florunner	4.33	3.33	3.0	3.0	85.9
8	Robut 33-2 x NC 2214	7.33	0.66	7.0	1.0	38.7
9	"	2.67	3.0	12.0	1.0	
10	Mani Pintar x (Robut 33-1 x NC 2232)	*	-	-	-	-
11	"	4.33	2.33	8.0	3.0	56.2
12	J11 x (M13 x NC 2232)	4.33	1.33	20.0	0.0	46.2
13	NC 1107 x (NC 2232 x NC 2214)	-	-	-	-	-
14	"	-	-	-	-	-
15	(NC 2232 x NC 2214) x TG 7	*	-	-	-	-
16	(Goldin-1 x Faizpur 1-5) x NC 2232	*	-	-	-	-
17	GP-NC 343 x NC 17367	1.33	2.67	7.0	1.0	15.4
18	10-P10-B1-B1-B1-B1-B2	*	-	-	-	-
19	GP-NC 343 x NC 7	7.0	2.0	12.0	0.5	26.1
20	GP-NC 343 x NC 5	3.0	4.0	8.0	1.0	45.4
21	"	-	-	-	-	-
22	PI 467807	6.0	1.33	4.0	0.0	159.8
23	NC 6 x NC 3083	1.17	3.0	3.0	4.0	124.7
24	F x (Var. 2750 x PI 259747) F2-B2-B1-B2-B1	5.62	1.67	5.0	8.0	55.4

[a] - indicates zero germination.

* - not planted this cropping season due to unavailable seeds.

Table 2. Reaction of UIN Test II (LHT) entries to common field insect pests. Cabagan, Isabela (Sept. '91-Jan. '92)

Entry No.	Identity	% Yellowing	% Leaf Damage	% Thrips damage	% Leafminer damage	Seed Yield (g/3-m row)
1	NC 7 x NCGP 343	9.75	3.75	8.75	1.0	0
2	"	9.5	1.5	4.25	3.0	64.8
3	"	3.6	3.6	3.25	1.0	0
6	"	5.0	1.75	2.0	5.0	103.8
7	"	5.0	3.3	0.25	0.5	0
9	"	8.0	0.83	7.33	0.5	19.7
11	"	17.33	1.33	6.67	2.0	65.5
12	"	7.0	2.83	6.0	6.0	53.0
13	"	3.67	2.33	2.33	2.0	159.7
14	"	4.8	1.1	4.5	1.0	0
15	"	6.5	2.0	9.75	3.0	56.8
16	"	4.4	2.4	5.75	3.0	47.6
17	"	4.2	1.7	10.5	3.0	60.1
19	"	7.67	1.0	4.67	1.0	89.6
20	"	4.25	3.38	4.0	3.0	107.2
21	NC 7 x NC 302	4.0	1.33	0.33	2.0	0
27	"	5.67	1.5	8.33	1.0	58.2
29	"	8.0	1.17	13.3	4.0	15.3
31	"	1.33	3.67	9.33	7.0	0
41	NC 7 NC 15745	7.6	0.80	1.25	1.0	0
42	"	11.33	4.67	4.0	5.0	0
44	"	4.75	0.875	10.0	2.0	73.1
45	"	9.4	2.2	2.0	1.0	23.6
46	"	10.0	0.125	7.5	1.0	10.9
47	"	4.67	0.167	12.5	1.0	16.6
48	"	2.33	1.33	3.67	0.5	14.4
50	"	5.67	2.0	2.0	0.5	65.8
51	"	9.5	2.0	10.0	1.0	13.7
54	"	5.0	0.67	1.67	1.0	24.2
57	"	11.33	3.33	5.67	4.0	0
58	"	13.33	2.0	6.33	6.0	0
59	"	6.6	1.2	4.75	1.0	119.1
60	"	9.75	0.625	1.75	1.0	53.0
66	NC 7 x 10247	4.0	2.25	10.75	4.0	4.4
68	"	9.0	2.33	10.67	0.5	38.2
69	"	12.5	2.0	13.5	1.0	22.5
73	"	4.0	4.33	15.67	3.0	69.1
74	"	10.8	1.0	4.25	2.0	62.6
78	"	4.67	1.33	7.67	0.5	30.4
79	"	20.0	4.0	9.75	1.0	46.9
80	"	11.75	2.25	12.25	3.0	59.4

Table 3. Reaction of IGT peanut germplasm to common field insect pests. Cabagan, Isabela (Aug. - Dec. '91)

Entry No.	Identity	% Yellowing	% Leaf Damage	Thrips damage	% Leafminer damage	Seed Yield (g/3-m row)
1	Early Bunch x NC 18016	10.67	4.83	1.8	3.0	1.6
2	"	5.17	5.83	0.25	1.0	74.7
3	NC 17213 x NC 7	6.0	5.4	3.8	1.0	147.5
4	NC 6 x Early Bunch	7.5	4.0	3.8	6.0	35.1
5	NC 7 Select	4.0	4.83	100	3.5	150.5
6	GP-NC 343 x NC 17367	3.8	4.2	0.0	0.0	2.9
7	"	23.67	3.25	2.0	6.0	48.6
8	2-P1-B1-B4-B1-B1-B2	9.4	5.4	1.0	3.0	18.3
11	FESR 1-P10-PT-B2-B1-B1-B2	10.17	2.5	0.6	1.0	80.1
13	Fx[Var. 55-437 x NC AC 17090]F2-B2-B1-B1-B1	5.67	2.83	0.0	1.0	0.0
15	Fx[Var. 2750 x PI 259747] F2-B2-B1-B2-B1	3.5	2.08	5.2	1.0	104.4
17	NC 5 x GP-NC 343	2.5	4.33	0.6	8.0	0.0
18	"	7.5	4.67	1.2	1.5	67.1
19	Florigiant x GP-NC 343	3.5	3.33	0.8	3.5	63.2
21	GP-NC 343 x NC 7	13.5	3.8	3.0	2.5	58.8
22	"	6.0	3.0	1.6	0.5	17.0
23	GP-NC 343 x NC 5	5.67	3.67	0.4	4.0	96.2
25	"	4.5	4.25	1.4	1.5	91.9
26	NC 17969 x NC 18233	9.0	8.83	3.8	1.5	72.1
27	NC 6	6.0	3.75	0.0	0.0	0.0
28	GP-NC 343	5.17	3.17	1.0	0.5	48.1
29	NC 17367 x GK 53	5.8	4.17	0.4	2.67	167.1
30	NC 18017 x NC 18018	25.67	5.42	3.6	3.5	9.2
31	(GP-NC 343 x NC 5) x UF 70115	4.0	4.25	0.0	0.5	0.0
32	(MGS 9 x NC 17090) F2-B1-B2-B1	10.5	5.0	3.2	0.5	67.0
34	MC 6 x MC 3033	10.0	2.83	1.0	0.5	18.4
35	NC 6 x NC 3033	13.67	3.83	1.0	2.0	21.7
36	"	7.5	8.83	1.2	2.0	80.8
38	"	9.67	3.5	1.2	0.5	47.1
39	"	10.0	2.67	2.2	2.0	57.5
40	"	5.83	2.67	0.8	1.5	90.5
41	"	13.17	8.0	1.0	0.5	101.2
42	"	7.33	3.17	1.2	1.5	7.2
43	"	8.5	3.17	1.75	1.0	30.7
44	AH 3275	19.83	10.5	1.4	2.0	91.4
45	Bhairhwa Local	13.5	8.33	0.4	3.0	0.0
46	Nangai	6.6	13.17	2.4	4.0	123.2
47	GP-NC 343	7.17	3.8	0.6	2.0	7.3
49	Valencia	29.67	17.17	7.0	4.5	109.5
50	Benihandach	13.33	17.17	5.0	8.5	109.8

Table 4. Reaction of IC plant genotypes to common field insect pests. Cabagan, Isabela (Aug. - Dec. '91)

Entry No.	Identity	% Yellowing	% Defoliation	Thrips damage	% Leafminer damage	Seed Yield (g/3-m row)
1	Manfredi 68 x GP-NC 343	14.0	2.83	3.8	0.8	0.0
3	(DH 3-20 x USA-20) x NC 2232	21.0	6.33	0.0	1.4	89.0
5	Robut 33-1 x GP-NC 343		3.83	2.83	0.75	66.2
7	M-13 x NC 2214	9.33	4.33	1.8	1.4	94.0
9	Robut 33-1 x NC 2214	4.67	3.08	0.75	0.0	178.3
12	M 13 x NC 2214	13.67	5.5	1.2	1.4	71.6
13	Robut 33-1 x NC 2214	13.33	2.83	0.0	0.2	0.0
15	Manfredi 68 x GP-NC 343	3.2	3.0	0.5	0.2	33.9
16	NC 17 x GP-NC 343	8.5	2.17	2.75	1.0	74.7
17	TG-1 x GP-NC 343	9.83	3.67	0.5	0.6	0.0
18	G-201 x NC Ac 2232	4.67	4.67	1.2	0.0	5.9
19	Mani Pintar x (Robut 33-1) x NC 2232	2.17	2.67	0.6	1.4	33.6
21	TMV-10 x NC Ac 2232	10.33	2.25	0.25	1.2	87.4
22	28-206 (France) x NC AC 10247	22.67	4.67	1.0	0.8	45.4
23	Manfredi 68 x GP-NC 343	3.67	4.83	0.0	0.8	0.0
24	X52-X-X-3-B x M 13 x NC Ac 2214	8.8	6.08	1.25	1.6	89.4
27	Manfredi 68 x GP-NC 343	7.83	7.8	0.75	0.6	47.8
30	(DH 3-20 x USA-20) x NC 2232	14.6	2.4	3.75	0.8	76.3
39	(Goldin-1 x Faizpur 1-5) x NC 2232	11.5	6.0	2.6	0.6	0.0
41	Florigiant	7.8	12.4	5.75	1.2	19.8
42	GP-NC 343	9.5	5.75	1.25	0.8	8.0

Table 5. Mean percent insect pest damage on different Philippine Seedboard peanut varieties intercropped with banana. Quirino, 1991-92.

Varieties	% Hopperburned leaves	% Yellowing per leaflet	% Defoliation	% Leaf damage due to thrips
UPL Pn-2	23.46 a	5.008 b	1.614 b	7.516 a
UPL Pn-4	23.69 a	4.016 cd	1.334 b	8.00 a
UPL Pn-6	24.49 a	4.492 bc	1.760 b	5.170 a
UPL Pn-8	23.57 a	3.486 d	1.936 ab	6.514 a
BPI Pn-9 (check)	23.26 a	7.028 a	2.484 a	5.314 a

[a]Values followed by the same letter are significantly different at P = 0.05, DMRT.

Table 6. Mean pest damage rating on UPL Pn-2 under different fertilizer management practices.

Fertilizer treatment	% Hopperburned leaves	% Yellowing per leaflet	% Defoliation	% Thrips damage
14-14-14-22S	24.25 ab	7.57 a	2.59 a	5.23 ab
21-0-0-24S	29.00 a	3.55 a	2.13 b	4.25 b
No fertilizer	18.75 b	0.87 a	0.69 b	8.25 a

[a]Means followed by the same letter are significantly different at P = 0.05, DMRT.

Table 7. Mean insect count of major peanut insect pests of Philippine Seedboard recommended peanut varieties[a]

Peanut variety	Cutworm	Earworm	Leaffolder	Leafhopper	Leafminer	Aphids
IPB Pn-6	0.07 d	0.51 a	1.04 bc	2.24 b	0.21 bc	0.047 d
IPB Pn-8	0.15 bcd	0.49 a	0.85 cd	2.78 a	0.13 c	0.057 b
IPB JL 24	0.09 cd	0.31 b	0.77 d	1.40 c	0.30 b	0.043 f
IPB PN 82-70-64	0.17 bc	0.35 ab	0.64 d	0.41 d	0.09 c	0.043 e
BPI P 9	0.42 a	0.45 ab	1.23 b	2.75 a	0.72 a	0.067 a
UPL Pn-2	0.21 a	0.39 ab	1.52 a	2.60 a	0.82 a	0.053

[a]Means followed by the same letter are not statistically different from each other at 0.05 level of significance.

Table 8. Resistances of peanut germplasm to insects, Prabuddhabat Experiment Station, 1991.

Entry identity	Thrips	PYSV	No. of damaged pods	Pod yield (g/plot)	Seed yield (g/plot)
1. NC7 x GP-NC 343	9.5	2.5 a-d	2.3 a-d	10.4 c-h	10.2 a-d
2. NC7 x NC 15745	3.0	2.1 bcd	1.7 cd	13.6 a-e	7.8 b-h
3. NC7 x NC 10247	8.5	2.3 bcd	1.7 cd	21.1 a-g	6.9 b-h
4. SK38 x GP-NC 343	9.0	3.1 a-d	2.4 abc	10.5 c-h	5.7 d-h
5. SK38 x NC 342	4.5	2.5 a-d	1.2 cd	8.0 c-h	6.5 c-h
6. SK38 x NC 15729	16.8	4.1 ab	1.2 cd	5.2 h	3.8 gh
7. SK38 x NC 10272	3.0	1.2 d	1.7 cd	6.2 gh	5.6 d-h
8. Lampang x GP-NC 343	8.0	3.2 a-d	2.0 bcd	13.6 a-e	10.3 a-d
9. NC 6	1.5	2.3 a-d	2.0 bcd	13.0 a-f	8.9 a-f
10. Lampang x NC 15729	4.5	1.7 cd	3.6 a	17.9 a	13.1 a
11. Lampang x NC 10247	4.5	2.9 a-d	1.1 cd	5.2 h	3.4 h
12. Tainan 9 x GP-NC 343	8.0	2.7 a-d	1.7 cd	10.0 c-h	6.8 b-h
13. Tainan 9 x NC 342	7.0	3.6 abc	1.3 cd	8.1 c-h	5.8 d-h
14. Tainan 9 x NC 302	18.5	4.0 abc	2.0 bcd	8.5 c-h	6.4 c-h
15. Tainan 9 x NC 10247	7.0	3.8 abc	1.3 cd	9.0 c-h	6.5 c-h
16. CES 101 x NC 343	10.0	3.2 a-d	1.5 cd	7.3 e-h	6.5 c-h
17. CES 101 x NC 15729	4.0	2.3 bcd	3.5 ab	17.1 ab	13.1 a
18. CES 101 x NC 10272	14.5	3.2 a-d	1.0 cd	5.6 gh	3.5 gh
19. UPL Pn4 x GP-NC 343	10.0	1.7 cd	1.0 cd	6.0 gh	4.2 fgh
20. UPL Pn4 x NC 15749	12.0	3.0 a-d	0.7 d	5.6 gh	4.2 fgh
21. UPL Pn4 x NC 10247	3.5	2.5 a-d	2.2 a-d	10.8 b-h	8.2 b-g
22. NC7 (KK 60-3)	7.5	3.1 a-d	2.4 a-d	9.8 c-h	6.7 b-h
23. SK 38	12.0	3.9 abc	2.3 a-d	13.7 a-e	10.8 abc
24. Lampang	10.5	2.1 abd	1.5 cd	6.8 fgh	5.3 e-h
25. Tainan 9	10.0	3.9 abc	1.8 cd	11.2 b-h	9.0 a-f
26. CES	16.0	4.5 a	2.5 abc	14.5 abc	11.5 ab
27. UPL Pn4	10.8	2.9 a-d	1.1 cd	8.1 c-h	7.6 b-h
28. GP-NC 343	3.5	1.1 d	1.1 cd	7.6 e-h	5.3 e-h
29. NC 301	11.0	2.9 a-d	2.1 a-d	14.4 a-d	10.0 a-e
30. Florigiant	9.5	2.2 bc	1.5 cd	8.3 c-h	7.5 b-h
31. NC7 x NC 301	7.0	2.9 a-d	1.2 cd	7.9 d-h	5.5 d-h
32. Tainan 9 x NC 10272	4.5	2.0 bcd	1.2 cd	9.7 c-h	7.4 b-h

*Means in the column followed by the same letter are not significantly different at $P < 0.05$ by DMRT.

Table 9. Number of thrips, PYSV incidence, leafhopper, hopperburn, damaged leaflets and yield of three peanut cultivars at three levels of insect control, Khon Kaen FCRC, 1991.

Cultivar	No. of thrips/				No. of PYSV incidence/			
	B1	B2	B3	Mean	B1	B2	B3	Mean
1. Tainan 9	50.8	45.3	27.0	41.0 c	74.3	67.8	54.5	68.5 c
2. S.K. 38	55.8	53.0	34.5	47.8 bc	84.5	88.5	50.0	74.3 bc
3. KK 60-3	64.8	92.8	48.3	68.6 a	84.3	108.3	45.8	86.1 a
Mean	57.1 a	63.7 a	36.6b		81.0 a	91.2 a	56.8 b	
Cultivar	No. of leafhoppers/				No. of hopperburns/			
	B1	B2	B3	Mean	B1	B2	B3	Mean
1. Tainan 9	4.3	6.3	4.5	5.0 c	108.5	134.8	78.5	107.3 c
2. S.K. 38	6.0	5.5	5.5	5.7 bc	108.3	144.5	70.3	107.7 bc
3. KK 60-3	8.5	7.8	9.0	8.4 a	113.0	1675.	94.3	124.9 a
Mean	6.3	6.5	6.3	.	109.9 b	248.9 a	81.0 c	
Cultivar	No. of damaged leaflets/				Pod yield (kg/ha)			
	A	B	C	Mean	A	B	C	Mean
1. Tainan 9	266.9	260.7	117.8	215.1 a	476.2	449.8	354.9	426.9 a
2. S.K. 38	263.3	258.1	118.7	213.3 a	402.5	415.8	354.6	391.0 ab
3. KK 60-3	220.4	188.6	86.6	165.2 b	419.3	259.3	242.7	307.1 b
Mean	250.2 a	235.8 a	107.7 b		432.7 a	374.9 ab	317.4 b	

Means in the same column (or row) followed by the same letter are not significantly different at $P < 0.05$ by DMRT.

A = spray 3 times at 4, 6 and 8 weeks after planting
B = spray 2 times at 4 and 6 weeks after planting
C = no insecticide application

Table 10. Number of thrips, leafhoppers, damaged leaflets and yield of Tainan 9 at different growth stages and levels of insecticide treatment, Rayong FCRC, 1991.

Treatment	No. of thrips				No. of leafhoppers			
	R5	R6	R7	Mean	R5	R6	R7	Mean
B1	23.5	18.3	31.0	24.3	10.0	11.3	12.8	11.3
B2	24.0	24.5	28.8	25.8	9.0	10.8	14.3	11.3
B3	21.5	28.8	34.5	28.5	7.8	12.8	18.3	12.9
Mean	23.0 c	23.6 bc	31.4 a		8.9 b	11.6 ab	15.1 a	
	Trts vs check = 25.0 v.s. 25.5^{ns} C.V. = 31.9%				Trts vs check = 12.1 v.s. 13.8^{ns} C.V. = 35.5%			
Treatment	No. of damaged leaflets				Dry pod wt. (kg/ha)			
	R5	R6	R7	Mean	R5	R6	R7	Mean
B1	100.1	85.2	69.2	84.8	1,165.0	1,320.0	1,215.0	1,233.3
B2	88.7	87.6	67.8	81.4	1.235.0	1.230.0	1,288.8	1,251.3
B3	92.9	71.5	70.6	78.3	1.297.5	1.237.5	1,250.0	1,261.7
Mean	93.9 a	81.4 ab	69.2 b		11,232.5	1,262.5	1,251.3	
	Trts vs check = 81.5 vs 78.9 C.V. = 18.8%				Trts vs check = 1,250.9 vs 1,270.0^{ns}			

Means in the same column (or row) followed by the same letter are not significantly different at $P < 0.05$ by DMRT.

R5 = beginning seed
R6 = full seed
R7 = full pod

B1 = 1 spray
B2 = 2 sprays
B3 = 3 sprays

Table 11. Total and mean no. of thrips and thrips damage found on plants inside and outside of emergence cages.

Location	No. of thrips		Thrips damage	
	Total	Mean	Total	Mean
Inside	112	5 b	12	0.5 b
Outside	535	27 a	70	3.0 a

Vertical means, per tetrafoliate leaf or sticky card, are separated by F test (P > 0.0001).

Table 12. Mean number of thrips captured per card for each combination of card color and compass direction.

Card color	No. of thrips				
	Card compass direction				
	North	South	East	West	Total
Yellow	48	51	60	62	56 a
Blue	22	25	25	24	24 b
White	1	1	2	1	1 c
Total	23 a	26 a	29 a	29 a	

Marginal means separated by protected LSD (P > 0.05).

Table 13. Total no. of thrips collected from peanut foliage and flowers.

Thrips species/stage	Thrips collected from	
	Foliage	Flowers
F. fusca adults	271	1059
F. tritici adults	41	203
Immatures	0	1355
Brachypterous	0	33
Other adults	1[1]	3[2]

[1] Haplothrips sp. on peanut foliage.

[2] Limothrips sp. (2) and F. occidentalis (1) on peanut flowers.

Table 14. Tillage effect on thrips; Chowan County; peanut 1991

Treatment	% thrips damaged leaflets		No. of thrips
	5/23	6/5	6/5
Plow + disc	66 a	92 cd	38.0 b
Plow + disc + rip	75 a	97 d	37.75 b
Disc	80 a	93 cd	38.25 b
No-till + fl. coult.	62 a	34 a	12.25 a
No-till + rip	66 a	50 b	12.50 a
No-till + raised beds	70 a	78 c	10.50 a

Means followed by the same letter are not significantly different. DMRT (P = 0.05) - Mean separation vertical.

GA/PV/N, TP

Peanut Viruses: Etiology Epidemiology and Nature of Resistance

The Georgia Station, University of Georgia, USA
Institute for agricultural Research,
Ahmadu Bello University, Nigeria
Khon Kaen University, Thailand

James W. Demski and Mike Deom, Co-Principal Investigators
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 local total 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 peanut 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. A recent report 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. 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 and more dramatically in 1990. 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 are 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. Fifty seven lines (selected from 260) having less than 10% rosette infection in 1991 were planted

in 1992. Thirty three of these lines were free of rosette and show promise of some being acceptable to growers. Promising lines are being multiplied for state trials. The yield ranges from 2500 to 3000 kg/ha and these are rosette resistant.

Three years data is now available on screening peanut lines for resistance to the peanut viruses. *Arachis diogoii* and *A. helodes* are two species that have good resistance, although not immunity, to peanut mottle and peanut stripe viruses. Likewise some lines have resistance to tomato spotted wilt (such as Southern Runner cultivar) but we have not identified lines with immunity.

A model system to regenerate peanut from protoplasts has been developed using *A. paraguariensis*. Protoplasts isolated from cell suspensions were co-cultured with actively growing nurse cells. These protoplasts formed microcalli. Multiple shoot and shoot primordia developed 40 to 50 days after transfer to a regeneration medium. Shoot primordia were than transferred to a rooting media and subsequently planted in soil and placed in a greenhouse.

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 recently completed her Ph.D. degree at the University of Georgia in virology/breeding. She has returned to Nigeria (Institute for Agricultural Research) and will carry 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 and/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 yellow spot, a disease 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 PStV and TSWV attached to a GUS marker gene.

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, PMB1044 Nigeria
Principal Investigator:	Dr. Phindile Olorunju
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 were 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. A geographical area with a low PStV incidence the previous year will be selected. If a low incidence area cannot be found, aluminum colored plastic will be used as an aphid repellant. Nine plots of approx. 10 m^2 with 20 m spacing between each plot 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.

4. To determine PStV 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.

5. A standard list of diagnostic hosts for PStV will be distributed by Dr. Sopone Wongkaew. Mechanical inoculation of these hosts may permit the grouping of PStV isolates into those that are mild, moderate or severe in respect to their severity on peanut.

6. Seed from the U.S. Plant Introduction Unit or the ICRISAT collection will be screened for PStV 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. Three 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.

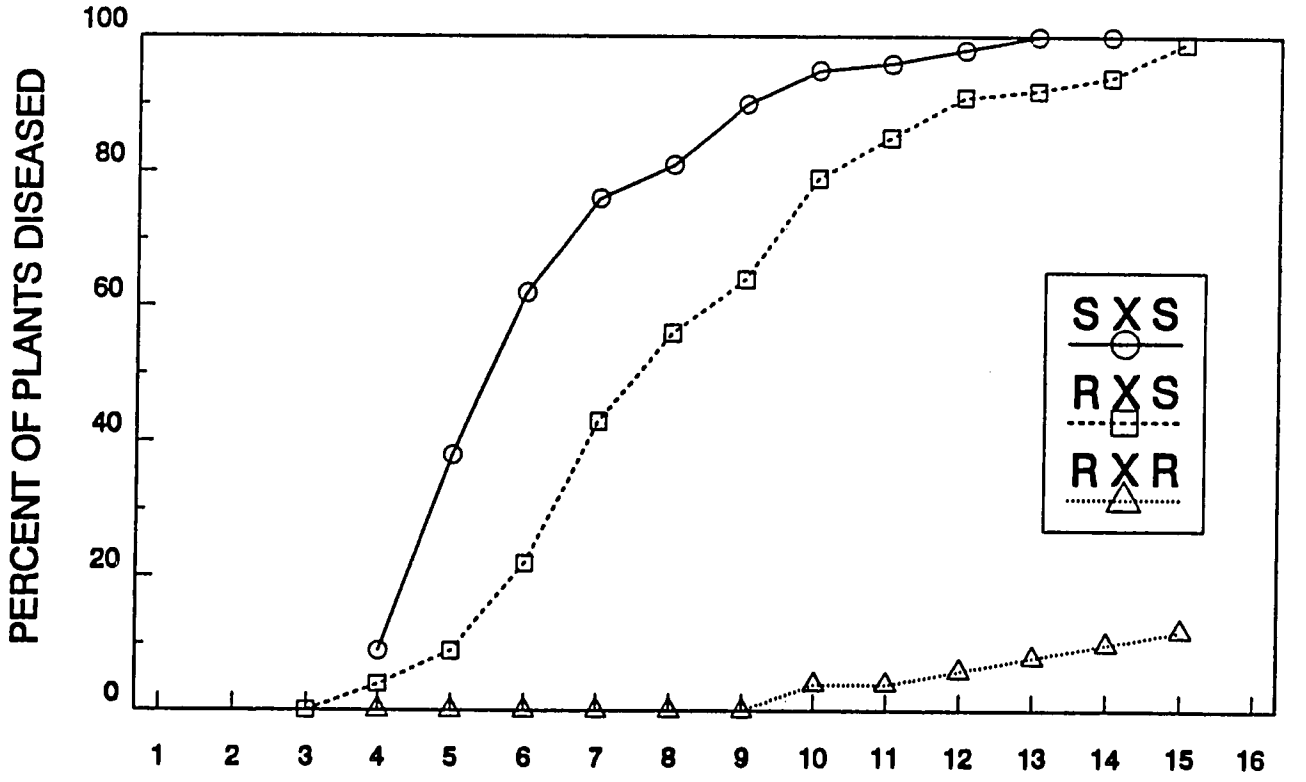
Electroporated protoplasts will be plated onto a GUS selection medium and those protoplasts showing incorporation of the coat protein sequence into their genomes, as determined by the GUS assay, will be regenerated into complete plants. The second approach will involve the direct bombardment of cultured peanut shoot tips or meristems utilizing the particle gun. In this procedure the coat protein sequence is bound to microscopic tungsten 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.

ACCOMPLISHMENTS IN DETAIL

Nigeria

Mechanical inoculation to screen peanut plants for resistance to groundnut rosette virus (GRV) has been perfected (Fig. 1). One hundred percent of susceptible peanut plants became infected. A few resistant plants also become infected by this technique indicating that we are dealing with a type of resistance, not immunity..

Fig. 1. Disease progress curves of rosette resistant and susceptible peanut crosses grown in the greenhouse and mechanically inoculated with GRV from infected peanut leaves of genotype F 452.4 plants. S x S = susceptible x susceptible, R x S = resistant x susceptible, and R x R = resistant x resistant cross. Data points represent the average percentage of diseased plants of F_2 populations.



Characteristics of the initial lines used in the breeding program are given in Table 1. Using the maturity characteristics of days from planting to 50% flowering, leaf color change, leaf senescence and pod color change, the eight genotypes could be grouped into two categories, early and late maturing. Considerable variation was observed among the genotypes for pod number, pod weight and also total seed weight. The oil and protein contents of seeds were acceptable for all genotypes.

High disease incidence in field plots at Samaru, Nigeria permits confidence in determining susceptibility and resistance of the progeny (Table 2). All plants of susceptible parents (480) and F452.4 (infector rows) (3366) were infected. About 5% of the resistant parents and R X R plants developed leaf symptoms and some stunting; the stunting was believed to have been caused by early infection allowing for a longer replication period. At the end of the cropping season, F_2 was subjected to various inheritance models and Chi-square used to test the fit of 3:1, 15:1, 13:3, and 9:7 phenotypic ratios of susceptible to resistant plants. F_2 plants in four of the eight R x S crosses segregated at a 15:1 ratio (Table 2). Three crosses deviated from a 15:1 ratio and segregated at 13:3 and 3:1 ratios. RMP 12 x M1204.78I had a ratio of 1 susceptible to 3 resistant plants. All Chi square values were within the acceptable probability limit for the model tested (Table 2).

Table 1. Maturity and yield characteristics and oil and protein content of eight peanut genotypes grown in a rosette-free environment in field plots at Samaru, Nigeria.

Genotypes	Maturity		Yield/plant				Shelling (g/kg)	Oil content (g/kg)	Protein content
	Days to 50% flowering	Days to harvest	Pod number (g)	Pod weight (g)	Seed weight (mg/seed)	Seed size (%)			
RMP 12	33	124	43	55	37.5	605	71.3	546	202
RG 1	33	124	37	41	23.6	558	62.0	555	212
M1204.78I	30	124	52	64	36.4	573	67.8	535	195
ICGS-56(E)	20	103	33	46	19.4	438	57.5	527	214
RRB	25	103	33	33	16.8	368	67.5	530	216
55-437	20	103	50	41	22.0	368	67.5	519	226
MK 374	33	124	46	53	35.7	545	70.8	552	203
JL 24	25	103	36	36	20.8	415	67.5	524	232
Mean			41	46.25	26.41	483	66.47	536	212
LSD			7.65	10.38	14.67	49.7	7.75	281.8	20.0

Table 2. Incidence (%) of groundnut rosette in parents and F_2 populations and segregation ratios of F_2 populations in field tests at Samaru, Nigeria

Genotype	Disease reaction[a]	Total no. of plants	Plants with susceptible reaction	Disease incidence (%) Observed	Disease incidence (%) Expected	Best fitting model	X^2 value	Probability
Infector plants	S	3366	3366	100	100			
Susceptible parents	S	480	480	100	100			
Resistant parents	R	432	20	5	0			
RMP 12 x RG 1	R x R	130	9	6.9	0 .0	0:1	0.6231	0.500-0.250
RMP 12 x M1204.78I	R x S	109	25	22.9	93.75	1:3	0.2477	0.750-0.500
RMP 12 x RRB	R x S	114	108	94.7	93.75	15:1	0.1894	0.750-0.500
RMP 12 x ICGS-56(E)	R x S	92	69	75.0	93.75	3:1	0.0000	
RMP x 55-437	R x S	128	117	91.4	93.75	15:1	1.2000	0.500-0.250
RMP x MK 374	R x S-	119	111	93.3	93.75	15:1	0.0454	0.900-0.750
RRB x RMP 12	S x R	122	99	81.1	93.75	13:3	0.0008	0.990-0.970
RG 1 x RRB	R x S	109	98	89.9	93.75	15:1	2.7456	0.100-0.050
RG 1 x M1204.78I	R x S	109	95	87.2	93.75	13:3	2.4956	0.250-0.100
RRB x 55-437	S x S	77	77	100	100	1:0	0.0000	
ICGS-56(E) x JL 24	S x S	125	117	93.6	100	15:1	0.0048	0.980-0.950

[a] R = resistant; S = susceptible.

Thailand

It is assumed that the world distribution of peanut stripe virus is due to its seed transmitted nature. Thus the mechanism that regulates seed transmission has great significance. Reports on the percent seed transmission has been highly variable. The influence of different symptom inducing isolates of peanut stripe were used to inoculate a single cultivar of peanut grown under identical conditions (Table 3). Conversely the peanut cultivar could greatly affect the rate of seed transmission. We inoculated 22 different peanut entries with one isolate of peanut stripe and grew the different peanut lines to maturity under similar environmental conditions. The rates of seed transmission is presented in Table 4.

Table 3. Effect of peanut stripe virus symptom variants on seed transmission frequencies for Tainan 9 peanut grown under field conditions at Khon Kaen, Thailand.

Virus Isolate	Seed[a] Transmission (%)
Stripe (T2)	13.30
Necrotic (T6)	8.38
Chlorotic Ring Mottle CP-N (T3)	10.91
Blotch (T8)	6.32
Mild Mottle (T1)	16.10

[a] 200-400 seeds using growing out test combined with indexing by direct antigen coating ELISA.

Table 4. Seed transmission frequencies of peanut stripe virus in peanut lines grown under field conditions at Khon Kaen, Thailand.

Peanut Line	Seed Transmission (%)
ICGS 36	1.60
ICGS 1	1.05
NC Ac 2240	0.00
ICG 19	1.02
148-7-4-3-12BxNCAc 17090	4.07
ICG 149 (Philippines pink)	0.00
RCM 387	0.29
(CometxNCAc17090)-F2-B2-4B1	1.63
ICG 43	0.76
FSB7-2x EC 76446(292)	6.72
No324	NA
NC7 (Khon Kaen 60-3)	0.00
Tainan 9	0.82
Moket (Khon Kaen 60-1)	0.00
(Comet x NCAc17090)-F2-3B1-B2-B1	1.98
KAC 290	0.00
TMV 3 (Khon Kaen 60-2)	0.34
ICG 18	1.11
EC 76446(292)	3.41
(MGS-9 x Robut33-1)-18-3-F6-1	0.49
ICG 12	0.35
EC 76446(292) x Robut3-1	3.18

NA = not available

United States

One hundred forty seven seeded commercial peanut types and 26 'wild' peanut types were field tested in two locations of South Georgia for resistance to peanut mottle, peanut stripe and tomato spotted wilt viruses. Each entry was replicated four times at each location. Control plots had virus incidence of 56% peanut mottle, 41% peanut stripe and 12% for tomato spotted wilt viruses. Plant introductions, (P.I.) 339964, 339966 and 341267 have only an occasional plant infected with peanut mottle or peanut stripe virus. P.I.'s 153342, 339967, 442733 and 475946 did not have infected plants with tomato spotted wilt virus. Further tests are needed to determine if these entries were escapes or indeed have resistance. Of the 'wild' peanut types, very little mottle or stripe virus was found in *Arachis diogoii* or *A. helodes*. Tomato spotted wilt virus was not observed in the entry Mt-1 (S-861). Again, further testing is needed to determine escapes or true resistance.

In a separate test, detection of tomato spotted wilt virus using ELISA was done on root and shoots of peanut in a destructive sampling test. Final incidence of infection among the root samples was greater than 20% according to ELISA results compared to only 7% apparent incidence of spotted wilt based upon foliar symptoms.

Individual plants of the peanut cultivar Florunner were evaluated over time for symptoms of tomato spotted wilt virus in field plots. Time of symptom appearance was recorded for symptomatic plants. Seed yield was determined for individual symptomatic plants and apparently healthy check plants on adjacent rows (Table 5). Across all times of appearance of symptoms, number of seed produced, mean weight per seed and total seed yield were lower for symptomatic

than for healthy plants.

Table 5. Effect of tomato spotted wilt infection on seed number, mean seed weight and total seed yield in individual Florunner peanut plants. Numbers in parentheses are standard deviations.

Date of Diagnosis		Number of seed	Seed wt (g/seed)	Yield (g)
12 June (R3)[a]				
	Infected	9.4 (11.8)[b]	0.26 (0.10)[b]	5.8 (8.2)[b]
	Healthy Check	81.7 (32.9)	0.55 (0.19)	42.0 (14.5)
26 June (R5)				
	Infected	11.2 (12.9)[b]	0.34 (0.09)[b]	5.7 (3.3)[b]
	Healthy Check	92.7 (46.1)	0.46 (0.05)	31.4 (24.9)
1 July (R6)				
	Infected	18.5 (14.5)[b]	0.34 (0.06)[b]	7.3 (7.1)[b]
	Healthy Check	83.3 (32.1)	0.49 (0.03)	40.4 (14.4)
24 July (R7)				
	Infected	35.2 (28.8)[b]	0.36 (0.11)[b]	17.5 (14.1)[b]
	Healthy Check	101.8 (65.3)	0.49 (0.49)	49.7 (31.0)
Total				
	Infected	21.4 (23.9)[b]	0.35 (0.10)[b]	11.7 (12.0)[b]
	Healthy Check	91.9 (51.5)	0.50 (0.10)	44.8 (24.7)

[a] Estimated average growth stage for the crop on the date of evaluation, based on growth stages reported by Boote.
[b] Significant at the 0.01 level of probability.

Volunteer peanut was intensively sampled for thrips during the fall and spring. Adults were 70-90% tobacco thrips in most samples, with western flower thrips comprising the remainder. Thrips larvae were collected in all samples, but were more numerous during the spring. Adult tobacco thrips were predominantly brachypterous during the late fall and early spring, suggesting that some populations of tobacco thrips overwinter in old peanut fields. Brachypterous adults rarely were observed on peanut transplanted during March into an old pearl millet, Pennisetum americanum (L.), field, but were common on peanut transplanted into an adjacent old peanut field. There is a potential of tobacco thrips, western flower thrips, and their plant hosts as winter reservoirs for tomato spotted wilt virus. Indeed ELISA positives were detected from individual brachypterous thrips.

An efficient protocol has been developed for protoplast culture and plant regeneration from wild peanut (*A. paraguariensis*) using a nurse culture method. Protoplasts were isolated from suspension cultures initiated from leaf-derived callus, imbedded in agarose blocks and co-cultured with nurse cells of same species. Up to 10% of the protoplasts divided and formed compact callus colonies. The protoplast plating efficiency was correlated with both the length of the nurse culture co-cultivation and the protoplast plating density. The optimal plating density was 2 x 10^4 protoplasts/ml plating medium. The optimal nurse culture duration was 14 d. Multiple shoots (up to 10 shoots per colony) were readily regenerated from protoplast-derived callus after transfer of callus to semi-solid modified MS medium containing 0.5 mgl^{-1} NAA and 1 mgl^{-1} BA (Table 6). Plantlets with normal leaflets were obtained by rooting shoots on porous rootcubes saturated with modified MS medium containing 1 mgl^{-1} NAA.

Table 6. Regeneration of somatic shoots from protoplast-derived colonies of *A. paraguariensis* on MS medium supplemented with different concentrations NAA and BA one month after inoculation.

NAA (mgl^{-1})	BA (mgl^{-1})	Total no. of colonies	Responsive colonies	Total no. of shoots	Mean no. of shoots per colony
0	0	15	0	0	0
0	1.5	15	13	79	6.1
0	1	15	13	54	4.2
0	3	15	12	59	4.9
0.1	0.5	15	15	85	5.7
0.1	1	15	15	139	9.3
0.1	3	15	9	90	10.0
0.5	0.5	15	10	52	5.2
0.5	1	15	15	134	8.9
0.5	3	15	13	109	8.4

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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.

Dr. Sopone Wongkaew from Khon Kaen University spent one month in the virology laboratory with Jim Demski where the current projects included; selection of peanut plants for virus resistance, identification of peanut viruses, the use of in-vitro procedures to maintain peanut virus isolates and the transformation and regeneration of peanut. Additionally Dr. Wongkaew traveled to the commercial peanut production areas of Georgia and attended the American Peanut Research and Education Society meetings in Norfolk, VA.

Dr. Phindile Olorunju traveled to Malawi where she attended the regional groundnut (peanut) workshop and conferred with peanut breeders.

PLANS FOR 1992-1993

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 the Peanut in SAT Africa

Alabama A&M University
University of Ouagadougou, Burkina Faso

Principal Investigators: Bharat Singh (Alabama) and Alfred 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.

Major Accomplishments

1. Full-fat peanut and sorghum multi-mix blends were extruded employing response-surface modeling techniques. Since peanut possess high levels of oil, extrusion to form stable snack food forms is hindered unless combinations of whole peanut with starch-rich, low-fat meals are considered. Development of convenient food model forms for the semi-arid tropics (SAT), such as in West Africa, has been pursued using minimally processed peanut and sorghum since both remain staples in the food-crop production efforts of the region. An optimization experiment involving three process factors in a central composite design served to set the variables in this study. Yellow sorghum and de-skinned peanut seeds were used to prepare five levels of ground meal combinations (in ratios ranging from 3:1 to 5:1) milled together from the pre-chilled components to avoid excessive oil separations. Similarly, extruder screw speed rates and meal feeder input rates were assigned at five levels to establish an orthogonal set for experimentation. An Appropriate Engineering AE-303 extruder was employed to form 18 preparations of kibble products which were evaluated in terms of physical parameters of force and work of TexturePress shearing, expansion, bulk density and chemical interactions including water absorption capacity and extractable fat. Additional parameters of machine function were observed including power usage, temperature development in barrel, process water rates applied and moisture levels resulting in the products. Response surface equations were produced from the data using the CADE Optimization application. A tentative optimum process space based upon parameters of product shear, expansion, bulk density and water absorption capacity restricted products to compositions of less than 20% peanut with considerable latitude for the other two process parameters.

2. Scientists at the University of Ouagadougou have continued with the assistance to a small peanut paste processor to package full-fat peanut paste in tin cans. The product had good quality as far as consistency, acceptability and shelf-life are concerned. Marketing of the product was the major concern of the company.

3. Scientists at the University of Ouagadougou have completed analyses of peanut grown in 1990-1991. The data including protein, fat, fiber, vitamin C and carbohydrates have been completed and evaluated. Only a limited number (100) of aflatoxin samples from the entomology project have been completed. Quality of peanut products in Burkina Faso (roasted, partially defatted peanut paste and whole peanut pastes) was evaluated for aflatoxins and nutrients. Peanut pastes prepared by traditional methods had more aflatoxins than those prepared by industrial methods by a local company. The amount of nutrients and free fatty acids varied according to location, time of sampling, and methods of preparation.

4. Scientists at the University of Ougadougou developed research study on fortification of staple foods such as toe with peanut proteins.

5. Mr. Tunde Koleosho completed his M.S. degree in Food Science at Alabama A&M University.

6. Mr. Xiaoyong Yan completed his M.S. degree in Food Science at Alabama A&M University.

Expected impacts of the project

The major constraint in increasing peanut utilization in SAT Africa is the unavailability of peanut in processed forms: packaged roasted peanut, peanut butter, defatted peanut flour, peanut milk, candies and other confectioneries at affordable costs. 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 and 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.

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 other SAT countries.

ORGANIZATION

USA

Alabama A&M University

Dr. Bharat Singh, Principal Investigator, Department of Food Science, Normal, Food Scientist.
Dr. John C. Anderson, Co-principal Investigator, Department of Food Science, Normal, Food Scientist.

Dr. Casimir Akoh, Cooperator, Department of Food Science, Normal, Food Scientist.
Dr. M. Elena Castell-Perez, Cooperator, Department of Food Science, Normal, Food Scientist.
Mr. Simon Ogutu, Research Technician, Department of Food Science, Normal, Food Scientist.

Burkina Faso

University of Ouagadougou

Dr. Alfred S. Traore, Principal Investigator, Food Scientist.
Mr. Solibo Some, Entomologist, Cooperator.
Mr. Albert Ouedraogo, Entomologist, Cooperator.
Mrs. Lactitia Ouedraogo, Food Technologist, Cooperator.
Mr. Herve Campaore, Food Technologist, Cooperator.
Mr. Francois T. Ouedraogo, Food Technologist, Cooperator.
Dr. Philippe Sankara, Phytopathologist, Cooperator.

Graduate students and research projects for thesis

USA

1. Tunde Koleosho: Storage stability studies on sorghum-peanut blends of flours (graduated July 1991).

2. Xiaoyong Yan: Single-screw extrusion preparations of whole peanut and sorghum multimixes mapped (graduated May 1992).

3. Ashok Mishra - Thesis Topic: Rheological properties of composites of peanut, sorghum and rice. MS degree expected June 1993.

4. Teresa Coleman - Thesis Topic: Protease inhibitors in processed peanut milk. MS expected August 1993.

5. Linda Griffith - Dissertation Topic: Precooked weaning foods based on cereal/peanut/legumes composites. Ph.D. expected August 1995.

6. Nelly Duarte - Dissertation Topic: Development of peanut fortified non-extruded snack foods. Ph.D. expected August 1995.

7. Rolfe Bryant - Dissertation Topic: Control of oligassacharide production in peanut. Ph.D. expected August 1995.

Burkina Faso

8. Simeon Nanema - Thesis Topic: Improvement of nutritional quality of toe on fortification with peanut proteins. MS degree in November 1992.

9. Rufin Simde - Dissertation Topic: Improvement of shelf life of peanut products (roasted peanut seed and locally made peanut pastes). Ph.D. expected January 1994.

10. Philippe Nikiema - Dissertation Topic: Physico-Chemical parameters evolution and aflatoxins production in peanut seeds during storage. Ph.D. expected February 1993.

Accomplishments and Approach in detail

RESPONSE-SURFACE MODELING OF EXTRUSION PROCESSED FULL-FAT PEANUT AND SORGHUM MULTI-MIX BLENDS

The purpose of this research was to consider combinations of whole peanut seed with sorghum to offer a potentially viable new food form for improving utilization of peanut in semi-arid tropic (SAT) Africa while offering a potential for improving nutrition of at-risk persons of the region.

The specific objectives of this research were (1) to evaluate the multiple effects of peanut-sorghum composition and processing conditions within a single-screw extruder upon a cooked and dried sorghum-peanut multimix product; (2) to evaluate the rheological parameters of the peanut-sorghum multimix products.

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Scientists at the University of Ouagadougou have completed analyses of peanut grown in 1990-1991. The data including protein, fat, fiber, vitamin C and carbohydrates have been completed and evaluated. Only a limited number (100) of aflatoxin samples from the entomology project have been completed. Quality of peanut products in Burkina Faso (roasted, partially defatted peanut paste and whole peanut pastes) was evaluated for aflatoxins and nutrients. Peanut pastes prepared by traditional methods had more aflatoxins than those prepared by industrial methods by a local company. The amount of nutrients and free fatty acids varied according to location, time of sampling, and methods of preparation.

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METHODS AND MATERIALS

The methodology applied for this experimentation involved selection of alternate levels of three extrusion formulation and process factors, namely: percentage peanut in sorghum-peanut combination (PEANUT%); extruder main screw speed (SCRWrpm) and rate of ingredient feed (FEEDmtr) designated by speed of drive motor for 20:1 gear reduction to the feed auger.

DESIGN OF EXPERIMENT

The process design and considerable portions of the data analyses employed a methodology known as CADE (Computer Aided Design of Experiments, a software package providing design understood as response surface methodology). A central composite design in the "Optimization Module" was used. Table 1 shows both the standard and a random order of extrusion processing runs with the combination of the three independent variable which are designated at each of 5 levels.

LABORATORY EXPERIMENTATION

U.S. Runner Grade peanut was acquired from Anderson Peanut Co., Goshen, Alabama. Yellow sorghum variety E39Y was obtained from 1989 crop year production of Bradley Rooney, Trenton, Nebraska. Separate pretreatments included removal of

Table 1. Three factor combinations for the experimental design of extrusion processing

TRIAL NUMBER	RUN ORDER	PEANUT RATIO (%)	SCREW SPEED (rpm)	FEED RATE (rpm)
1	11	17.43	280	211
2	7	24.27	280	211
3	13	17.43	470	211
4	8	24.43	470	211
5	12	17.43	280	408
6	9	24.27	280	408
7	14	17.43	470	408
8	10	24.27	470	408
9	15	16.70	375	310
10	2	25.00	375	310
11	4	20.85	260	310
12	5	20.85	490	310
13	6	20.85	375	190
14	1	20.85	375	430
15	3	20.85	375	310
16	17	20.85	375	310
17	18	20.85	375	310
18	16	20.85	375	310

the red skins of the peanut and seed cleaning for the sorghum. Both were then stored in a refrigerator prior to their being blended together by the design considerations and ground as a blend that dilutes the effect of the high-fat peanut. The blends were additionally mixed in the ground state to promote a further uniformity of extruder feed material.

The eighteen extrusion products were prepared in a random order using an Appropriate Engineering AE303 single-screw extruder with each of the several batch blends introduced to the feed hopper and the appropriate screw speed and feeder auger speeds set. Excess water was metered into the mixture and adjusted to an appropriately reduced rate subjectively determined by the operator as the product flow developed and barrel temperature increased. Water flow adjustments were guided by attempts to get significant expansion of the products at the dies without producing scorched or charred defects. The products were first sampled while moist and the power and water use rates and barrel temperature were recorded for each preparation. The extruder operation parameters and moisture levels and output rates of products are shown on table 2. Products were dried in a Proctor & Schwartz cabinet dryer loaded on perforated trays. Textural characterizations of the dried forms were investigated by a series of physical testing procedures. The measures are tabulated in table 3.

Depending on the three independent variables (feed blend peanut percentage, extruder screw speed and speed of feed drive), responses were regressed to a complete model equation with terms as shown:

$$\hat{y} = b'_0 + b'_p \cdot PEANUT\%' + b'_s \cdot SCRWrpm' + b'_f \cdot FEEDmtr' + b'_{pp} \cdot PEANUT\%'^2 + b'_{ss} \cdot SCRWrpm'^2 + b'_{ff} \cdot FEEDmtr'^2 + b'_{ps} \cdot PEANUT\%' \cdot SCRWrpm' + b'_{pf} \cdot PEANUT\%' \cdot FEEDmtr' + b'_{sf} \cdot SCRWrpm' \cdot FEEDmtr'$$

where $\hat{y}$ represents any of the dependent variables (among 14 responses); the b'(s) are model equation coefficients; PEANUT%' = (PEANUT% - 20.85)/(24.26 - 20.85) represents the standardized variable for percentage of peanut in the multimixes, SCRWrpm' = (SCRWrpm - 375)/(470 - 375) represents the standardized variable for screw speed and FEEDmtr'= (FEEDmtr - 310)/(408 - 310) represents the standardized variable for feed motor rate.

An alternate regression procedure without the potential for variable interaction terms was also considered using any of the same three variables and/or any additional measurements employing the Harvey least-squares maximum likelihood analysis for mixed models (designated LSMLMW). Either regression process allows restriction of variable terms to those that are determined to be significant. Because the CADE process always preserved even the nonsignificant linear terms, the value of the expressions (without the non-significant terms) were assessed manually by calculations of the coefficients of determination (R^2's). Table 4 shows the regression equations in which good agreement is seen by either of the CADE and LSMLMW processes. Table 5 shows the regression expressions that contrast the representations of the observations based only on design factors (CADE) with representations of some of the covarying parameters (LSMLMW).

Based upon constraints selected for five of the most significant responses of product character produced by these response surface experiments using the model equations produced by the interactive development with the CADE application, overlay plots were generated. Five responses (work of shearing, peak shear force, water absorption capacity, expansion ratio, and bulk density) are each rheological characteristics. Several do represent qualities such as sizes and shapes of the pieces of extrudate, and physical sensory qualities (crispiness and elasticity) of the final products. In each case, the interactive application of the CADE efforts explained much of the variation of the responses by their regression equations.

The limitations were established as 200 - 300 (arbitrary units) for work of shearing, 11% - 25% (full-scale 3000 lb_f) for peak shear force sensed, 300 - 600

Table 2. Conditions of extruder processing operations.

Preparation Number (Std.)	Main Drive Motor Electrical Voltage (Volts)	Current (Amperes)	Power (kW)	Barrel Temperature (°C)	Process Water (cc/min)	Fresh Moisture (%)	Rate Thruput (g/min)
1	126	19	2.394	105	35	12.08	319.0
2	127	12	1.524	110	70	19.62	219.6
3	215	21	4.515	118	35	9.75	196.6
4	214	13	2.675	115	65	11.85	254.9
5	126	28	3.528	119	45	10.40	412.6
6	125	20	2.500	110	25	10.14	335.5
7	215	22	4.730	115	55	11.80	408.2
8	213	13	2.769	112	25	13.20	450.7
9	172	30	5.160	124	50	8.22	298.8
10	173	12	2.076	119	65	12.02	290.9
11	120	21	2.520	115	60	13.93	308.2
12	223	22	4.906	128	50	12.38	326.2
13	170	12	2.040	127	70	14.87	267.8
14	173	21	3.633	119	65	16.18	375.1
15	173	17	2.941	113	50	13.11	330.5
16	172	18	3.010	106	50	14.86	353.5
17	172	17	2.924	105	50	14.24	331.9
18	172	16	2.752	103	50	14.16	344.2

Table 3. Physical characteristics of finished extruded products.

Formula Number	Work of Shearing	Peak Shear Force	Water Absorption Capacity	Expansion Ratio	Bulk Density	Dried Moisture
	(Arbitrary units)		(g/L)	(%)	(g/L)	(%)
1	248	24.1	440	170	386.9	9.79
2	291	33.6	325	130	490.4	2.01
3	216	12.5	483	210	174.7	5.69
4	227	27.2	301	140	503.0	1.50
5	225	31.8	290	130	512.0	3.43
6	179	24.0	110	110	444.5	1.00
7	243	27.3	361	150	450.7	3.09
8	194	25.8	76	110	454.0	2.21
9	240	14.5	482	200	209.3	4.96
10	244	30.5	228	150	475.5	1.83
11	247	31.7	184	140	534.5	1.93
12	269	39.0	288	130	544.5	1.72
13	212	20.7	470	140	342.5	2.62
14	212	27.6	111	130	392.5	1.56
15	244	31.6	208	150	510.7	1.30
16	235	28.6	311	150	503.3	1.08
17	237	27.7	230	150	507.8	1.66
18	211	29.1	241	130	498.7	1.81

Table 4. Regression expressions representing the variations of machine and product parameters in terms of experimental design parameters

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E_{LSMLMW} (Volts) = 172 + .460*(SCRWrpm-375) - .000144·(SCRWrpm-375)^2; R^2 = .999

E'_{CADE} (Volts) = 171 + 43.7·SCRWrpm' (the two other linear terms are not represented since they are not significant); R^2 = .998

POW'_{CADE} (kW) = 3.144 - .862·PEANUT%' + .698·SCRWrpm' + .398·FEEDmtr'; R^2 = .804

POW_{LSMLMW} (kW) = 3.155 - 24.8·(PEANUT%-.209) + .00745·(SCRWrpm-375) + .00392·(FEEDmtr-310); R^2 = .801

FAT'_{CADE} (%) = 11.59 + 1.99·PEANUT%' + .931·FEEDmtr' - .382·FEEDmtr'^{2}; R^2 = .989

FAT_{LSMLMW} (%) = 11.58 + 57.9·(PEANUT%-.209) + .00941·(FEEDmtr-310) - .0000380·(FEEDmtr-310)^2; R^2 = .988

EXP_{LSMLMW} (%) = 145.6 - 614.0·(PEANUT%-.209) - .150·(FEEDmtr-310); R^2 = .626

EXP'_{CADE} (%) = 145.6 - 21.1·PEANUT%' - 14.8·FEEDmtr'; R^2 = .624

WAC'_{CADE} (g/L) = 252.7 - 97.8·PEANUT%' + 53.9·PEANUT%'^{2} - 104.8·FEEDmtr'; R^2 = .883

WAC_{LSMLMW} (g/L) = 285.5 - 2850·(PEANUT%-.209) - 1.06·(FEEDmtr-310); R^2 = .825

Table 5. Alternate regression expressions of product and process variations based on experimental design factors or on other covarying parameters

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DRY'_{CADE} (%) = 1.79 - 1.74·PEANUT%' - .963·FEEDmtr' + 1.55·PEANUT%'^{2} + .643·PEANUT%'·SCRWrpm' + 1.08·PEANUT%'·FEEDmtr' + .685·SCRWrpm'·FEEDmtr'; R^2 = .917

DRY_{LSMLMW} (%) = 1.86 - .820·(FAT-11.36) + .288·(FAT-11.36)^2; R^2 = .830

OUT'_{CADE} (g/min) = 323.6 + 68.2·FEEDmtr' + 34.7·PEANUT%'·SCRWrpm' + 24.8·SCRWrpm'·FEEDmtr'; R^2 = .907

OUT_{LSMLMW} (g/min) = 323.6 + .690·(FEEDmtr-310); R^2 = .707

I'_{CADE} (amperes) = 18.5 - 4.96·PEANUT%' + 2.69·FEEDmtr' - 1.94·SCRWrpm'·FEEDmtr'; R^2 = .803

I_{LSMLMW} (amperes) = 18.6 - 143·(PEANUT%-.209) + .0267·(FEEDmtr-310); R^2 = .732

$WORK'_{CADE}$ (arbitrary units) = 241.6 - 12.87·FEEDmtr' - 15.95·FEEDmtr'^{2} - 18.6·PEANUT%'·FEEDmtr' + 16.1·SCRWrpm'·FEEDmtr'; R^2 = .696

$WORK_{LSMLMW}$ (arbitrary units) = 232.2 - .0281·(SCRWrpm-375) + .00219·(SCRWrpm-375)^2 - .0729·(FEEDmtr-310) - .00206·(FEEDmtr-310)^2 - 1.02·(H_2O-50.83); R^2 = .599

WET'_{CADE} (%) = 14.3 + 1.41·PEANUT%' - 2.27·PEANUT%'^{2} - 1.06·PEANUT%'·FEEDmtr' + 1.82·SCRWrpm'·FEEDmtr'; R^2 = .649

WET_{LSMLMW} (%) = 12.9 + .0748·(H_2O-50.83) - .128·(I-18.6) - .734·(P-3.155); with power "P" in kW and current "I" in amperes. R^2 = .527

WET_{LSMLMW} (%) = 13.1 - .116·(FAT-11.36) - .500·(FAT-11.36)^2 + .0642·(H_2O-50.83) + .00726·(H_2O-50.83)^2; R^2 = .596

$FORCE'_{CADE}$ (% of 3000 lb_f of strain gage calibration) = 27.9 + 3.135·PEANUT%' - 1.080·SCRWrpm' - 5.036·PEANUT%'^{2} + 3.668·SCRWrpm'^{2} - 4.188·PEANUT%'·FEEDmtr'; R^2 = .617

$FORCE_{LSMLMW}$ (% of 3000 lb_f of strain gage calibration) = 30.13 + 1.429·(FAT-11.36) - 1.015·(FAT-11.36)^2; R^2 = .595

$BULKV'_{CADE}$ (L/kg) = 2.093 - 0.662*PEANUT%' +.663·PEANUT%'^{2} + .570·PEANUT%'·FEEDmtr'; where bulkv = 10^3/bulkd were the values admitted to the regression process. R^2 = .526

$BULKV_{LSMLMW}$ (L/kg) = 2.497 - .374·(FAT-11.36); R^2 = .404

T_{LSMLMW} (°C) = 110.8 + 6.14·(P-3.155) + .384·(H_2O-50.8) + .0207·(H_2O-50.8)^2; with power "P" in kW, water feed rate "H_2O" in cc/min. R^2 = .579

g/L for water absorption capacity, 150% - 230% for expansion ratio, and 150 - 425 g/L for bulk density as indicated based on product qualities judged appropriate by the experimenter. The most sensitive of these constraints appeared to be the bulk density response which when confined to a lesser range reduced the size of the overlay regions of acceptance in a manner not shared by the other constraints listed. Figure 1 portrays the region in which constraints are all met with the "X's" in two dimensions of the factorial design space for the cross-section selected.

This overlay figure shows the middle level of the extruder screw speed constant as a cross-section with horizontal and vertical axes varying by the changes of the feed motor speed and the feed composition (as percentage peanut), respectively. Only minor changes were indicated from cross-section to cross-section as a consequence of the variation of the extruder screw speed as all cross-sections show a wedge of surface for low percentage peanut formulation that further narrows as the material feed rates were increased.

PUBLICATIONS AND PRESENTATIONS

A. Manuscripts

1. Singh, B. and U. Singh. 1991. Peanut as a source for human foods. Plant Foods for Human Nutrition 41:165-177.

2. Singh, U., B. Singh, and O. D. Smith. 1991. Effect of varieties and processing methods on phytic acid and protein digestibility of groundnut (*Arachis hypogaea* L). J. Fd. Sci. Technol. 28(6):345-347.

3. Singh, U. and B. Singh. 1991. Functional properties of sorghum-peanut composite flour. Cereal Chemistry. 68:460-463.

4. Singh, B. 1991. Cereal-based foods using groundnuts and other legumes. In Proc. Consultant's Meeting on Uses of Grain Legumes, ICRISAT, Patancheru, India. ICRISAT. pp 293-301.

5. Singh, U. and B. Singh. 1992. Tropical grain legumes as important human foods. Economic Botany 46:310-321.

6. Agbo, F. O., J. C. Anderson and B. Singh. 1992. Lipid Oxidation of edible peanut pastes during storage with variation of environmental and processing factors. Peanut Science 19(2):101-105.

7. Hinds, M. J., Singh, B. and Anderson, J. C. 1992. Determination of pod and crop maturity for peanuts using percent pod-fill. Can. J. Plant Sci. 72:000-000 (Oct. 1992).

8. Traore, A. S., and B. Singh. Comparative Study of the nutritional quality of peanut paste from various regions of Burkina Faso. Peanut Science (Submission date April 1992).

B. Presentations:

1. Anderson, J. C., X. Yan, and B. Singh. Response surface modeling of extrusion processed full-fat peanut and sorghum multi-mix blend. Annual Meeting of American Peanut Research and Education Society, Norfolk. VA, July 1992.

INTERNATIONAL TRAVEL

- September - October 1992 - Visit to Burkina Faso.
- Traveler Singh to review collaboration work at the University of Ouagadougou.

OVERLAY

CONSTANTS		VALUE
SCREWspeed	=	375.00

RESPONSES	LOW---LIMITS---HIGH	
WORKspecif	200.00	300.00
FORCEpeak	11.00	25.00
WATERabsor	300.00	600.00
EXPANSIONr	1.50	2.30
BULKdensit	150.00	425.00

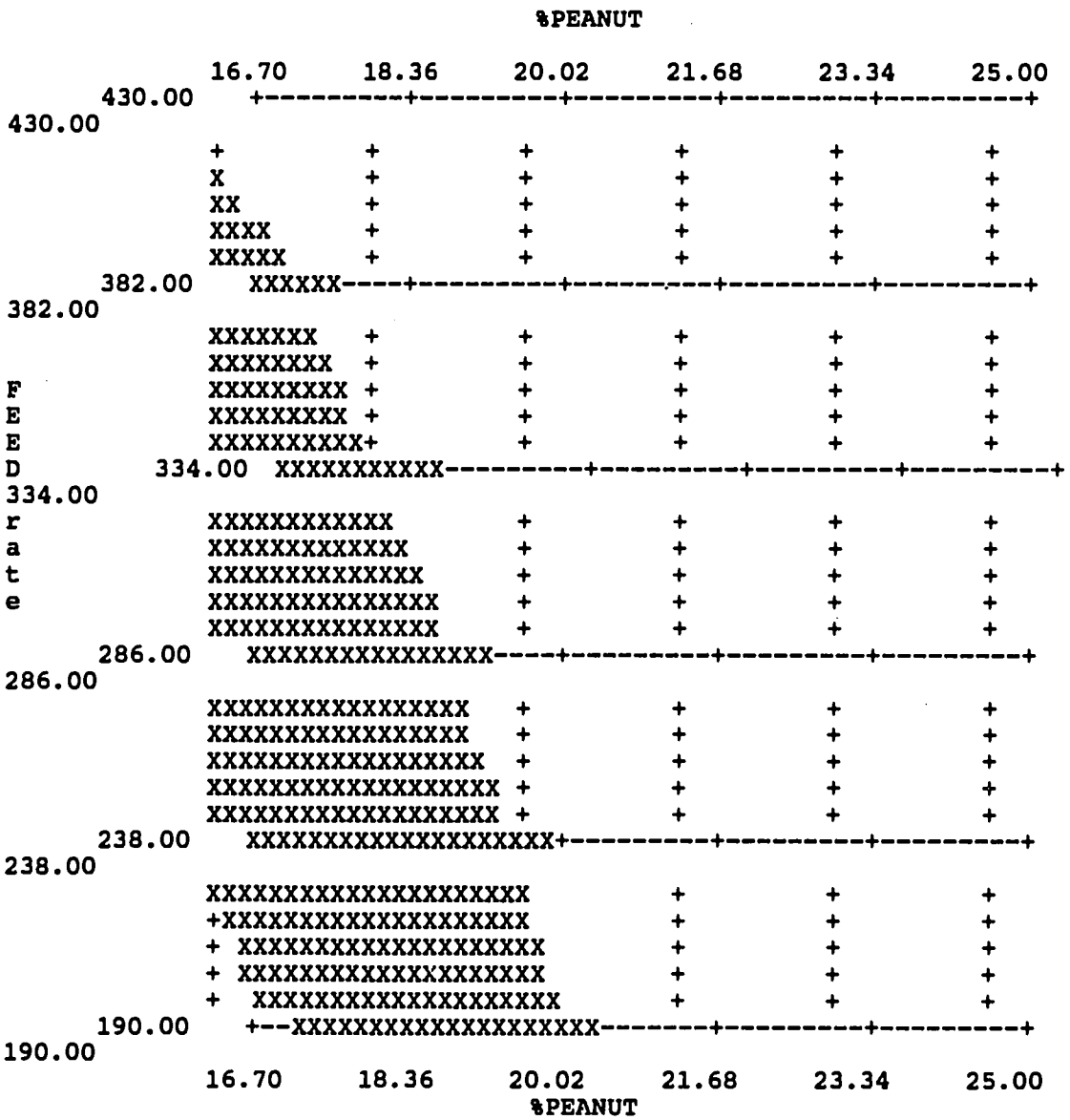

Figure 1. Overlay pattern for the predicted acceptance of

Ghana: To establish MOU to conduct research in collaboration with Sorghum/Millet and Bean/Cowpea projects as well as the Peanut CRSP.

Research Plan for 1992-1993

1. Research thrusts/endeavors planned for 1992 - 1993

U. S.

A. Roasted peanut product improvement by extension of shelflife

1. Earlier work at Alabama A&M University indicated that blanching of peanut with water or steam extends the shelflife of roasted peanut. It was also indicated that blanching with water or steam leads to a reduction in amounts of soluble sugars including raffinose and stachyose. Raffinose and stachyose are considered responsible for flatulence in peanut and peanut products. Organic acids and fatty acids are also reduced. Data has been submitted for publication.

2. Studies will be conducted to evaluate the shelflife of blanched peanut packaged in various packaging materials under a variety of environmental conditions. The aim of this study is to determine the most suitable packaging material at an affordable cost especially in Burkina Faso and other SAT peanut-producing countries. This study is in progress in Burkina Faso.

B. Peanut butter and peanut paste quality improvement

1. Peanut paste is one of the most utilized product forms in Burkina Faso and other Sahelian countries like Mali, Niger and Senegal. A survey of the quality of peanut paste was conducted. Peanut pastes were collected from four regions of Burkina Faso. Results indicated significant variations in chemical composition, microbial contamination and aflatoxin levels. It was also noted that peanut paste packaged in cans had uniform quality and insignificant amounts of microbial contamination. The packaging was done in large tin containers and marketing of the larger sized products was a problem. A research plan has been developed to evaluate suitable packaging materials at affordable costs.

Preliminary studies will be conducted at Alabama A&M at various environmental conditions. The study will extend to Burkina Faso.

2. A preliminary study for determination of the effects of sugars and processing methods on the rheological characteristics of peanut butter has been completed by a graduate student at Alabama A&M University.

Publication of these findings is pending analysis and interpretation of the data collected.

3. In order to appropriately recommend modification of peanut butter rheology by processing and additions of sugars for industrial application, further enhancements of the experimental design will be made to refine the basis of rheological parameter characterization of the products. This study will benefit US Food industries and will have impact in improving peanut paste for the host country. An Instron Universal Testing Machine will be used to determine flow properties of the peanut butter samples related to processing. Expected completion of these efforts will be May 1993.

4. To develop low fat and low calories peanut butter using newly developed fat substitutes. This will complement ongoing research in lipid laboratories at Alabama A&M University. The reasearch will involve studies on effects of fat substitutes on rheology of peanut butter.

C. 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. Research has also been completed, to develop a composite based on sorghum and peanut flours to make TOE', a commonly utilized product in Burkina Faso and other SAT countries. 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 1993.

   b. Development of snack foods like tortilla chips using peanut, corn and soybeans. Research will include rheological properties, sensory evaluation and processing parameters. Research will be completed in may of 1994.

   c. Introduction of the composite as a pilot-scale in the market place in 1992 (host country research). Completion date, December 1992.

2. Extruded snacking food products from wheat flour/ defatted peanut flour blends and sorghum/peanut mixtures have been produced at Alabama A&M University which characterize the cooking forming process of high-fat combinations of these cereal-based extrusion forms. The research is progressing and will involve combined effort.

3. An effort involving full-peanut product extrusion forming to fabricate a texturized meat-like substitute has been delayed after preliminary experimentation due to limitations of the A&M University extruder as currently configured but is anticipated to be revived as adaptations can be facilitated.

4. 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, and wheat will be investigated to adapt approaches to include peanut in appropriate combinations that should be safe and efficacious to improve the nutritional status of children and other at risk persons in the SAT regions of Africa. Research will include calculations to 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. The research will be completed in April 1994.

5. 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.

6. Qualities of peanut for processing are being assessed in collaboration with scientists in a variety trial project at Texas A & M. Samples have been analyzed for protein, fat, moisture and fatty acids in peanut grown at various locations in Texas in 1989 - 1990. A Ph.D student is working on control of galactosidase in peanut. Study is in progress to determine variations in anti-nutritional factors due to variety and processing methods. Data have been collected on selected cultivars on phytic acid and protein digestibility. A Ph.D student is working on control of oligosaccharide production in peanut. The study will be completed in April 1993. A new study has been planned to determine mono- and diglycerides and phospholipids of peanut cultivars. These constituents have both health and functional properties implications.

Host Country: Burkina Faso

A. A survey on quality of peanut paste available in four regions of Burkina Faso has been completed. Research has been planned to evaluate suitable packaging material to extend shelf-life and control contamination of the product. This study will be completed by December 1992. (See detail in U.S. Section).

B. Nutrient composition and aflatoxin contamination of cultivars grown in 1992 in Burkina Faso will be determined by May, 1993.

C. Peanut fortified toe' will be tested for acceptability in Burkina Faso and possibly in Mali (October 1992 - December 1993).

D. Sornut flour (composite of sorghum and peanut) will be introduced in urban market with suitable packaging by December, 1993.

E. Honey-roasted peanut has been produced and research is in progress on determination of acceptability by consumers in Burkina Faso. The study will also be conducted on shelf-life of honey-roasted peanut. Completion date, June 1993.

F. In collaboration with agronomists, research is in progress on use of antibodies reaction to determine the biological cycle of *Aspergillus* in the field. A student is working on his thesis.

GA/FT/TP

Appropriate Technology for Storage/Utilization of Peanut

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 seed 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 seed was also a high priority.

In the current phase of the project, a major effort is 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.

FY92 saw the initiation of a technology transfer project to village scale peanut processors at Huay Bong-Nua, Phroa District, Cheingmai Province, Thailand. Linkage with Cheingmai University through project investigators at Kasetsart University, Bangkok was established to facilitate this effort. Commercial production of peanut-supplemented noodles in Bangkok for the purposes of a marketing study was achieved.

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 Banos continue to be supported by the Peanut CRSP. 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 desire to have an impact on the entire region.

MAJOR ACCOMPLISHMENTS

A. Kasetsart University (KU) (Host Institution)

Shelf-life and consumer acceptance studies on the snack formula developed from defatted peanut and tapioca flours were completed. Products packed in aluminum foil bags can be stored for at least 2 months at ambient temperature without loss of quality. Ninety-five percent of the consumers surveyed indicated that the product was acceptable.

Supplementation of Thai sausage with 30% dried peanut tempeh resulted in no differences in sensory scores for color, flavor, texture and the acceptability.

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Replacing dried shrimp with dried peanut tempeh in Nam-Prik-Narok (hot chilli paste) resulted in no different acceptability scores between vegetarian and non-vegetarian consumers.

Production of peanut flour from small sized peanut (Tainan-9 variety) with qualities comparable to Indian and U.S. flours was made on a pilot scale.

Quality attributes of Tuub Taab marketed in Thailand were evaluated. Tuub Taab varied in weight, chemi-cal composition (especially protein and sugar contents) and price per piece. Thirty percent of the samples analyzed contained >100 ppb aflatoxin. Improvement of formula and processing of Tuub Taab were done.

Textured vegetable protein (TVP) from defatted peanut flour was developed using a village scale texturizer. Dough containing 35% moisture and processed at 165°C produced good TVP. Replacing chicken meat with 60% ground TVP in a ground chicken product resulted in comparable qualities.

A flavoring sauce from peanut press cake was developed. A mixture of mungbean protein isolate and peanut press cake containing 70% protein resulted in a flavoring sauce which met Thai standards.

Technologies for processing oil-roasted and ground-roasted peanut developed by Peanut CRSP were transferred to a group of 7 housewives at Hauy-Bong-Nua village, Phroa District, Cheingmai Province. Two products were processed and marketed at downtown Cheingmai and at Phroa District. Quality of those products was considered good. The housewives learned techniques not only about the processing of peanut products, but also about business and marketing management. This will help them to improve their quality of living. Profit from selling ground roasted peanut at the Phroa District is presently 1,088 Bahts/month/group.

B. <u>University of the Philippines - Los Banos (UPLB) (Linkage Institution)</u>

The peanut soft curd formulation was improved. Sensory acceptance was determined using a 1:6 peanut to water ratio. Agar-agar was most preferred as a firming agent. The product was comparable with a commercial soybean soft curd in its physico-chemical characteristics. Flavored peanut soft curds were also acceptable.

Carageenan and sodium alginate were evaluated as stabilizers in yogurt prepared from peanut milk. The effects of sucrose and glucose on growth of lactic bacteria were also determined. None of the concentrations of the stabilizers tested was effective.

Peanut kisses and cake were formulated. Both had high acceptability when subjected to sensory evaluation.

Peanut milk residue was utilized to formulate a cheese-flavored spread. Based on a_w and pH values, its stability was comparable with that of commercial spreads, thereby requiring refrigeration to prolong shelf-life. Spreads offer a potential for use of the peanut milk residue as a human food.

The effect of boiling, roasting and addition of baking soda and soda ash on the aflatoxin content of peanut was investigated. Considerable reduction of aflatoxin content was achieved.

Commercial peanut butter samples were analyzed for aflatoxin. Of the samples analyzed, only one exceeded 20 ppb.

Toxicity of <u>Cladosporium fulvum</u> biomass was evaluated using chick embryo bioassays. No toxic or inhibitory component was detected and thus the mold might be used to inhibit the growth of <u>Aspergillus parasiticus</u> under controlled conditions.

C. University of Georgia (UGA)

Consumer tests involving 416 respondents were conducted, in cooperation with UPLB team members, at six central locations in the Philippines to determine the acceptability of a cheese-flavored peanut-based spread. The spread was most acceptable to people over twenty years of age who had a monthly income of less than P 24,000. Consumers were willing to pay a higher price for the cheese-flavored spread than for peanut butter but lower than that for a dairy-based spread. Discussions were held with Dr. V. Garcia (UPLB) and Dr. Sonia de Leon (UP - Dilliman) concerning the preparation of a proposal for working with a private Filipino food company.

The effects of substituting fermented peanut milk for buttermilk, sour cream and yogurt in salad dressing, muffin and cookie formulations were investigated. Fermented peanut milk can be substituted for buttermilk in salad dressing at levels up to 25% without substantial reduction in sensory qualities. Dried fermented peanut milk can be substituted for powdered buttermilk, sour cream and yogurt in muffin and cookie recipes without sacrificing sensory qualities.

Chemical hydrolysis of defatted peanut flour was carried out with hydrochloric acid and neutralized with sodium carbonate. Various combinations of time, temperature and acid concentrations were employed. Optimization of hydrolysis conditions is being resolved using response surface methodology and chemical evaluation.

Hydration of peanut butter/paste to make an oil in water emulsion similar to mayonnaise was studied. The viscosity increased and then decreased as water or acid were added. The adhesive properties of the mixture were also shown to change with the phase change. The protein component is deemed to be the effective agent. The utilization of this emulsion as a base for spreads is being investigated.

A comparison of one-way analysis of variance and cluster analysis as statistical methods for selecting members of a descriptive panel for a coffee whitener prepared from peanut extracts was done. Five factors were adequate to model the data. Means and standard deviations of the scores showed that greater variability among panelists' ratings resulted when the panel was selected using one-way ANOVA than when cluster analysis was used.

An expandable lexicon that will be useful in describing performance of peanut-based whiteners in coffee was developed. Fourteen descriptors of appearance, flavor, mouthfeel and suspension stability were used to evaluate the performance of four whiteners. Descriptors relating to physical appearance were the most significant. Creamy and powdery were not reliable descriptors. A final lexicon composed of the descriptors color, grainy, curdled, lumpy, nutty, oily flavor, beany, painty, bitter, viscosity, oily suspension, and surface layer thickness was reliable and valid.

The fate of ^{14}C-labeled aflatoxin B_1 (^{14}C-B_1) in the presence of a bacterium, Flavobacterium aurantiacum, was determined. The normally chloroform-soluble ^{14}C-B_1 is rapidly converted to water-soluble degradation products. Some radioactivity initially associated with the pellet fraction is lost at about the same rate as the water-soluble degradation products appear; some ^{14}C is then gradually reincorporated into the pellet fraction. The evolution of $^{14}CO_2$ is further evidence that at least a portion of the ^{14}C-B_1 is metabolized by F. aurantiacum.

The feasibility of separating aflatoxin-contaminated peanut seed from sound seed by treatment in H_2O_2 solution was investigated. Concentrations of 0.075, 0.150 and 0.225% H_2O_2 resulted in a reduction in aflatoxin content in the seed in the sinker fraction by 90% within 1 min regardless of the initial aflatoxin content. Response surface methodology was used to determine optimum treatment conditions

for giving a maximum yield of the sinker fraction with low aflatoxin content. For peanut containing 50 ppb aflatoxin, optimum conditions consist of a 0.08% H_2O_2 treatment for 0.7 min. This procedure results in a maximum sinker fraction yield of 85.5% of the original lot with a residual aflatoxin content of ≤ 5 ppb.

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 (1991-92)

A. Kasetsart University

1. Assist in transferring technologies developed by Peanut CRSP to Huay Bong-Nua, Phroa District, Cheingmai Province, and evaluate the socio-economic impact on peanut farmers.
2. Investigate the use of peanut tempeh in Thai food systems.
3. Determine shelf-life and consumer acceptability of snack foods containing defatted peanut flour and pregelatinized tapioca flour.
4. Work on pilot scale production of peanut flour using the Tainan-9 variety and study its quality.
5. Improve and further develop tuub taab in Thailand.
6. Initiate work to develop textured vegetable protein from low fat Thai peanut flour.
7. Develop a seasoning sauce from peanut press cake.
8. Determine market potential for peanut-supplemented Chinese-type noodles in Thailand.

B. University of the Philippines - Los Banos

1. Continue product development and improvement studies for snack foods, sauces, spreads and fermented products from peanut.
2. Study the utilization of peanut residue from the extraction of peanut milk.
3. Study the effect of processing on aflatoxin content and continue monitoring the aflatoxin content in commercial peanut and peanut products.
4. Study conditions necessary for promoting microbiological control of aflatoxin production and to identify and characterize the safety of such systems.

C. University of Georgia

1. Continue studies on developing alternate uses of peanut in foods, including coffee/tea whiteners, paste, bakery items and sauces appropriate for the U.S. and other markets.
2. Optimize conditions for separating mold-infected seed from sound seed by a H_2O_2 treatment.
3. Conduct experiments to determine the mechanism of "detoxification" of aflatoxin-contaminated peanut by a bacterium, *Flavobacterium aurantiacum*, and to investigate physical and chemical methods for detoxification.

ORGANIZATION AND PERSONNEL

A. Kasetsart University

Department of Product Development (KU)

Dr. Penkwan Chompreeda, Principal Investigator
Dr. Chintana Oupadissakoon, Co-Investigator
Mr. Vichai Haruthaithanasan, Co-Investigator
Mr. Paiboon Thramratwasik, CopInvestigator
Mr. Sombat Khotaveewattana, Co-Investigator
Mr. Wiwat Wattanatchariya, Graduate Student (M.S.)
Mr. Thongchai Suwonsichon, Graduate Student (M.S.)
Mr. Chaiwat Tipsuk, Graduate Student (M.S.)
Ms. Sujinda Suwannakij, Graduate Student (M.S.)
Ms. Sirin Pussayapaiboon, Graduate Student (M.S)
Ms. Sumet Amnuaysirisuk, Graduate Student (M.S.)
Ms. Nantana Chutimantanon, Laboratory Technician

Department of Agricultural Economics (KU)

Dr. S. Wattanatchariya, Cooperator

Department of Marketing (KU)

Dr. C. Piemsomboon, Coopeerator
Dr. S. Chuenputhi, Cooperator

Thai Preserved Foods Factory

Mr. O. Praepanichchai, Cooperator

Department of Food Science and Technology, Cheingmai University

Dr. Narin Thongsiri, Cooperator

B. University of the Philippines, Los Banos

Institute of Food Science and Technology

Dr. Virgilio V. Garcia, Principal Investigator
Dr. Ricardo del Rosario, Co-Investigator
Dr. Reynaldo C. Mabesa, Co-Investigator
Ma. Gracia L. Bailon, Research Associate
Angelina M. Alvarez, Research Associate
Lorelei M. Zoleta, Research Associate
Helen G. delos Reyes, Research Associate
Olivia Estioko, Research Associate
Emilia T. de Castro, Undergraduate Student
Rhoda L. Natividad, Undergraduate Student
Arlene M. Villena, Undergraduate Student

C. University of Georgia

Department of Food Science and Technology

Dr. Larry R. Beuchat, Principal Investigator
Dr. Robert E. Brackett, Co-Investigator
Dr. Tommy Nakayama, Co-Investigator
Dr. Anna V. A. Resurreccion, Co-Investigator
Dr. Yen-Con Hung, Cooperator
Mr. Eric Line, Graduate Student (Ph.D.)
Mr. Witoon Prinyawiwatkul, Thai Graduate Student (M.S.)
Ms. Rudeepan Wattanapat, Thai Graduate Student (M.S.)
Ms. Therese Malundo, Filipino Graduate Student (M.S.)
Ms. Rocelle Clavero, Filipino Graduate Student (M.S.)
Mr. Richard Stinchcomb, 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. Brenda Nail, Research Technician III (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, no support)

ACCOMPLISHMENTS IN DETAIL

RESEARCH

A. Accomplishments at Kasetsart University

Work at the Department of Product Development, Kasetsart University in FY92 was devoted to improvement and development of peanut products as foods and/or ingredients. Moreover, studies on the socio-economic impact by technology transfer and marketing potential of selected products were also done.

1. Shelf-Life Stability and Consumer Acceptability of a Snack Containing Defatted Peanut and Pregelatinized Tapioca Flour

The development and quality characteristics of a buttered caramel flavor snack prepared from defatted peanut and pregelatinized tapioca flours was reported in the FY91 report. The snack base contained 33% defatted peanut flour, 46% pregelatinized starch and 21% water. The process for preparing the snack is shown in Fig. 1. The snack contains a very good source of protein (24%) as compared to the commercial product (5%).

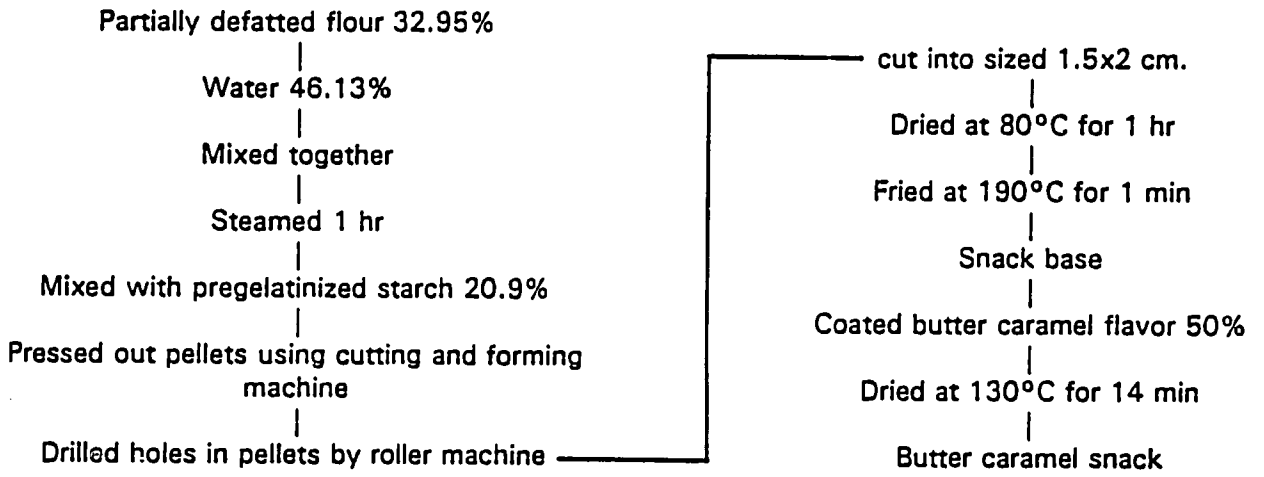

Fig. 1. Flow diagram of process of butter caramel snack.

To evaluate shelf-life of the snack,products were packed in polypropylene and aluminum foil bags and stored at 25° and 30°C for 8 weeks. Water activity of the snacks increased slightly at the end of the storage period. Peroxide values steadily increased while compressive force values decreased regardless of package and storage temperature (Table 1.) Sensory analysis revealed that panelists still accepted all products at the end of 8 weeks.

Table 1. Water activity, peroxide value and compressive force of snack food stored in various packages for 8 weeks.

Storage time wk)	Package[1]	Water Activity 25°C	Water Activity 30°C	Peroxide Value (Meq./kg) 25°C	Peroxide Value (Meq./kg) 30°C	Compressive force (N) 25°C	Compressive force (N) 30°C
0		0.26		2.17		7.66	
2	PP	0.26	0.28	7.23	6.85	10.30	12.34
	AL	0.26	0.26	5.84	5.86	7.78	7.48
4	PP	0.27	0.34	11.24	11.50	10.97	13.31
	AL	0.27	0.27	5.85	6.21	9.21	9.98
6	PP	0.29	0.34	11.82	12.31	11.60	15.29
	AL	0.28	0.29	8.56	9.56	9.05	9.64
8	PP	0.31	0.42	15.96	18.92	12.53	16.15
	AL	0.30	0.29	8.74	10.21	9.11	9.15

[1]PP = Polypropylene; AL = Aluminum foil

Table 2.Mean hedonic scores (9-point scale) for a butter caramel peanut-supplemented snack obtained from 500 secondary school students.

	Sex[1]		Grade (G)			
Sensory quality	Boy	Girl	G7	G8	G9	Mean
Appearance	5.78a	5.67a	6.05a	5.42c	5.72b	5.72
Color	5.59b	5.95a	5.94a	5.47b	5.88a	5.77
Butter aroma	7.09a	6.71b	7.21a	6.52c	6.97b	6.90
Sweetness	7.02a	6.59b	7.04a	6.39b	6.96a	6.80
Crispiness	7.23a	6.94b	7.37a	6.75b	7.14a	7.08
Flavor	7.21a	6.57b	7.39a	6.35c	6.94b	6.89
Overall Impression	7.27a	6.82b	7.59a	6.44c	7.11b	7.04

[1]Means in the same column which are not followed by a common letter are significantly different ($P \leq 0.05$).

Snacks were subjected to consumer acceptance tests using 500 secondary school students in Bangkok. Hedonic scores (1=dislike very much, 9=like very much) for appearance, color,crispiness, sweetness, butter aroma, flavor and overall impression are shown in Table 2. Boys like the snack more than girls and students in grade 7 like the product the most. Consumers (95%) indicated that the snack was acceptable, and of these, 62% were willing to pay US$ 0.20 for a 40-g bag.

2. Consumer Acceptability of Thai Foods Containing Peanut Tempeh

Qualities of peanut tempeh prepared from partially defatted peanut locally grown in Thailand were reported in the FY91 report. Peanut tempeh has high potential for use in the Thai food system. Two Thai foods were prepared using dried ground peanut tempeh: extended Thai sausage and imitation Nam-Prik-Narok (hot chilli paste).

a. Thai Sausage. Thai sausages were prepared according to the formulations in Table 3. Extended Thai sausages were prepared by replacing ground pork each with 30% partially defatted peanut flour and 30% dried ground peanut tempeh. A flow diagram for preparing extended Thai sausage is shown in Fig. 2. Consumer tests of Thai sausage containing partially defatted peanut and dried peanut tempeh were conducted at the Department of Product Development, Kasetsart university. Two randomly coded samples were served to 60 consumers. Panelists were asked to rate each sample using 9-point hedonic scales (1=dislike very much, 9 = like very much) for overall preference and preference for color, flavor and texture.

Table 3. Ingredients of extended Thai sausage.

Ingredients	Gram
Ground pork	35.0
Dried peanut tempeh (or partially defatted peanut flour)	15.0
Cooked rice	25.0
Lard	12.0
Cooked shredded pork skin	5.0
Minced garlic	5.0
Salt	1.0
Ground black pepper	0.3
Sugar	0.5
Ground coriander	0.2
Natural casing	30.0

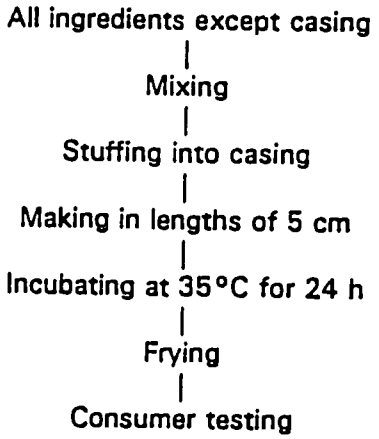

Fig. 2. Flow diagram for preparation of Tha sausage extended with peanut tempeh and partially defatted peanut flour.

Table 4. Mean sensory scores[1] of Thai sausage supplemented with 30% partially defatted peanut flour (PDPF) and peanut tempeh (PT).

Sensory factor	Thai sausage - PDPF	Thai sausage - PT
Color	6.9 a	6.9 a
Flavor	6.7 a	7.0 a
Texture	6.3 b	6.8 a
Overall preference	6.6 b	7.0 a

[1]n = 60 consumers; Mean in the same column followed by a different letter are significantly different ($P \leq 0.05$). Dislike very much = 1; like very much = 9.

Mean scores for extended Thai sausage containing partially defatted peanut flour and dried ground peanut tempeh are shown in Table 4. Responses of 60 Thai consumers for color and flavor were not significantly different. Texture and overall preference for extended Thai sausage containing peanut tempeh were significantly higher than that of sausage containing partially defatted peanut flour. The overall preference for Thai sausage extended with peanut tempeh rating of 7.0 corresponds to "like moderately" on the 9-point scale.

b. Imitation Nam-Prik-Narok Preparation. Imitation Nam-Prik-Narok (hot chilli paste) was prepared by replacing dried shrimp with dried ground peanut tempeh. Imitation Nam-Prik-Narok was prepared according to the diagram in the Fig. 3.

Consumer tests of imitation Nam-Prik-Narok were conducted at the Kasetsart Fair, Kasetsart University using non-vegetarian consumers, and at a vegetarian food shop in Bangkok for vegetarian consumers. Samples were served to 45 consumers in each group. Panelists were asked to rate each sample using a 9-point hedonic scale for overall preference and preference for color, odor, spicy flavor and texture. Responses for preference of color, odor, spicy flavor and overall preference were not significantly different. These preference ratings of 5.8 to 7.2 correspond to "like slightly" to "like moderately". Vegetarian consumers liked the texture of the imitation Nam-Prik-Narok more than the non-vegetarian consumers did. Results indicate that peanut tempeh prepared from locally grown peanut can be used as a meat extender, and for vegetarian products as well as snacks to produce acceptable products. Products would be appropriate for Thais as well as for people in other developing and developed countries.

Table 5. Mean sensory scores[1] of the consumers for imitation Nam-Prik-Narok prepared from dried peanut tempeh.

Sensory factor	Vegetarian consumers	Non-vegetarian consumers
Color	7.2 a	6.6 a
Odor	6.5 a	6.1 a
Spicy flavor	6.0 a	5.8 a
Texture	6.8 a	5.6 b
Overall preference	6.9 a	6.4 a

[1]n = 45 consumers; Mean in the same column followed by a different letter are significantly different ($P \leq 0.05$). Dislike very much = 1; like very much = 9.

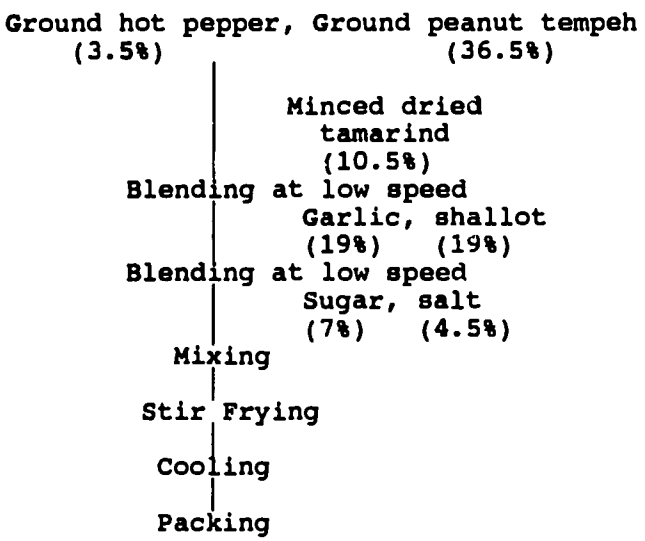

Fig. 3. Flow diagram for preparation of imitation Nam-Prik-Narok using dried peanut tempeh.

3. Pilot Scale Production of Defatted Peanut Flour from Small Sized Peanut

Potential utilization of defatted peanut flour in several products on a commercial scale has been demonstrated. Production of defatted peanut flour using Tainan-9 variety of peanut was done at the DOA pilot scale oil extraction plant. During the past 2 yr, this flour was used as an ingredient in products such as snacks and noodles. This study was conducted to evaluate the potential of small sized peanut for producing defatted peanut flour on a pilot scale. Quality characteristics of defatted peanut flour were determined.

A preliminary study indicated that partially defatted peanut containing 37% fat and 6.4% moisture prepared from blanched small sized peanut was suitable for the DOA - pilot scale oil extraction plant. After extraction of a 200 Kg batch for 11 hr, defatted peanut was heated at 65°C under vacuum for 3 hr to remove hexane. Then the peanut was ground into flour. The yield was 27.6%. Quality characteristics are shown in the Table 6. Quality of flour prepared from small sized peanut met both the Indian Standard Institute (ISI) and U.S. Flour Standards for defatted peanut flour for human consumption.

4. Improvement and Development of Tuub Taab in Thailand

Tuub Taab is a traditional Thai sweet snack. Containing up to 50% roasted peanut. The household process for making Tuub Taab is shown in the Fig. 4. Quality characteristics of Tuub Taab were studied by sampling products obtained from four locations in Bangkok and two locations in Khon-Khaen Province. Samples were taken from each location twice monthly.

Table 6. Quality characteristics of defatted peanut flour prepared from small sized peanut (TPF), Indian Standard Institute (ISI) and U.S. Flour standard for defatted flour.

Characteristics Flour	TPF	ISI	U.S.
Moisture (%)	7.19	<8.0	<9.0
Fat (%)	1.29	<1.5	<2.0
Protein (N x 6.25) (%)	63.34	>47.0	>55.0
Fiber (%)	1.68	<5.0	<5.0
Ash (%)	4.18	<5.0	<4.5
Acid insoluble ash (%)	0.02	<0.35	<0.2
Aflatoxin (ppb)	ND	<120	<20
Total count (Colony/g)	<30	$<5x10^4$	$<5x10^4$
Salmonella (1g)	ND[1]	ND	ND
E. coli (1g)	ND	10	10
Pathogenic microorganisms	ND	-	-
Color			
L	94.40	-	-
a	-0.73	-	-
b	7.36	-	-
a_w	0.53	-	-
Bulk Density (g/ml)	0.41	-	-
Protein Dispersion Index (%)	75.97	-	-

[1]ND = None detected

Water, Sugar, Glucose Syrup
|
Boiling - to concentrate them until boiling come up to 155°C
Mixing - with fully roasted peanut 50% or less
Beating - with wooden hammer
- folding and repeating beating until light in texture and and crispness
Folding - into rectangular shape 2.5 x 6.5 cm, and 1.5-2.0 cm thick
|
Wrapping - with waxed paper
|
Tuub Taab

Fig. 4. Flow diagram of household process for preparation of Tuub Taab.

Results show that Tuub Taab is rectangular in shape (3.0 x 6.0 cm) and 2.0-2.5 cm thick. Each piece of product is wrapped with cellophane or waxed paper and packed in polyethylene pouch. The price varied from 8-30 bahts per pack (Table 7). The chemical composition, a_w, peroxide value and aflatoxin content of the products are shown in the Table 8. The protein content of the product varied (0.7-19.1%) from location to location. It was shown that each location had a different recipe, the amount of roasted peanut varying most greatly. Results also indicated that products from only 2 of 6 locations [Sam-Yaek-kaset, Bangkok (SB) and Khon-Khaen 2 (K1)] contained very high aflatoxin (>100 ppb), which is over the Thai FDA limit (100 ppb).

Table 7. Physical qualities, number of Tuub Taab/package, price of tested Tuub Taab from various locations.

Sample[1]	Wt/piece[2] (g)	Length (cm)	Width (cm)	Thickness (cm)	Pieces/ package	Price (Baht)
PB	21.40 bc	4.36 c	2.72 b	2.24 a	5	10
BB	24.84 ab	4.02 c	3.76 a	2.22 a	5	10
AB	26.92 a	8.16 a	3.62 a	1.24 b	10	8
SB	16.38 a	8.48 a	3.38 c	1.26 b	10	10
K1	18.10 a	7.04 b	2.14 c	1.21 b	20	30
K2	18.10 ad	7.04 b	2.06 c	1.21 b	20	30

[1]PB = Phathom-Wan, Bangkok (1st location)
BB = Bang-Lum-Poo, Bangkok (2nd location)
AB = Amorn-Pan, Bangkok (3rd location)
SB = Sam-Yaek-kaset, Bangkok (4th location)
K1 = Khon-khaen 1 (5th location)
K2 = Khon-khaen 2 (6th location
[2]Values in the same column which are followed by a common letter are significantly different ($P \leq 0.05$).

Table 8. Chemical composition and water activity (a_w) of surveyed Tuub Taab..

Compositions	PB	BB	AB	SB	K1	K2
Moisture (%)	2.5	3.2	3.2	3.4	5.1	3.5
Protein (%)	13.6	11.4	9.7	9.9	16.4	19.1
Fat (%)	23.4	18.8	20.5	15.5	26.2	28.0
Carbohydrate (%)	60.4	68.2	67.9	72.5	54.7	50.2
Fiber (%)	1.3	0.7	0.6	0.4	1.5	1.3
Ash (%)	1.4	0.9	1.4	1.7	1.2	1.4
a_w	0.23	0.24	0.33	0.32	0.33	0.30
Peroxide value (Meq./kg)	7.2	10.6	24.5	14.7	11.4	13.5
Aflatoxin (ppb)	20	<10	<10	>100	>100	<10

*PB = Phathom-Wan, Bangkok (1st location)
BB = Bang-Lum-Poo, Bangkok (2nd location)
AB = Amorn-Pan, Bangkok (3rd location)
SB = Sam-Yaek-kaset, Bangkok (4th location)
K1 = Khon-khaen 1 (5th location)
K2 = Khon-khaen 2 (6th location)

Products contained different amounts of reducing sugar, sucrose and total sugar recipe (Table 9). It was concluded that all the products were microbiologically safe. Sensory attributes scores of the products are shown in the Table 10. Systematic product improvement was employed to standardize Tuub Taab quality through improvement of formulas and processing conditions. The optimal formula of Tuub Taab contained 50% ground roasted peanut, 45% sugar, 47.5% glucose syrup,

and 0.25% salt and was subjected to the process according to the Figure 5. Consumer acceptance as well as shelf life of the improved Tuub Taab will be investigated to determine the market potential and storage stability (Table 11).

Table 9. Sugar contents in Tuub Taab.

Sample[1]	Reducing sugar (%)	Sucrose (%)	Total sugar (%)
PB	10.88	44.95	55.83
BB	9.45	55.44	64.88
AB	13.88	33.27	47.15
SB	16.26	34.67	50.93
K1	7.56	33.80	41.36
K2	7.21	36.58	43.78

[1]PB = Phathom-Wan, Bangkok (1st location) SB = Sam-Yaek-kaset, Bangkok (4th location)
BB = Bang-Lum-Poo, Bangkok (2nd location) K1 = Khon-khaen 1 (5th location)
AB = Amorn-Pan, Bangkok (3rd location) K2 = Khon-khaen 2 (6th location

Table 10. Mean attribute scores of surveyed Tuub Taab as determined by a sensory panel[1].

Sample	Color	Extra Peanut	Hardness	Sweet Crispiness	Peanut Taste	flavor	Rancid
PB	8.05 b	4.53 d	5.66 c	8.92 a	8.89 a	7.61 a	1.80 b
BB	8.12 b	9.16 b	7.74 b	8.53 ab	9.60 a	5.92 b	1.61 b
AB	4.22 c	6.61 c	3.77 d	5.50 c	7.46 b	4.83 b	4.27 a
SB	3.08 c	7.07 c	4.37 d	6.75 c	7.26 b	4.85 b	3.62 a
K1	9.73 a	12.04 a	9.07 a	6.80 c	7.71 b	8.60 a	2.84 ab
K2	10.42 a	10.42 a	11.51 a	7.35 b	7.02 bc	8.51 a	2.98 ab

[1]Attributes were evaluated using a 15 cm continuous line scale anchored at both ends with terms: light to dark for color; none to too much for extra peanut; soft to hard to hardness; soft to very crispy for crispiness; weak to strong for sweet taste, peanut flavor and rancid flavor. Means in the same column which are not followed by a common letter are significantly different ($P \leq 0.05$).
PB = Phathom-Wan, Bangkok (1st location) SB = Sam-Yaek-kaset, Bangkok (4th location)
BB = Bang-Lum-Poo, Bangkok (2nd location) K1 = Khon-khaen 1 (5th location)
AB = Amorn-Pan, Bangkok (3rd location) K2 = Khon-khaen 2 (6th location

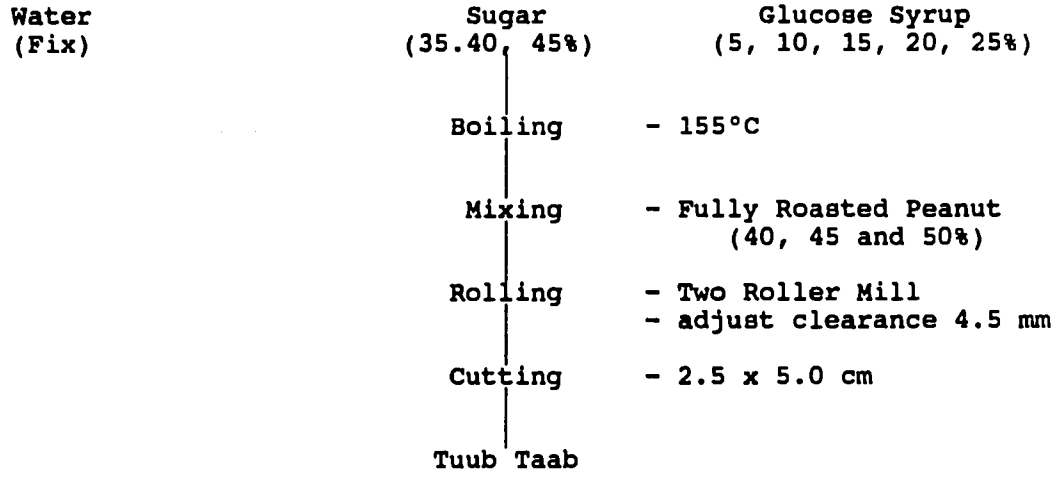

Fig. 5. Flow diagram for improved formula and for making Tuub Taab.

Table 11. Quality characteristics of improved Tuub Taab.

Characteristics	Value	Characteristics	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
Color		Peroxide value	0
L	63.04	Aflatoxin (ppb)	<10
a	5.31		
b	23.01	Total count (colony/g)	<30-380
Moisture	1.79	Yeast and mold (colony/g)	20-90
Protein	13.92	*S. aureus*	ND
Fat	23.40		

Table 12. Chemical composition of texturized peanut protein and defatted peanut flour.

Composition (%)	Texturized Protein	Defatted peanut flour
Moisture	5.10	4.76
Protein	44.18	45.50
Fat	3.02	2.25
Carbohydrate	39.95	39.34
Fiber	2.94	3.67
Ash	4.81	4.48

Table 13. Quality characteristics and sensory scores of chicken balls supplemented with 60% TVP.

Characteristics Score	Value	Sensory Factor	
Physical			
Color			
L	37.45	Color	8.23
a	8.42		
b	12.45	Flavor	6.89
Chemical		Texture	6.87
Moisture	52.13		
Protein	34.76	Overall	
Fat	3.16	impression	7.02
Microbiological			
Total count (colonies/g)	34		
Coliforms (MPN/g)	<3.0		
Salmonella	ND		

5. **Optimization of Parameters for Production of Textured Vegetable Protein from Peanut Flour**

Defatted peanut flour (2% fat) was used to prepare TVP. TVP prepared from a 35% moisture dough processed at 165°C resulted in good characteristics. The chemical composition of TVP as compared to that of the defatted peanut flour are shown in the Table 12. Replacing chicken meat with 60% of ground peanut RVP resulted in comparable qualities to control chicken balls. Quality characteristics and sensory scores of extended chicken ball are shown in the Table 13.

6. **Development of a Flavoring (Seasoning) Sauce from Peanut Press Cake**

Peanut press cake, the by-product from peanut oil extraction, has been studied as a base for preparing a flavoring sauce. An acid hydrolysis method was employed. The ratio of peanut press cake to acid, acid concentration and hydrolysis conditions was studied. Preliminary results showed that a ratio of 1:4 of peanut press cake to 6N HCl acid and digestion at 121°C, 15 psi for 3 h gave the best sauce. However, the chemical composition, particularly total nitrogen content, amino acid nitrogen and sodium chloride content, did not meet the Thai standard for sauce.

Therefore lactic casein and mungbean protein isolates were added to increase total nitrogen content and amino acid nitrogen. Three mixtures of raw material (A, B,C) were prepared by mixing peanut press cake with lactic casein to obtain protein contents of 60%, 65% and 70%, respectively. The next three mixtures (D, E, F) were prepared by mixing peanut press cake and mungbean protein isolate to obtain the same amount of protein content as the first three. The raw control material was peanut press cake alone. Six different mixtures of raw material were subjected to the process which is shown in the Figure 6. The mixture of mungbean protein isolate and peanut cake containing 70% protein resulted in a total nitrogen content which met the Thai standard (Table 14). Sensory attribute scores for peanut-based flavoring sauces and commercial sauce are shown in Table 15. Results indicated that only the color was significantly different. These results indicate that further studies, particularly in the development of a sauce with flavor which would be highly acceptable by the consumer, are needed.

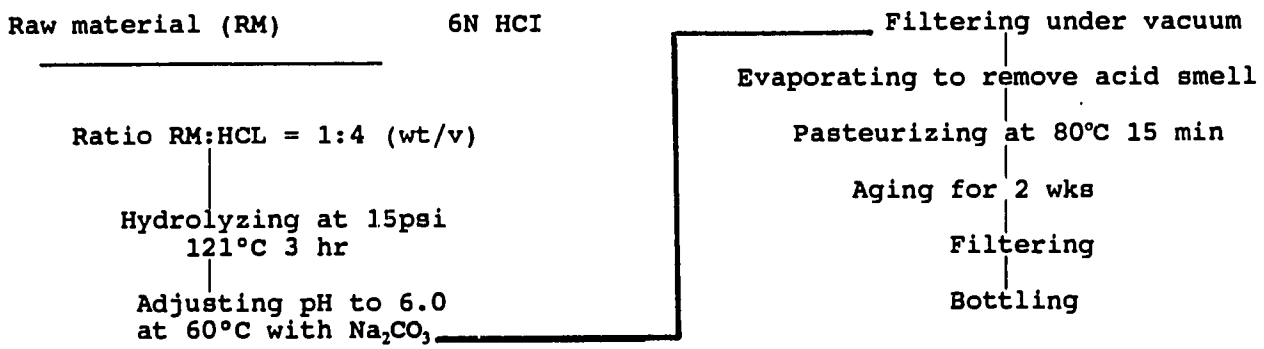

Fig. 6. Flow diagram for processing a flavoring sauce from peanut press cake.

Table 14. Specific gravity and chemical composition of flavor sauces and a commercial flavor sauce.

Sample[1]	Specific gravity	aaN pH	Total N (g/l)	NaCl (g/l)	Formal (g/l)	Titration	
Standard	>1.24		5.0-6.2	>20.0	>30.0	200	--
Commercial	1.25		6.1	27.02	47.21	211.41	22.20
Control	1.21		6.2	15.94	19.04	270.08	18.61
A	1.21		6.1	16.59	23.84	275.56	17.03
B	1.21		6.2	18.09	26.10	272.51	17.44
C	1.21		6.1	18.47	27.30	277.69	17.90
D	1.21		6.0	17.94	28.18	278.60	17.56
E	1.22		6.2	18.35	29.31	274.95	17.78
F	1.22		6.2	19.01	30.63	275.25	18.65

[1]Control = Peanut press cake (PC):
A = PC + Lactic casein = 60% protein equivalent
B = PC + Lactic casein = 65% protein equivalent
C = PC + Lactic casein = 70% protein equivalent
D = PC + Mungbean protein isolate = 60% protein equivalent
E = PC + Mungbean protein isolate = 65% protein equivalent
F = PC + Mungbean protein isolate = 70% protein equivalent

Table 15. Mean attribute scores of flavor sauces prepared from different raw materials as determined by a sensory panel[1]

Sample[2]	Color	Clearness	Aroma	Salt	Sweet	Sour	Bitter
			non-significant				
Commercial	7.73 a	6.19	6.41	7.63	2.68	2.60	1.82
Control	7.19 ab	5.86	6.84	8.20	2.56	2.05	2.13
A	6.94 b	6.16	6.84	8.40	3.03	2.13	1.67
B	6.20 cd	6.23	7.12	7.80	2.92	2.01	1.67
C	5.83 cde	6.91	7.31	7.75	3.20	2.23	1.49
D	5.66 def	7.02	6.25	7.48	2.36	1.94	1.45
E	5.07 fg	6.81	6.38	8.15	2.79	2.14	1.54
F	5.48 dg	7.04	5.85	7.73	2.52	1.86	1.69

[1]Attributes were evaluated using a 150 mm continuous line scale anchored at both ends with terms: light to dark for color; turbid to clear for clearness; weak to strong for aroma, salt, sweet, sour and bitter. Means in the same column which are not followed by a common letter are significantly different at $P < 0.05$.
A=PC+Lactic casein=60% protein equivalent
B=PC+Lactic casein=65% protein equivalent
C=PC+Lactic casein=70% protein equivalent
D= PC+ Mungbean protein isolate=60% protein equivalent
E= PC+ Mungbean protein isolate=65% protein equivalent
F= PC+ Mungbean protein isolate=70% protein equivalent

7. Transfer of Technology Developed by Peanut CRSP to Huay Bong-Nua Village, Phroa District, Cheingmai Province

Huay-Bong-Nua Village is located in the Phrao-District in Northeastern Cheingmai Province, about 90 Km from downtown Cheingmai. The total area of this village is 3,895 Rai (1 acre = 2.5 Rais). The village is located on newly developed land as an Agricultural Co-Operative Park for poor farmers who own no land. Each family tends about 10-20 Rais for living and farming (crops, livestock and fisheries). Almost all of the area is used for growing rice in the rainy season. Peanut is a second crop which is grown on about 80% of the land area. The total population of the village is 658 persons, of which 316 are men and 342 are women. The total number of households in this village is 193 families. Many crops are grown in the village, e.g., rice, peanut, soybean, mungbean, corn and chilli. The land utilization for growing peanut is 5.76 Rai which is about 45% of total land per household. Net income of cash per household is shown in Table 16; 6,388 Baht per year was earned from selling peanut, which was about 32.9% of total income (19,409 Bahts). Expenditure for food was 10,815 Bahts/year/household (Table 17) which was 67.6% of the total expense (15,997 Bahts). The total expenditure of peanut production per rai was 2,050 Bahts. Table 18 shows the production cost and net income of peanut production per rai at Huay-Bong-Nua Village. Production yield was 225 kilograms per rai and selling price was 93.9 Baht; therefore, net income was 1,882 Baht. Net profit over cash farm expense was 1,085 Bahts/rai for peanut (Table 19), which was the highest profit among 6 crops.

Table 16. Land utilization for farming at Huay-Bong-Nua Village, Crop Year 1990-91.

Crop	Planted area (Rais/household)	%
Peanut	5.76	45.04
Chilli	2.34	18.30
Maize	1.89	14.78
Soybean	1.50	11.73
Rice	1.16	9.07
Blackpea	0.35	0.78
Mungbean	0.32	0.31
Total	13.32	100.00
Cropping intensity	1.07	

Table 17. Cash farm expenses per household

Item	Expense (Baht)	%
Food	10,815.28	67.61
Clothes	1,271.80	7.95
Medicine	881.40	5.51
Festivals	1,024.80	6.41
Others	2,003.40	12.52
Total	15,996.68	100.00

Table 18. Net investment and return for peanut production in Huay-Bong-Nua Village

Item	Value
Yield (Kg/Rai)	225.52
Average price (Baht/Kg)	9.39
Income per rai (Baht)	1882.27
Variable cost per rai (Baht)	1971.70
Fixed cost per rai (Baht)	77.88
Total cost per rai (Baht)	2049.58
Total cash cost per rai (Baht)	797.77
Net return (Baht)	-89.43
Net profit over cash cost (Baht/rai)	1084.50
Net profit over total cost (Baht/rai)	-167.31

Table 19. Comparison of net profit over cash for various crops grown in Huay-Bong-Nua Village

Crop	Net profit over cash (Baht/rai)
Peanut	1084.50
Chilli	962.14
Maize	768.82
Soybean	667.95
Blackpea	335.43
Mungbean	150.00

The Department of Product Development, Kasetsart University joined with the Department of Food Science and Technology, Cheingmai University to conduct an investigation of the effect of transferring technology of peanut product on socio-economic status of farmers at Huay-Bong-Nua Village, Phrao District, Cheingmai Province. Six steps were involved in the transfer process:

Step 1. Seven housewives comprised a pioneer test group for processing peanut products to market in downtown Cheingmai and Phrao-District markets. A District Home Economist served as their advisor.

Step 2. Handouts describing the processing of large oil roasted peanut and ground roasted small peanut were distributed, and all necessary equipment was purchased and set up at the site of the project.

Step 3. The housewives were trained in the techniques for processing and quality control of oil roasted peanut and ground roasted peanut as well as marketing the products.

Step 4. The activity on-site was followed up with monthly visits by Peanut CRSP workers to observe, discuss and solve any problems. One graduate student worked closely to cooperate with the housewives.

Step 5. Qualities of the products processed by the group and marketed in downtown Cheingmai and Phroa District were monitored.

Step 6. The socio-economic status of the group was evaluated.

The quality of the products produced by the housewives was evaluated prior to shipping to markets. Products contained no aflatoxin, no defects and low microbial contamination. Consumer acceptability of both products was high, especially for the ground roasted peanut because of its better qualities compared to commercial ones. Results revealed that the housewives were well trained and

understood the techniques in processing of fried roasted peanut and ground roasted peanut very well. The shelf-life of both products was short, about 6 weeks for oil roasted peanut and 4 weeks for ground roasted peanut. High storage temperature and unsuitable packaging resulted in development of rancidity of the products, and this resulted in rejection after a short marketing period. Short shelf-life of ground roasted peanut was not a problem because the demand for this product was high.

Expense for processing oil roasted and ground roasted peanut was 43.44 and 17.20 Bahts/Kg, respectively. Twenty percent of sale price was paid to the owner of the shops as a marketing premium. The profit from oil roasted peanut and the ground roasted peanut was 36.56 and 6.80 Bahts/Kg, respectively.

Researchers have recommended that housewives continue to process ground roasted peanut. Although the profitability of this product was less than that of the oil roasted peanut, it was in constant demand, turn over rate was rapid and its qualities were better than those of the commercial products. In addition, housewives can process up to 100 Kg/day compared to 30 Kg/day for oil roasted peanut.

At this point, the socio-economic status of households is promising. Since the project was initiated only 6 months before this analysis, permanent change in socio-economic status is uncertain. Women learned techniques not only about processing of peanut products, they also learned techniques for business and marketing management. This will help them to improve their quality of living in the broadest sense. At the moment, the housewives consistently earn a profit by selling ground roasted peanut at Phroa District at a rate of at least 1,088 Bahts/month/group.

Table 20. Processing cost of oil roasted and ground roasted peanut.

Product	Item	Expense (Baht/Kg)	%
Oil roasted peanut	Peanut	26.32	60.59
	Fuel	1.23	2.83
	Package and label	4.00	9.21
	Oil	1.37	3.15
	Labor cost	10.52	24.2
	Total cost	43.44	100.00
Ground roasted peanut	Peanut	12.57	73.08
	Fuel	1.07	6.22
	Package and label	0.70	4.07
	Labor cost	2.86	16.63
	Total cost	17.20	100.00

B. Accomplishments at the University of the Philippines at Los Banos

1. Development and Improvement of Peanut Soft Curd

Peanut soft curd was developed from peanut milk prepared from steam-blanched and water-blanched peanut. Firming agents (agar-agar, $MgCl_2$, $CaCl_2$ and $CaSO_4$) at 0.5-10% were tested. Peanut milk containing agar-agar (0.3-0.4%) and 0.5% $MgCl_2$ or $CaSO_4$ produced a peanut soft curd with good consistency and texture. The use of agar-agar (0.2-0.4%) as the sole firming agent together with sugar (12-18°Brix)

produced a palatable curd which was comparable to soybean soft curd. This was confirmed by sensory evalu-ation. Seventy-two peanut soft curd formulations were prepared and subjected to sensory evaluation. Results showed that the five most acceptable formulations (18°Brix) contained (a) water blanched peanut with 0.2% agar-agar; (b) water blanched peanut with 0.3% agar-agar; (c) steam blanched peanut with 0.2% agar-agar; (d) steam blanched peanut with 0.3% agar-agar; and (e) steam blanched peanut with 0.4% agar-agar.

The five most acceptable peanut soft curd formulations were subjected to proximate analysis, strength tests and instrumental color evaluation. Curds contained 0.85-1.43% protein and 0.65-0.83% fat and were comparable to commercially produced soft soy cured (Table 21). Curd strength values were comparable with soybean curd. Instrumental color tests showed that the dry blanched (60-65°C) then steam blanched products had higher lightness (L) values than the water blanched samples.

Four flavorings (mango, pineapple, strawberry and vanilla) were added to the peanut soft curds and sub-jected to sensory evaluation. The most acceptable flavored peanut soft curds consisted of (a) water blanched peanut with 0.2% agar-agar, 18°Brix, strawberry flavored; (b) dry blanched peanut with 0.3% agar-agar, 18°Brix, mango flavored; and (c) water blanched peanut wit 0.2% agar-agar, 18°Brix, vanilla flavored.

Table 21. Proximate analysis, curd strength and instrumental color measurements of five most acceptable peanut soft curd formulations

Constituents (%) and curd strength	Formulations[1]					
	A	B	C	D	E	F
Moisture	78.84a	78.42b	79.94a	81.47c	79.66a	---
Ash	0.20a	0.23a	0.38a	0.33a	0.29a	---
Crude fat	0.67a	0.67a	0.83a	0.67a	0.67a	---
Crude protein	1.43a	1.40a	0.85b	0.90b	0.98a	---
Curd strength ($dyne/cm^2$, x 10^2)	2.15	5.07	2.97	4.67	42.70	1.74
Color Lightness (L)	74.2	72.8	76.2	75.5	75.4	---
Chromaticity $(a^2 + b^2)^{1/2}$	10.71	11.54	10.77	11.64	11.59	---
Hue angle [TAN^{-1} (BA)]	85.36	85.28	79.84	79.61	79.56	---

[1]Formulation A: water blanched with 0.2% agar-agar; B: water blanched with 0.3% agar-agar; C: dry blanched with 0.2% agar-agar; D: dry blanched with 0.3% agar-agar; E: dry blanched with 0.4% agar-agar (all at 18°Brix); F: commercially produced soybean curd. Values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

2. Studies on Fermented Peanut Milk

Peanut milk was processed according to procedures outlined in the FY91 Annual Report. The peanut:water ratio was 1:5. To the peanut milk, varying levels of sodium alginate and carageenan were added separately before fermentation. Peanut milk prepared by high temperature (85-100°C) roasted seed had a more desirable aroma than that prepared from blanched roasted peanut and low temperature (60-65°C). Roasting at 85-100°C produced a pleasant aroma that was retained even after processing. There may have been some compounds formed during roasting at this temperature that affected the growth or activity of lactic acid bacteria. It was observed that acidity was lower in products produced from roasted peanut. Curd of products made from blanched seed was firmer. Uniform curdling was

observed in blanched peanut milk inoculated with all test bacterial. Addition of carageenan (0.35-0.50%) yielded a very firm product, uncharacteristic of a typical yogurt. Settling of some particulates and creamy constituents was observed in peanut milk. This was carried over to the fermentation stage, where settled solids were also visible. This heterogeneity may have some effect on the consistency of the curd produced, perhaps due to enhanced activity of lactic acid bacteria in the portion containing high solids.

Sensory evaluation of aroma, appearance and flavor characteristics was done informally within the premise of the laboratory. Addition of glucose increased the activity of lactic acid bacteria as indicated by a decrease in pH (3.95-4.20) and consequently a rise in titratable acidity (0.40%). Addition of sucrose resulted in similar trends, although changes were less. Moreover, addition of glucose rather than sucrose gave a more acceptable product. The product sweetened with sucrose had desirable aroma and off-odor. Taste was less pleasant compared with the products to which glucose was added.

3. Utilization of Peanut Milk Residue as a Base for Cheese-Flavored Spread

The utilization of peanut milk residue as a base in the development of a cheese-flavored spread was investigated. The objectives of the study were to compare the proximate composition of the peanut residue with fresh peanut seed, to determine the effect of the addition of cheese flavoring and salt on sensory characteristics and acceptability of the product and to compare the quality of various formulations of cheese-flavored spread with a commercially available dairy-based cheese spread.

Peanut milk residues were obtained from the extraction of peanut milk prepared using two different blanching treatments. Residues contained about half the amount of fat and protein in whole peanut seed (dry weight basis). The steam blanched roasted peanut produced a light brown residue. The residue obtained from water blanched peanut was light colored and more bland, with a slight raw beany taste. The water blanched peanut milk residue was judged to be more suitable as a base ingredient for developing a cheese spread.

Six formulations of peanut milk residue-based cheese spread were prepared by combining cheese flavored powder (CFP), cream cheese flavoring (CCF), salt, annatto extract, whole milk powder and Worcestershire sauce into the peanut milk residue paste (Table 22). The protein content of peanut milk residue-based spread is less than one-half of the amount in commercial spread, while the fat content is less than one-third. Sensory evaluation of spreads by judges was obtained. Results in Table 23 indicated significant differences in ratings for cheese flavor intensity and saltiness, but not in cheese aroma and off-flavor. Overall preference ratings for the six samples were not significantly different, but the formulation with 15% CFP, 0.10% CCF and 2% salt received the highest mean rating, which corresponded to neither like nor dislike to like slightly. Experimental spreads had lower hue angles and a more orange hue than the commercial sample. Based on a_w and pH values, its stability is comparable with that of the commercial spread, thereby requiring refrigeration to prolong shelf-life. Spreads provide a potential vehicle use for the peanut milk residue as a human food.

4. Development of Peanut Cakes and Candies

Peanut kisses, a sweet confectionery, were prepared from defatted (21.4% oil) and roasted peanut meal. The peanut kisses turned brown upon baking; however, a lower temperature could be employed to yield a light colored product similar to that produced commercially. The product is stable and highly acceptable.

Table 22. Formulations, proximate analysis, a_w and pH of peanut milk residue-based cheese spread and a commercial dairy based cheese spread (CS)

Item	Formula Code[1]						
	CS	1	2	3	4	5	6
Formulation							
Cheese flavor powder (CFP) (g)	---	15	15	15	15	20	20
Cream cheese flavoring (CCF) (g)	---	0.05	0.05	0.10	0.10	0.05	0.05
Salt (g)	---	1	2	1	2	1	2
Whole milk powder (g)	---	5	5	5	5	5	5
Worcestershire sauce (ml)	---	0.50	0.50	0.03	0.03	0.03	0.03
Annatto extract (ml)	---	0.03	0.03	0.03	0.03	0.03	0.03
Proximate Composition (%)							
Moisture	47.12b	65.47a	66.26a	66.73a	66.29a	63.48a	64.86a
Crude Protein	11.94a	5.33b	5.18b	4.98b	4.82b	5.25	5.12b
Crude Fat	19.40a	6.19b	6.18b	5.73c	5.76c	5.86bc	5.31d
Ash	5.02a	2.76bc	3.25c	3.02bc	3.58c	3.33c	4.32ab
Crude Fiber	1.06c	2.29ab	2.08b	2.55a	2.04b	2.25ab	2.35ab
Carbohydrates	15.46	17.96	17.05	16.99	17.51	19.83	18.04
Sodium chloride	1.80d	1.84cd	2.32bd	2.01cd	2.66b	2.41bc	3.43a
Instrumental Measure							
A_w	0.93a	0.94a	0.95a	0.94a	0.94a	0.98a	0.98a
pH	5.5	5.2	4.9	5.5	5.4	5.3	5.2

[1]Percent by weight of peanut paste residue in formulation. Means in the same row which are not followed by the same letter are significantly different ($P \leq 0.05$).

Peanut cakes of high acceptability were produced. Preliminary tests were done to determine the best processing method for peanut cake production. The process of production is similar to that for peanut brittle except that after removing from heat, the peanut mixture is pounded into a thin flat sheet using a wooden hammer, spread with filling and rolled before cutting. Various amounts of peanut and light syrup, sizes of peanut and proportions of sugar to peanut in the filling were evaluated. Samples from different treatments were subjected to sensory evaluation together with commercial samples for comparison purposes. Sensory evaluation showed that the best formulation contained 22.3 g sucrose, 0.16 g salt, 66.4 g peanut, 0.40 g butter, 22.3 g light syrup, 0.64 g baking soda, 0.45 ml vanilla and 13.0 ml water. As for the filling ratio of sugar and peanut, 1:2, 1:3 and 1:4 can be used. The sizes of peanut that can be used are pieces which can pass through a 16 mesh sieve, those that can pass through 10 mesh sieve but are retained in a 16 mesh sieve and irregularly sized peanut ground in mortar and pestle.

5. Effect of Processing on Aflatoxin Content of Peanut

The objectives of this study were to determine the effect of processing on the aflatoxin content of peanut products and to optimize conditions for detoxification of the aflatoxin content of peanut products. Naturally contaminated peanut obtained from the Department of Food Product Development, Kasetsart University, Bangkok, Thailand were subjected to oil roasting, dry roasting and boiling treatments. Peanut were analyzed for moisture (oven-drying at 105°C), defatted and analyzed for aflatoxin. For every batch of peanut analyzed, each seed was halved and designated as "initial" and "final." The initial batch was set aside to be analyzed for aflatoxin content (without any treatment or process applied). The final batch was processed, ground into a meal, defatted and analyzed for aflatoxin.

Sodium bicarbonate (0.25% and 0.5%) and sodium carbonate (0.4M and 1.25N) were added to water used for the boiling and soaking process. Peanut brittle and peanut candy were prepared using contaminated peanut. Table 24 shows the reduction of aflatoxin as a result of various processing treatments. Roasting resulted in the highest reduction (88.3%) followed by dry roasting (75.4), then boiling (65.8%).

Tables 25 and 26 show the effect of adding baking soda and soda ash, both at 0.25 and 0.5% concentration, on detoxification of peanut. Samples soaked and boiled in 0.25% solution reduced aflatoxin up to 81.0%, whereas for peanut boiled without soaking in 0.25% solution, detoxification was up to 87.6%. Aflatoxin content in peanut boiled with and without soaking in 0.4M Na_2CO_3 solution (Table 27) was reduced to 66.7% and 69.7% respectively, compared to reductions of 36.5% and 48.9%, respectively, in 1.25N Na_2CO_3 (Table 28). Peanut candy and peanut brittle containing peanut with initial aflatoxin contents of 115 and 75 ppb, respectively, were found to be free of aflatoxin. Decontamination was attributed in part to dilution with other recipe ingredients. Further tests such as screening and optimization of concentration bases are needed to confirm these observations.

6. Monitoring Aflatoxin Content of Commercial Peanut Products

Commercial peanut butter samples were obtained from three outlets in Los Banos, Laguna and one outlet in Cagayan de Oro City, Philippines. Samples represented eight brand names and from different commercial manufacturers. Using one analytical method, all the samples were positive for aflatoxin. However, using the minicolumn method, the aflatoxin contents detected in the peanut butter samples were below the limit (20 ppb) set by the WHO standards. One commercial brand contained an alarming level of aflatoxin (30-50 ppb).

7. Microbiological Control of Aflatoxin in Peanut

This study was undertaken to isolate organisms that exhibit inhibitory properties against aflatoxigenic *Aspergillus parasiticus*, to identify the organisms(s) that suppress or inhibit the growth of aflatoxin-producing fungi in peanut and potato-based recovery media, and to define optimum conditions in these media to favor inhibition of *A. parasiticus*. Previous work was concentrated on optimizing the conditions for growth of *Cladosporium fulvum*. Work in FY92 focused on an evaluation of the potential toxicity of *C. fulvum* and the inhibitory effect of *C. fulvum* against *A. parasiticus* on peanut dextrose agar.

Water-soluble and oil-soluble extracts were obtained from *C. fulvum* mycelium. These extracts were utilized to evaluate the toxicological property of *C. fulvum* using chick embryo bioassay. Results (Table 29) suggest that there were no toxic constituents present in extracts from the growth medium or the oil-soluble extracts from *C. fulvum*. Survival in the control eggs, control water and water-soluble extract from *C. fulvum* was 97% and 80% for the control oil. These values are considered acceptable because normal hatching eggs at Alabang Experimental Station have an 80% fertility rate. Results indicate that *C. fulvum* has no toxic or inhibitory properties and thus could be used to inhibit the growth of *A. parasiticus* under controlled conditions in food and feed systems.

The inhibitory activity of *C. fulvum* against *A. parasiticus* was assessed (Table 30). *A. parasiticus* was exposed to various concentrations of filtrate from *C. fulvum* (10^{-3}, 10^{-2}, 10^{-1}, and 10^{0}; 10%, 20%, 30%, 40% and 50%). Addition of low concentrations (10^{-3}, 10^{-2}, 10^{-1}, 10^{0}) to peanut dextrose agar resulted in reduced spore production and swelled hyphae. Treatments with 10% to 30% filtrates resulted in wrinkled contracted spores and wrinkled and emaciated hyphae. Further increase to 40% and 50% greatly suppressed germination as evidenced by minimal hyphal growth and probably negative aflatoxin formation.

Table 23. Mean sensory scores and instrumental color measurements of peanut milk residue based cheese spreads and a commercial dairy based cheese spread (CS)

Item	Formula Code[1]						
	CS	1	2	3	4	5	6
Sensory attribute							
Cheese aroma[2]	—	4.00 a	4.20 a	4.52 a	4.48 a	4.64 a	4.68 a
Saltiness[3]	—	4.12 b	5.48 a	4.12 b	5.60 a	4.68 b	5.78 a
Cheese flavor intensity[2]	—	3.80 b	4.12 b	3.96 b	4.92 a	4.56 ab	5.08 a
Off flavor[2]	—	2.20 a	2.56 a	2.32 a	2.40 a	2.20 a	2.88 a
Overall preference[4]	—	4.16 a	4.04 a	4.52 a	4.56 a	4.52 a	3.84 a
Color							
Lightness	62.0 d	62.5 b	62.3 c	62.9 a	61.8 e	56.9 g	60.4 f
Hue angle	74.3 a	71.2 c	70.5 de	71.4 b	70.7 d	70.4 e	67.9 f

[1]Means in the same column within sensory attribute and color items which are not followed by the same letter are significantly different ($P \leq 0.05$). [2]Very weak = 1, very strong = 7; [3]Very bland = 1, very salty = 7; [4]dislike very much = 1, like very much = 7.

Table 24. Reduction in aflatoxin content as affected by processing treatment

Processing	Aflatoxin (ppb)						
	Trial I		Trial II		Trial III		
	Initial	Final	Initial	Final	Initial	Final	Average
Boiling	125	62 (50.4)[1]	100	25 (75.0)	125	35 (72.0)	(65.8)
Oil roasting	54	T (100)	148	37 (75.0)	160	16 (90.0)	(88.3)
Dry roasting	413	106 (74.3)	119	15 (87.4)	229	81 (64.0)	(75.4)

[1]Percent reduction

Table 25. Aflatoxin content of peanuts treated with $NaHCO_3$

Treatment	Aflatoxin (ppb)		
	Trial I	Trial II	Trial III
Experiment 1			
Untreated, unprocessed peanuts (raw)	79.79	147.22	164.00
Soaked and boiled in 0.25% $NaHCO_3$ solution	19.92	T	41.00
Boiled in 0.25% $NaHCO_3$ solution w/o soaking	T	41.12	T
Experiment 2			
Untreated, unprocessed peanuts (raw)	15.76	107.75	35.00
Soaked and boiled in 0.5% $NaHCO_3$ solution	10.13	69.24	21.00
Boiled in 0.5% $NaHCO_3$ solution w/o soaking	T	47.08	T

Table 26. Comparative detoxification of aflatoxin in 0.25 and 0.5% $NaHCO_3$ solutions

Treatment	% Reduction			Average % Reduction
	Trial I	Trial II	Trial III	
Experiment 1				
Soaked and boiled in 0.25% $NaHCO_3$ solution	75	100	75	83.3
Boiled in 0.25% $NaHCO_3$ solution without soaking	≈100	72	100	90.7
Experiment 2				
Soaked and boiled in 0.5% $NaHCO_3$ solution	36	40	35	37.0
Boiled in 0.5% $NaHCO_3$ solution without soaking	≈100	56	≈100	85.4
% Moisture	7.32	7.57	6.75	

Table 27. Aflatoxin content of peanuts treated with 0.4M Na_2CO_3

Treatment	Aflatoxin (ppb)			Average
	Trial I	Trial II	Trial III	
Untreated, unprocessed peanuts (raw)	50	70	120	---
Soaked and boiled in 0.4M Na_2CO_3 solution	25 (50)[1]	20 (71)	25 (79)	(67)
Boiled in 0.4M Na_2CO_3 solution w/o soaking	20 (60)	18 (74)	30 (75)	(70)

[1]Percent reduction

Table 28. Aflatoxin content of peanuts treated with 1.25M Na_2CO_3

Treatment	Aflatoxin (ppb)			Average
	Trial I	Trial II	Trial III	
Untreated, unprocessed peanuts (raw)	65	110	105	---
Soaked and boiled in 0.4M Na_2CO_3 solution	45 (30.8)[1]	60 (45.5)	70 (33.3)	(36.5)
Boiled in 0.4M Na_2CO_3 solution w/o soaking	30 (53.9)	55 (50.0)	57 (45.7)	(49.9)

[1]Percent reduction

Table 29. Percentage survival of the chick embryos after 4 days of inoculation

Treatments injected into 30 fertile eggs	No. of eggs with live embryos	Embryo survival %
Control eggs	29	97
Control oil	24	80
Control distilled water	29	97
Water-soluble extract from media	30	100
Water-soluble extract from C. fulvum	29	97
Oil-soluble extract from media	30	100
Oil-soluble extract from C. fulvum	30	100

Table 30. Morphological characteristics of A. parasiticus grown in peanut dextrose agar with various concentrations of C. fulvum filtrate incubated at room temperature (27 ± 3°) for three (3) days.

Treatments	Morphological characteristics of A. parasiticus: Spores	Hyphae
Control	large and numerous	normal
10^{-3}, 10^{-2}, 10^{-1}	reduced spore production	swelled hyphae
10^{0}	very few spores produced	same as 10^{-1} - 10^{-3}
10%	wrinkled appearance	slightly wrinkled
20%	same as 10%	wrinkled appearance
30%	same as 10%	very wrinkled
40%	same as 10%	constricted hyphae
50%	same as 10%	highly constricted, thin hyphae

C. Accomplishments at the University of Georgia

1. Consumer Acceptance and Storage Stability of Cheese-Flavored Peanut Spread

The objectives of this study were to assess Filipino acceptance of a cheese-flavored peanut-based spread, to determine sensory attributes which correlate with overall liking of the product, to measure purchase intent and the price consumers would be willing to pay for the product, to monitor changes in color and flavor of the spread during storage and to determine the protein content of the cheese-flavored spread. Consumer tests were done in the Philippines in collaboration with UPLB investigators whereas storage stability tests were done at UGA.

Dried water-extracted peanut were prepared using shelled peanut purchased from a wholesaler in Divisoria, Philippines. A commercial peanut butter manufacturer in the Philippines was commissioned to prepare the cheese-flavored spread using the formula demonstrated to be most liked by a simulated consumer panel (Table 31). Dried whole milk, cheese and sugar powders, stabilizer, monosodium glutamate, and salt were manually mixed with the water-extracted peanut. To this mixture, palm oil, Worcestershire sauce, cheese and cream flavors, and colorants were gradually added. The mixture was passed through a "coarse" grinder three times and a "smooth" grinder four times. Jars of spreads were sealed, held at ca 20°C overnight and stored thereafter in a refrigerator until needed.

Consumer affective tests on spreads were conducted at six central locations in four supermarkets in Metro Manila, Philippines and two UPLB building lobbies. Persons (416) at these locations were intercepted and invited to participate in the test. Consumers were asked to spread the product on a slice of white bread, applying the amount they would normally use for a sandwich and to answer demographic questions and then evaluate the spread for six attributes using a 7-point intensity scale: color (1 = very pale, 7 = very dark), tex-ture (1 = very thin, 7 = very thick), cheese flavor (1 = very weak, 7 = very strong), saltiness (1 = not salty, 7 = very salty), overall flavor (1 = very bland, 7 = very tasty) and overall liking (1 = dislike very much, 7 = like very much). Participants also answered questions on purchase intention (1 = definitely will not buy, 5 = definitely will buy) and the price they would be willing to pay for 250 g of spread if the same amount of the leading brand of cheese spread was selling for P 25.00 ($1.10). One-way analysis of variance was used to determine the effect of demographic characteristics on overall liking and purchase intention, and of purchase intention based on price willing to pay. Mean separation was obtained by Fisher's least significant difference. Pearson's correlation coefficients (r) were calculated for sensory characteristics and overall liking. Stepwise regression analysis of sensory data was done to determine which sensory attributes could be used in a prediction model for overall liking of the spread.

Table 31. Formulation of the cheese-flavored spread from peanuts

Ingredient	%	Consumer test, weight (g)	Storage study, weight (g)
Peanuts, dry water extracted		10000	4000
Whole milk powder	12.5	1250	500
Cheese powder (CP 3, Bush-Boake-Allen)	8.0	800	320
Palm oil (Home Pride, Gen. Milling Corp.)	6.25	625	250
Sugar, powdered (Peotraco, People's Trading Co.)	3.0	300	120
Stabilizer (Lipidan HP 100, Marsman)	2.0	200	80
Monosodium glutamate (Union Ajinomoto)	1.0	100	40
Salt, fine	0.5	50	20
Worcestershire sauce, liquid (Lea & Perrins)	0.5	50	20
Cheese flavor, liquid (PFL-896H, IFF)	0.19	19	7.6
Cream flavor, liquid (PFL-224, IFF)	0.06	6.0	2.4
Annatto oil, soluble (Warner Jenkinson)	0.05	5.0	2.0
Paprika oleoresin (Warner Jenkinson)	0.025	2.5	1.0

Table 32. Definitions of sensory characteristics used in evaluating cheese-flavored spreads

Descriptors	Definition
Aromatics	
Peanutty	Associated with peanuts
Cheesy	Associated with cheddar cheese-flavored popcorn
Buttery	Associated with butter-flavored popcorn
Sweet aromatic	Associated with butterscotch candy
Oxidized	Associated with rancid peanut paste
Cardboard	Associated with a paper sack used for flour
Taste (on tongue)	
Sweet	Associated with sugars
Salty	Associated with sodium chloride
Sour	Associated with acids
Bitter	Associated with caffeine
Feeling factor	
Astringent	Chemical feeling that causes the tongue to pucker
Throat burn	Chemical feeling which leaves a burning sensation in the throat

For storage studies at UGA, cheese-flavored spread was prepared using peanut imported from the Philippines. Samples from each replication of freshly prepared spread were stored at 4, 30 and 50°C under darkness. After 14, 28, 45 and 60 days of storage, samples were evaluated for color and flavor. Definitions of sensory characteristics used to evaluate spreads using a descriptive analysis panel are summarized in Table 32. The general linear method was used to determine the effect of storage temperature and time on color and sensory evaluation scores. Mean separation was achieved using Fisher's protected least significant difference.

Data from 362 questionnaires without missing values were used for further analyses. Demographic characteristics of the respondents in the Filipino consumer test are summarized in Table 33. Panelists consisted primarily of single women in their 20's having a monthly income of less than P 9000. Age and income were the only demographic characteristics which significantly affected overall liking and purchase intention for the cheese-flavored spread ($P < 0.05$). Mean scores for overall liking and purchase intention by age and income groups are presented in Table 34. Consumers above 50 years of age like the spread more than those who were under 20 years of age and the former was more likely to purchase the product than the latter. Overall liking and purchase intention was least for consumers earning over P 24,000/month.

The effect of purchase intention on the price consumers were willing to pay is shown in Table 35. Persons who would definitely buy the product when available in the market were willing to pay an average between P 20.00 and 22.50 for 250 g. This price was higher than the average price for 250 g of peanut butter but lower than the average price for 250 g of cheese spread.

Characteristics of the cheese-flavored spread as scored by consumers, and the relationship of these charateristics with overall liking, are given in Table 36. Color was judged as being slightly dark; texture, slightly thick; cheese flavor, slightly weak; saltiness, slightly salty; and overall flavor, neither bland nor tasty. Color, cheese flavor and overall flavor significantly correlated with overall liking ($P < 0.05$). The negative correlation coefficient for color suggests that acceptance of the spread decreased as it became darker. However, cheese flavor and overall flavor had positive contributions to spread liking. The mean protein content of the cheese-flavored spread was 24.53%. This is twice the protein content of commercial cheese spreads in the Philippines. Hence, the peanut-based cheese-flavored spread is a more economical source of protein compared to dairy-based spreads.

Table 33. Demographic characteristics of Filipino consumers who evaluated a cheese-flavored spread

Characteristic	% Responding (n = 362)	Characteristic	% Responding (n = 362)
Sex		Occupation	
Male	37.0	Student	34.3
Female	63.0	Homemaker	11.3
		Technical	3.9
Age (years)		Administrative	10.8
under 20	26.5	Clerical	7.5
20 to 29	32.0	Professional	27.6
30 to 39	21.3	Retired	1.4
40 to 49	9.7	Unemployed	3.3
50 to 59	7.7		
above 59	2.8	Monthly Family Income	
		Less than P 3,000	24.6
Marital status		P 3,000 to 5,999	22.7
Single	58.0	P 6,000 to 8,999	14.9
Married	39.8	P 9,000 to 11,999	8.0
Separated	1.1	P 12,000 to 14,999	6.4
Widowed	1.1	P 15,000 to 17,999	4.1
		P 18,000 to 20,999	3.3
		P 21,000 to 23,999	2.2
		over P 24,000	13.8

Conversion factor P 22.80 = $1.00

Changes in lightness, chroma and hue angle of cheese-flavored spread during storage at three temperatures are shown in Fig. 7. Statistical analysis indicates that there is an interaction between storage temperature and time. Cheese-flavored spreads stored at 4 and 30°C had similar color characteristics which remained fairly constant during storage. Those stored at 50°C, however, showed marked changes in color. Lightness decreased with time indicating darkening; this may have been due to Maillard reaction. Chroma, likewise, decreased indicating fading of original color. This may have been due to the migration of the oil-soluble colorants with the free oil which rose to the surface of the spread. Four percent of the original weight of the spread separated as oil on the surface sample. Hue angle increased with time, indicating yellowing. Again, this may have been due to the partitioning of the colorant into the oil which was skimmed off the top of the spread prior to analysis.

Both storage temperature and time significantly affected ($P < 0.05$) peanutty, buttery, sweet aromatic, oxidized, cardboard, sweet and sour intensities of the cheese-flavored spread (Table 37). Peanutty, buttery, sweet aromatic and sweet intensities decreased during storage; spreads held at 50°C had the least intensity for these attributes. Oxidized, cardboard and sour intensities, on the other hand, increased with storage time and the increase was most noticeable in samples stored at 50°C (Fig. 8a, b, c). Increase in throatburn intensity with storage time was restricted to samples stored at 50°C; spreads held at 4 and 30°C exhibited a decrease in throatburn intensity (Fig. 8d). Cheesy and bitter intensities of the spread were significantly affected only by storage temperature (Table 37). Samples stored at 4 and 30°C had similar cheesy and bitter intensities but those stored at 50°C were less cheesy but more bitter. Results indicate that flavor characteristics of the spread were not adversely affected by holding at 50°C. Samples stored at 30°C were not significantly different from those held at 4°C. This observed storage stability is a highly desirable attribute of the product especially if the product were to be marketed in countries such as the Philippines that are characterized by warm climatic conditions and where home refrigerators are not widely available.

In summary, technologies for formulating and processing a highly acceptable cheese-flavored spread have been developed and verified by project investigators at UGA and UPLB. It is now up to an enterprising food processor in the Philippines to commercialize the product. Project investigators are eager to provide guidance and advice to assist in a successful transfer of these technologies.

Table 34. Effect of age and income on the overall liking and purchase intention for cheese-flavored spread b Filipino consumers[1]

Variable	Overall liking[2]	Purchase intention[3]	Variable	Overall liking[2]	Purchase intention[3]
Age (years)			Monthly Family Income[4]		
under 20	4.1 c	3.2 c	Less than P 3,000	4.8 a	3.7 ab
20 to 29	4.4 bc	3.3 c	P 3,000 to 5,999	4.5 ab	3.5 ab
30 to 39	4.4 bc	3.5 bc	P 6,000 to 8,999	4.4 ab	3.6 ab
40 to 49	4.6 bc	3.1 c	P 9,000 to 11,999	4.2 ab	3.3 ab
50 to 59	5.1 ab	3.9 ab	P 12,000 to 14,999	4.6 ab	3.2 abc
above 59	5.6 a	4.4 a	P 15,000 to 17,999	4.9 a	3.1 c
			P 18,000 to 20,999	4.2 ab	3.6 ab
			P 21,000 to 23,999	3.7 b	2.7 c

[1]Means in a column within each variable that are not followed by the same letter are significantly different ($P \leq 0.05$); [2]A 7-point scale was used: 1 = dislike very much, 4 = neither like nor dislike, 7 = like very much; [3]A 5-point scale was used: 1 = definitely will not buy, 3 = undecided, 5 = definitely will buy; [4]Conversion factor P 22.80 = $1.00.

Table 35. Effect of purchase intention on price consumers were willing to pay for a 250 g jar of cheese-flavored spread.[1]

Purchase Intention	% Responding (n = 362)	Category of price willing to pay[2]
Definitely will buy	12.8	3.3 ab
Probably will buy	36.1	2.8 b
Undecided	31.3	2.5 b
Probably will not buy	14.2	1.6 c
Definitely will not buy	5.7	1.4 c

The category scale for price willing to pay: 1 = P 15, 2 = 17.5, 3 = P 20, 4 = P 22.5, 5 = P 25, 6 = P 27.5 and 7 = P 30. [2]Means not followed by the same letter are significantly different ($P \leq 0.05$)

Table 36. Mean sensory scores for characteristics of cheese-flavored spread from peanut as rated by Filipino consumers (n = 362), and the relationship with overall liking.

Attribute	Mean score	Correlation with overall liking[1]
Color	4.8	-0.19
Texture	4.9	NS
Cheese flavor	3.0	0.39
Saltiness	2.4	NS
Overall flavor	4.0	0.61

[1]Reported correlation coefficients are significant ($P \leq 0.05$); NS = not significant.

Table 37. Mean intensity scores of flavor attributes of cheese-flavored spread from peanut stored at various storage temperatures and time, as evaluated by a descriptive flavor analysis panel[1]

Attribute	Temperature (C°) effect[2]			Time (days) effect[3]				
	4	30	50	0	14	28	45	60
Peanutty	2.31a	2.42a	2.03a	2.89a	2.08b	2.05b	1.94b	2.29b
Cheesy	3.09a	2.94a	2.59b	3.00a	2.70a	3.04a	2.85a	2.81a
Buttery	3.16a	2.90a	2.56b	3.43a	2.63b	2.68b	2.79b	2.83b
Sweet aromatic	3.27a	3.02a	2.45b	3.36a	3.06ab	2.59c	2.88bc	2.68c
Oxidized	0.10b	0.27b	1.31a	0.00b	0.21b	0.83a	0.85a	0.90a
Cardboard	0.14b	0.21b	0.69a	0.00c	0.26bc	0.35ab	0.57a	0.55ab
Sweet	3.71a	3.53ab	3.31b	3.96a	3.48b	3.25b	3.49b	3.39b
Salt	3.44ab	3.55a	3.30a	3.61a	3.44a	3.35a	3.33a	3.41a
Sour	0.23ab	0.17b	0.43a	0.00b	0.26ab	0.26ab	0.33a	0.52a
Bitter	0.26b	0.27b	0.53a	0.43a	0.29a	0.37a	0.33a	0.35a
Astringent	0.54a	0.59a	0.76a	0.79a	0.49a	0.57a	0.80a	0.50a
Throatburn	1.43a	1.44a	1.66a	1.79a	1.43a	1.42a	1.40a	1.51a

[1]Means in a row for each variable not followed by the same letter are significantly different ($P \leq 0.05$). Intensity scales used for each attribute ranged from 0 (none) to 15 (strong); [2]Values reported are means of 70 observations. Interaction of temperature and time were significant for oxidized and throatburn attributes; all other interactions were non-significant.

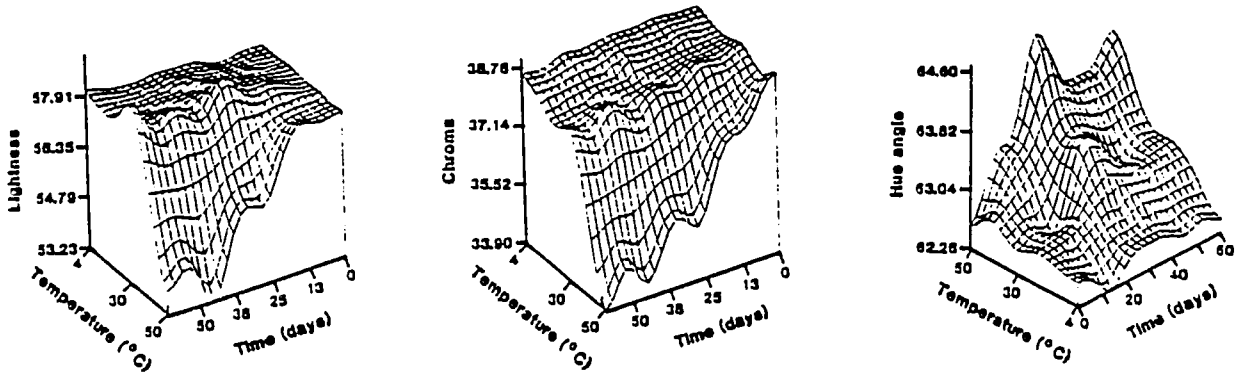

Fig. 7. Effect of storage temperature and time on instrumental color measures of cheese-flavored spread from peanut: (a) lightness, (b) chroma, and (c) hue angle.

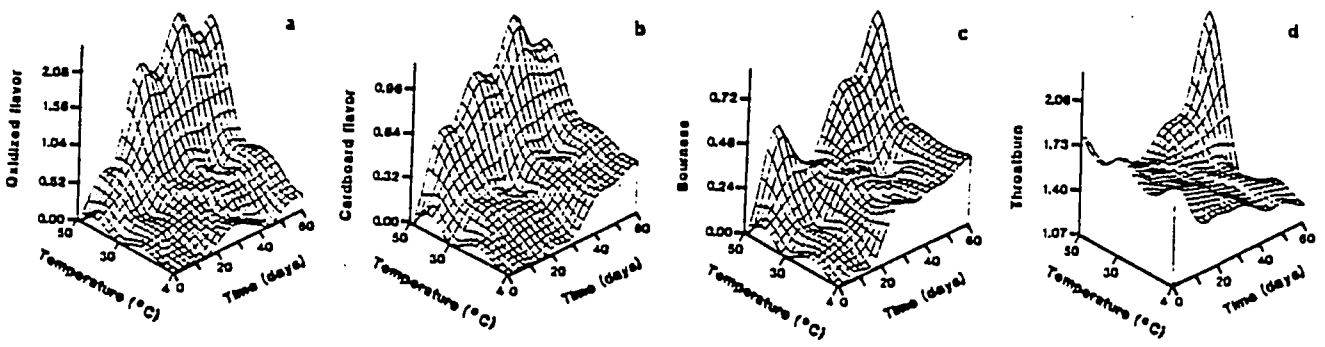

Fig. 8. Effect of storage temperature and time on sensory scores for the flavor attributes of cheese-flavored spread from peanuts, as evaluated by a descriptive flavor analysis panel using a 0 (none) to 15 (strong) intensity scale: (a) oxidized flavor, (b) cardboard flavor, (c) sour, and (d) throatburn.

2. Physical and Sensory Qualities of Salad Dressing, Muffins and Cookies Containing Fermented Peanut Milk

Information on functional properties of fermented peanut milk when incorporated into various food systems is meager. The objectives of this investigation were to determine the effects of incorporating fermented peanut milk into ranch-style salad dressing, muffins and cookies on functional and sensory properties and to compare these properties to those products containing cultured dairy products.

The procedure for preparing aqueous extracts of peanut (peanut milk) was described in the FY91 report. Mixed cultures of *L. debrueckii* subsp. *bulgaricus*

and S. salivarius subsp. thermophilus were used. Active cultures served as inocula (1% each for each strain). Cultures were added to 200-mL quantities of sterile peanut milk which had been supplemented with 2% glucose and adjusted to 43°C. Two brands of powdered ranch style salad dressing mix were purchased from a local supermarket. To brand A (11 g) and brand B (25 g), 227 g (8 oz) of buttermilk (brand AO), whole fat milk (brand BO) or fermented peanut milk (brands A and B) and 227 g of mayonnaise were combined and thoroughly mixed. Buttermilk and fermented peanut milk were adjusted to 8°C before formulations were prepared. A third series of formulations was prepared using brand C ranch dressing mix. The control formula consisted of 227 g of buttermilk, 23 mL of vinegar (120 grain) and 11 g (0.04 oz) of mix. Fermented peanut milk was substituted for buttermilk at 25, 50, 75 and 100% levels to result in four test formulations. All formulations were adjusted to 8°C before subjecting to chemical, physical and sensory analyses.

The pH, titratable acidity, color and emulsion capacity of samples were measured. Descriptive sensory analysis of ranch style dressings prepared from brand A, brand B and brand C mixes was conducted using ten trained panelists. Preference tests were done on brands A and B dressing formulas using twenty-four untrained panelists. Sensory attributes were rated for intensity using a 15-cm unstructured scale. Standards representing five flavor intensities were provided to each trained panelist for judgment of flavor terms characteristic of raw peanut. Flavor characteristics were creamy, beany/green, spicy, sour,sweet and astringent; the anchor for each characteristic was weak/strong. Ratings for mouthfeel and color were also determined using the 15-cm scale. Anchors for mouthfeel characteristics were chalky (absent/present), viscosity (thin/thick), gummy (absent/strong) and smoothness (smooth/lumpy). Anchor points for color were light/dark.

The whiteness of ranch style salad dressings was unaffected by the presence of fermented peanut milk in dressings prepared from brand A and brand B dry mixes. The beany/green flavor detected in brand A salad dressing containing fermented peanut milk was scored significantly higher compared to buttermilk and milk control formulations. No significant differences in beany/green flavor were noted in brand B dressing when fermented peanut milk was substituted for milk.

The viscosity of brand B salad dressing, which contains milk, was significantly thicker than that of all other formulations as determined by both trained and untrained panelists. This observation is in agreement with results obtained from instrumental analysis. A significant decrease in viscosity occurred in brand C dressings in which buttermilk was substituted with 50% or more fermented peanut milk. Smoothness, however, appeared not to be greatly affected by level of fermented peanut milk. With the exception of beany/green flavor, trained panelists did not detect significant differences in sensory attributes of the six brand A and B dressing formulations. Untrained panelists rated flavor of brand A dressings containing fermented peanut milk significantly lower in intensity compared to the buttermilk control. Untrained panelists were unable to detect significant differences in appearance and color of the six formulations.

Lightness (L) of salad dressing containing milk (brand B control formulation) was significantly lower than all others tested, but had a high chroma value which represents an increase in saturation. This increase in saturation may reflect an increased ability to hold water. Incorporation of fermented peanut milk into formulations had a lightening effect, although differences in lightness were not significant in brand A dressings. Whiteness, creamy flavor and viscosity decreased significantly as the substitution level of fermented peanut milk was increased in brand C formulations. The titratable acidity of salad dressings containing brand B mix and fermented peanut milk was significantly higher than that of the brand B control dressing. A significant decrease in pH corresponded with an increase in titratable acidity. The pH and titratable acidity of salad dressing formulations containing various amounts of buttermilk and fermented peanut milk were not greatly affected except in the formulation containing no buttermilk. The slightly lower titratable acidity of fermented peanut milk (0.35%) compared to buttermilk (1.0%) caused this difference. Emulsions prepared using brand B ranch style salad dressing mix were quite stable over the 21-day

storage period at 5°C. Separation of emulsions prepared using brand A mix was detected within 4 days. The amount of fluid released was greater in emulsions containing fermented peanut milk compared to the buttermilk control. Substitution of fermented peanut milk at a level of 25% or more resulted in a significant decrease in emulsion capacity.

The incorporation of fermented peanut milk in three brands of ranch style salad dressings has been demonstrated to result in increased lightness (L), oil emulsion capacity, viscosity and creamy flavor. There appears to be a correlation between decreased viscosity as determined instrumentally and low sensory scores for creamy flavor. The three brands of dressing mixes performed somewhat differently with regard to chemical, functional and sensory qualities of products produced from them. This was to be expected, and, in fact, is encouraging, since additional modifications to successfully facilitate the incorporation of fermented peanut milk into ranch style salad dressing would appear to have greater potential. Based on the results from the study reported here, it is concluded that ranch style salad dressing with acceptable quality can be made using fermented peanut milk substituted for buttermilk at a level up to 25%. The use of fermented peanut milk in place of fermented dairy products in salad dressings and perhaps other foods (e.g., bakery items) provides an opportunity for reformulating a wide range of traditional food products.

Although extracts of peanut seed (peanut milks), which have been fermented with lactic acid bacteria and then dried, have been evaluated as ingredients in bakery products, the performance of dried fermented peanut milk when substituted for buttermilk, yogurt and sour cream powders in bakery products has received meager attention. Dried fermented peanut milk may have potential as a substitute for fermented dairy milk powders in various foods. However, if functional properties or sensory qualities of foods containing fermented peanut milk are significantly inferior to those containing fermented dairy products, its application may be limited. For this reason, studies were needed to evaluate the performance of dried fermented peanut milk in food systems. The objectives of this investigation were to determine the effects of substituting drum-dried fermented peanut milk for powdered, fermented dairy products on physical and sensory qualities of muffins and cookies.

Fermented peanut milk was prepared according to the procedure outlined above. Mixed cultures were grown in sterile peanut milk supplemented with 2% glucose. Fermentation was carried out at 43°C for 14 h after which products were drum dried and reduced to a powder form. Analyses included measurements of viscosity, water adsorption and functionality in muffins and cookies. Comparisons were made between backed items containing dried fermented peanut milk and three commercial dried fermented dairy products, viz., buttermilk, yogurt and sour cream. Sensory qualities of muffins and cookies prepared from experimental formulas were also evaluated.

Dried fermented peanut milk had a moisture adsorption isotherm similar to that of buttermilk and yogurt powders. Sour cream powder had a lower affinity for water. Viscosities of rehydrated fermented peanut milk and commercial dairy milk powders differed greatly. Differences are attributed to differences in substrate composition and fermentation and processing conditions. Substitution of fermented peanut milk powders for most fermented dairy milk powders in muffins did not cause significant changes in volume or uniformity. The spread ratio of cookies was unaffected by substitution of fermented peanut milk for dairy products. Substitution of fermented peanut milk for buttermilk, yogurt and sour cream powders did not result in major differences in overall sensory qualities of muffins and cookies. Muffins containing one brand of yogurt and sour cream powders had significantly higher hue values for external and internal surfaces compared to muffins containing fermented peanut milk powder. The addition of fermented peanut milk to cookies resulted in softer texture compared to that of cookies containing buttermilk or sour cream powders.

Overall, substitution of drum-dried fermented peanut milk for fermented dairy powders in bakery products such as buttermilk muffins and cookies resulted in no major deleterious effects on selected sensory characteristics as determined by untrained panelists. It is concluded that drum-dried fermented peanut milk can

be successfully used as a substitute for fermented dairy milk products such as buttermilk, yogurt and sour cream powders. Other bakery product formulations may also be amenable to incorporation of fermented peanut milk powder, and evaluation of these applications is in progress in our laboratory.

3. Evaluation of Peanut as a Substitute for Preparing Tempeh Starter Cultures

Heat-pasteurized partially defatted peanut, cassava root, cowpeas, rice and soybeans were evaluated for their suitability to support growth and sporulation of the tempeh mold, *Rhizopus microsporus* var. *oligosporus*, and the oncom mold, *Neurospora intermedia*. All substrates supported growth of *R. microsporus* var. *oligosporus* and *N. intermedia* at 25, 30 and 37°C. Growth with subsequent spore and conidium production was most rapid at 37°C. Cassava and rice clearly served as better substrates than cowpea, peanut or soybean for mycelium, spore and conidium formation. Survival of the molds after drying and storing powdered substrates for up to 30 weeks was determined. Survival was best when powders (a_w 0.48) were stored at 5°C, although storage at 25°C did not cause a marked decline in CFU/g. The inactivation rate was highest at 37°C. Experimental cassava- and rice-based starter cultures containing *R. microsporus* var. *oligosporus* which had been stored at 5, 25 and 37°C for 20 weeks compared favorably with commercial (control) tempeh starter and spore powder for preparing tempeh. Results from the textural measurements indicated that there were no differences in firmness for tempeh made using experimental rice-based and control starter cultures containing predominantly *R. microsporus* var. *oligosporus*, not unlike those used in the present study, offer great potential for developing and introducing tempeh-making processes in areas of the world where people could greatly benefit by consuming this product of substantial nutrition quality.

4. Chemical Hydrolysis of Peanut to Make Sauce

Florunner variety peanut obtained from the Georgia Seed Commission were blanched, ground to a meal and extracted with hexane in a three miscella arrangement. The final material contained 2% oil. The ratio of meal to acid was calculated to give a protein content of not less than 10% after neutralization. Preliminary experiments indicated that temperatures below 100°C took too long for desired hydrolysis. Therefore, treatment at 100, 110 and 120°C were investigated in a time range of 12 to 72 h in 3N, 4N and 5N HCl solutions. Maximization of hydrolysis was determined by measuring three amino groups using the trinitrobenzene sulfonic acid (TNBS) method. The method was standardized using leucine as a standard. Results indicate that a dark colored sauce similar to soy sauce results when the hydrolysate is neutralized. Sensory and amino acid analyses are underway to determine the time and temperature required for optimum sensory characteristics. It is believed that aflatoxin will be destroyed under such conditions. When the process is optimized, experiments will be done to test this theory.

5. Hydration of Peanut Butter to Form an Aqueous Emulsion

Peanut butter is the single largest item for which peanut are used in the U.S. However, there appears to be a limit to the consumption. Therefore, it was decided to investigate other forms in which peanut butter or paste might be used. The most familiar is a paste made from the sesame called tehina, which is consumed in large quantities in Mid Easter countries. Sesame is used in an emulsified form with the addition of various other condiments. The use of peanut paste in a similar fashion is reported. Experiments to determine the physical characteristics of such an emulsion were conducted. Additions of water or a 6% citric acid solution caused a phase reversal at a ratio of approximately 1:1 of peanut butter:diluent. The viscosity is increased five fold, after which it decreases until it is less than that of peanut butter. A more important characteristic is that the stickiness of the butter is greatly decreased from an adhesion value (g/g) of 177 to 25 during the transition. Thus, a product with a continuous aqueous phase with oil inclusions is produced which has a character somewhat like mayonnaise. The research is now focusing on microbial and emulsion stability after which an examination of sensory characteristics will be conducted.

6. Comparison of Sensory Panelists' Performance

This study was conducted to compare one-way analysis of variance, a univariate method, and cluster analysis, a multivariate method, for selecting members of a descriptive panel for peanut based coffee whiteners. Panelists evaluated the performance of two whiteners, a premium brand of commercial powdered non-dairy coffee creamer and the same whitener subjected to temperature abuse. Attribute rating was done using 150-mm unstructured line scales. Twelve panelists were trained for 6 1-h sessions. Panelists were monadically presented with the whiteners dissolved in coffee. Descriptive terms were suggested by the panel for the appearance, flavor, mouthfeel and suspension stability. The final list of attributes with their corresponding definitions, decided upon by panel consensus, are enumerated in Table 38. The panelists also suggested standard references for each attribute.

To orient the panelists with the use of the 150-mm unstructured line scale and to standardize their evaluations, they were presented with caffeine and sucrose solutions recommended for the descriptive analysis of flavor using the Spectrum™ intensity scale. Water was used as an intensity standard at the 0 end of the scale. According to the intensity scale established, the panelists rated the standard references suggested earlier for each attribute (Table 39). Four replicate tests were conducted. Samples were prepared by dissolving 10 g of whitener in 250 ml coffee (65-70°C). Aside from the warm-up whitener sample served at the beginning of each evaluation, the panelists were provided with reference standards to standardize their evaluations. Panelists were instructed to use cups provided for the expectoration of all the samples. Water and water biscuits were given to clear the palate in between samples.

The data were analyzed using the Statistical Analysis System. Panel data were subjected to factor analysis to visualize interrelationships among attributes. The reliability of the sensory ballot was evaluated to ensure that the variability in panelists' ratings was not due to an unreliable sensory ballot. The reliability coefficient, omega (Ω), which for multidimensional scales is the closest estimate to the true reliability of measure as opposed to the other reliability coefficients, alpha (α) and theta (Θ), was calculated: $\Omega = 1 - (a - \Sigma hi^2)/(a =+ 2b)$, where a = number of descriptive terms, b = sum of correlations among the items, hi^2 = communality of the ith item. Panel selection was done two ways, using one-way analysis of variance and cluster analysis. One-way ANOVA was applied to each panelists' scores for each attribute to determine whether the F values between the samples were significant. If the probability of an F value was less than or equal to 0.50, the assessor was contributing to discrimination. Following the binomial procedure, a panelist was accepted if he/she was able to discriminate the samples in 11 out of 14 attributes. The VARCLUS procedure was used to divide the sensory variables into non-overlapping, essentially unidimensional clusters; and to calculate scoring coefficients of every variable for each attribute were multiplied with the corresponding attribute response using the SCORE procedure to calculate cluster scores. If plotted cluster scores of an individual panelist appeared to be outlying, the panelist was considered an outlier and his scores were dropped from the analysis. Performance of the ANOVA panel and the cluster panel were evaluated by comparing the means and standard deviations of each attribute by each panel.

Table 38. Definitions of the attributes used to evaluated performance of coffee whiteners

Attribute	Definition
Appearance	
Color	Hue of whitened coffee
Grainy	Precipitate similar to grains
Curdled	Precipitate with a soft appearance and similar to curdled milk
Lumpy	Clumps of undissolved whitener
Flavor	
Aromatic	
Nutty	Associated with fresh hard-shell nuts
Creamy	Associated with cream
Oily	Associated with vegetable oil
Beany	Associated with legumes
Painty	Associated with linseed oil and oil-based paints
Taste	
Bitter	Associated with caffeine
Mouthfeel	
Viscosity	Tendency of whitened coffee to resist flow
Powdery	Sensation of fine particles or powder in the mouth
Suspension Stability	
Oily	Presence of oil on the surface of 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 39. Intensity ratings of standards for attributes used to evaluate the performance of coffee whiteners

Standard	Intensity[1]	Standard	Intensity
Appearance		Aromatics	
Color		Nutty	
whole milk	0.0	whitener	20.0
whitener	42.0	pecans	57.0
Kraft caramel	69.0	Creamy	
coffee	150.0	whitener	28.0
Grainy		Olde Tyme Coffee Cream	80.0
whitener	0.0	Oily	
10 ml curdled milk in coffee[2]	40.0	whitener	15.0
40 ml curdled milk in coffee[2]	110.0	heated Crisco oil	55.0
Curdled		Beany	
whitener	0.0	whitener	0.0
1:8 egg to water suspension	137.5	peanuts	8.1
Lumpy		Painty	
whitener	0.0	whitener	5.0
3 g soft curd cheese in coffee	80.0	latex paint	115.0
15 g soft curd cheese in coffee	137.5		
Taste			
Bitter		Suspension stability	
0.05% caffeine	20.0	Oily	
whitener	27.0	whitener	21.0
0.08% caffeine	50.0	Double Dutch Choc. Coffee Bev.	37.0
Mouthfeel		5 ml oil in whitened coffee	130.0
Viscosity		Surface layer thickness	
Mountain Valley Spring Water	10.0	whitener	5.0
whitener	21.0	1/4 volume of coffee	75.0
Carnation Evaporated Milk	39.0	1/2 volume of coffee	150.0
Hershey Chocolate Syrup	92.0		
Powdery			
whitener	0.0		
Dynatrim	27.0		

[1]Intensity ratings based on 150-mm unstructured line scales anchored with the following descriptors: white (=0) and brown (= 150) for color; slight (= 12.5) and extreme (137.5) for grainy, curdled, lumpy, powdery, and oily (suspension stability); weak (=12.5) and strong(=137.5) for nutty, creamy, oily (flavor), beany, painty, and bitter; thin (= 12.5) and thick/creamy (=137.5) for viscosity; and none (=0) and thick (=150) for surface layer thickness. [2]Curdled milk was prepared by adding 50 ml vinegar to 250 ml whole milk.

Results of factor analysis are shown in Table 40. Factor analysis indicated that 5 factors were adequate to model the data and resulted in an eigenvalue of 1.02. The five-factor model accounted for 73% of the total variance. Factor 1 includes all the appearance and suspension stability terms, and one mouthfeel term but no flavor term. This indicates that when evaluating the performance of whiteners in coffee, attributes relating to physical appearance were the most significant. The calculated reliability coefficient, Ω, of the score sheet was equal to 0.93.

Results of one-way ANOVA applied to all panelists' scores for each attribute are shown in Table 41. Panelist H should not be included in the panel since he discriminated samples in only 9 ($p < 0.50$) terms out of the 11 required. Visual inspection of 6 cluster plots indicated that the response pattern of Panelist J was not in conformity with the majority of the panelists. Cluster analysis did not obviate decision-making, and decisions could be grounded on groupings which are arrived at objectively and comprehensively. When one-way ANOVA was used to

select panelists, a considerable number of subjective decisions based on the inspection of several F values had to be made.

The mean ratings and standard deviations of the two panels for each sample are listed in Table 42. Ratings for each attribute varied depending upon the composition of the panel. This indicated that the panels selected using either test performed differently. Smaller standard deviations resulted for the two whitener samples in 11 of 14 attributes evaluated when panelists were selected using cluster analysis. This indicated that there was greater variability among panelists' scores when the panel was selected using one-way ANOVA than when cluster analysis was used. Overall, cluster analysis was a better statistical method than one-way ANOVA for selecting descriptive panel members because it resulted in panel scores with smaller deviations. The technique selects panelists based on their performance in rating the most important variables and provides a graphical representation that is easy to interpret.

Table 40. Rotated factor analysis pattern resulting from sensory data on coffee whitener.

Attribute	Attribute Classification[1]	Factor 1	2	3	4	5
Color	A	84				
Grainy	A	88				
Curdled	A	92				
Lumpy	A	83				
Nutty	F		53		-65	
Creamy	F			52		66
Oily (flavor)	F		73			
Beany	F		52		50	
Painty	F		39	-53		
Bitter	F			-42	-45	41
Viscosity	M		39	65		
Powdery	M	56				
Oily (suspension stability)	S	39	59			
Surface layer thickness	S	85				

[1]Where A is an appearanc attribute; F is a flavor attribute; M is a mouthfeel attribute; and S is a suspension stability characteristic.

Table 41. Panelist performance in discriminating samples as determined by one-way ANOVA[1]

Attribute	Panelist A	B	C	D	E	F	G	H	I	J
Color	d	d	d	d	d	d	d	d	d	d
Grainy	d	d	d	d	d	d	d	d	d	d
Curdled	d	d	d	d	d	d	d	d	d	d
Lumpy	d	d	d	d	d	d	d	d	d	d
Nutty	d	d	nd	d	d	nd	nd	nd	d	d
Creamy	d	d	nd	d	d	d	nd	nd	d	nd
Oily (flavor)	nd	d	d	d	d	d	d	nd	d	d
Beany	nd	d	d	d	d	d	d	d	d	d
Painty	d	nd	d	nd	d	d	d	nd	d	d
Bitter	d	nd	nd	d	d	d	d	d	d	d
Viscosity	d	d	d	d	d	d	d	nd	d	d
Oily (suspension stability)	d	d	d	d	d	d	d	d	d	nd
Surface layer thickness	d	d	d	d	d	d	d	d	d	d

[1] d = discriminating ($p \leq 0.50$); nd = not discriminating ($p > 0.50$)

Table 42. Mean ratings and standard deviations of sensory attributes for the two coffee whiteners

Attribute	Mean Rating and Standard Deviation[1]			
	Commercial Whitener		Abused Whitener	
	ANOVA	Cluster	ANOVA	Cluster
Color	41.56 ± 10.81	40.03 ± 8.43	109.58 ± 31.06	115.78 ± 32.84
Grainy	5.50 ± 3.89	4.69 ± 3.58	83.14 ± 44.34	85.08 ± 43.80
Curdled	2.64 ± 4.30	1.75 ± 3.16	67.92 ± 27.19	65.94 ± 26.21
Lumpy	0.53 ± 2.05	0.17 ± 0.56	72.83 ± 37.19	68.53 ± 35.22
Nutty	29.50 ± 11.30	29.33 ± 11.31	34.78 ± 15.28	32.94 ± 15.18
Creamy	42.11 ± 14.51	38.83 ± 12.08	28.33 ± 18.46	25.50 ± 13.31
Oily (flavor)	17.69 ± 7.41	15.80 ± 8.24	22.00 ± 12.20	18.75 ± 9.85
Beany	8.00 ± 5.52	7.36 ± 5.46	13.47 ± 10.83	12.03 ± 10.49
Painty	4.97 ± 4.60	4.58 ± 4.56	9.28 ± 7.46	8.80 ± 7.72
Bitter	36.36 ± 13.12	34.61 ± 11.49	46.69 ± 16.10	48.06 ± 14.69
Viscosity	28.30 ± 8.12	27.25 ± 7.36	27.83 ± 12.48	27.56 ± 11.96
Powdery	6.61 ± 4.68	5.22 ± 4.30	15.14 ± 7.97	13.97 ± 7.91
Oily (suspension stability)	23.50 ± 9.76	20.72 ± 11.54	33.11 ± 12.91	30.08 ± 16.08
Surface layer thickness	4.06 ± 3.30	4.00 ± 3.27	41.30 ± 20.89	44.28 ± 17.49

[1]See Table 39 for description of intensity ratings and descriptors

7. Development of a Lexicon for Evaluating Peanut-based Coffee Whiteners

This study was conducted to evaluate the performance of mono- and diglyceride emulsifiers in enhancing the whitening capacity and viscosity of a liquid whitener using various concentrations of peanut extract and no added fat. Specific objectives were to determine the effects of peanut:water ratios on the composition , color lightness and emulsion stability of peanut extract, to determine the effects of peanut extract concentration and emulsifier level on the sensory quality and physical properties of liquid whitener from peanut, to model the sensory quality and physical properties of the liquid whitener using varying peanut extract concentrations and emulsifier levels, and to identify the level combinations of peanut extract and emulsifier that will result in a liquid whitener comparable to a commercial product.

Three whitener samples were selected to exhibit various performance characteristics when dissolved in coffee. These were a liquid coffee whitener from peanut extract processed following procedures previously developed in our laboratory (See FY91 Annual Report), a premium brand of a commercial powdered non-dairy coffee creamer, and the same premium whitener subjected to temperature abuse. Ten panelists trained in our laboratory to judge the performance of coffee whiteners were used throughout the study. Using the descriptors, reference standards and intensity scales established during training, the panelists evaluated samples. Four replicate tests were conducted as described above (C.1.). The data were analyzed using the Statistical Analysis System. Panel selection was carried out using cluster analysis. Panel data were subjected to factor analysis to visualize interrelationships among descriptors and to calculate communality estimates. Mean panel ratings of the whitened coffee samples were determined.

Factor analysis indicated that 4 factors were adequate to model the data (Table 43). The four-factor model accounted for 68% of the total variance. Factor 1 includes all the appearance, 1 suspension stability and 1 mouthfeel descriptor but did not include any flavor descriptors. Since factor 1 contained the most important information and included the more important descriptors, results of factor analysis indicated that when evaluating the performance of whiteners in

coffee, descriptors relating to physical appearance are the most significant. The flavor of whiteners was not considered to be more important, especially when evaluated against the predominating flavor of coffee. The primary function of whiteners is to impart a desirable color change in coffee.

In factor analysis, the communality estimate is equivalent to the variance of an observed variable accounted for by the common factors. In this study, the communality estimate was used as an indicator of variability. It was decided that a communality estimate less than or equal to 0.60 indicated that the panelists' responses to the descriptor corresponded to a low communality was so variable. A value of 0.60 was chosen after taking into consideration the inherent variability of behavioral and biological data. The creamy and powdery descriptors had extremely low communality estimates. It was concluded that these two descriptors were not reliable since panelists' responses were too variable.

Table 44 shows the mean panel ratings of the 4 whitened coffee samples evaluated. Only means of descriptors previously identified as reliable are shown. Results indicate that the coffee sample which was dissolved the temperature-abused whitener had the highest ratings for color, grainy, curdled and lumpy. The high color score indicated poor whitening capacity of the whitener, while high grainy, curdled and lumpy scores point to poor dispersibility. The high temperature to which the powdered whitener was subjected caused a disruption of the emulsion concentrate structure of the whitener which resulted in poor dispersibility and emulsion breakdown consequent "oiling off" of the fat phase of the whitener when added to coffee.

Coffee whitened by the liquid whitener processed from peanut extract had the highest score for beany and the whitened coffee containing non-fat dry milk had the lowest rating for oily suspension. The lexicon developed in this study contains four appearance descriptors (color, grainy, curdled, lumpy), five flavor descriptors (nutty, oily, beany, painty, bitter), one mouthfeel descriptor (viscosity) and two descriptors to evaluate suspension stability (oily, surface layer thickness). These descriptors have been evaluated for reliability and validity.

Table 43. Results of factor analysis performed on data from descriptive analysis of whitener samples.

Descriptor	Descriptor Classification	Factor 1	Factor 2	Factor 3	Factor 4	Communality Estimate
Color	A	86				0.82
Grainy	A	89				0.81
Curdled	A	93			0.88	
Lumpy	A	87			0.78	
Nutty	F			83	0.75	
Creamy	F			55		0.40
Oily (flavor)	F		64	49		0.68
Beany	F		77			0.63
Painty	F		59			0.64
Bitter	F				77	0.67
Viscosity	M			81		0.68
Powdery	M	56				0.42
Oily (suspension stability)	S		58	46		0.65
Surface layer thickness	S	88				0.81
Eigenvalue		4.76	2.14	1.61	1.12	
Proportion of variance explained (%)		34	15	11	8	

[1]Where A is an appearance attribute; F is a flavor attribute; M is a mouthfeel attribute; and S is a suspension stability characteristic.

Table 44. Mean panel ratings for coffee whiteners[1]

Descriptor	Whitener[2] 1	2	3	4
Color	55.0	37.0	115.8	40.0
Grainy	7.4	5.0	85.1	4.7
Curdled	2.0	1.4	65.9	1.8
Lumpy	0.9	0.4	68.5	0.2
Nutty	33.2	31.6	32.9	29.3
Oily (flavor)	13.5	24.6	18.8	15.8
Beany	9.2	28.7	12.0	7.4
Painty	5.8	7.9	8.8	4.6
Bitter	42.8	39.5	48.0	34.6
Viscosity	22.7	28.0	27.6	27.2
Oily (suspension stability)	13.5	27.5	30.1	20.7
Surface layer thickness	3.5	5.5	44.3	4.0

[1]See Table x for description of intensity ratings and descriptors
[2]Where 1 is the non-fat milk powder, 2 is liquid whitener from peanut extract, 3 is the abused commercial powdered whitener, and 4 is the premium brand of a powdered non-dairy whitener.

8. Separation of Protein Fractions from Partially Defatted Peanut Flour

Partially defatted peanut flour (PDPF) proteins are of great interest as functional ingredients in formulation of protein-fortified foods. However, more information on the physicochemical and functional properties of the two major globulins, arachin and conarachin, is needed. This research was undertaken to investigate electrophoretic and isoelectric properties of protein fractions from PDPF.

Total soluble protein (TSP) was extracted from PDPF using 1 M NaCl-20mM Na_2HPO_4 buffer (pH 7), at a ratio of 1:18 (w:v), containing 0.005% thimerosol and 0.2 mM phenylmethylsulfonyl fluoride. Arachin and conarachin were then fractionated using 40% and 85% $(NH_4)_2SO_4$ saturation, respectively. Preparative isoelectric focusing was conducted to separate proteins and each fraction was analyzed for protein concentration and pH. Fractions with highest protein concentration at either acidic or alkaline pH values, as well as unfractionated proteins were concentrated and analyzed by SDS-PAGE slab gel analysis using 10% separating and 4.5% stacking gels.

The most significant finding from this study was that two isoelectric regions at acidic pH (4.4-5.6) and at alkaline pH (11.8-12.4) were observed in TSP, arachin and conarachin extracts. Alkaline pI values for peanut proteins have not been reported in the literature. However, certain polypeptide bands found in TSP, arachin and conarachin at both acidic and alkaline pIs were common to previously described poly-peptides. TSP contained 1-5 major polypeptides (45,900-21,000) and 1-6 minor polypeptides (68,800-21,800). Arachin contained 3-6 major polypeptides (43,500-21,000) and 2-5 minor polypeptides (66,900-21,500). Conarachin contained 1 major polypeptide (21,000) and 1-6 minor polypeptides (63,400-21,500). The results have implications with regard tc functionality and utilization of PDPF, since arachin and conarachin significantly affect the functional, sensory and nutritional qualities of food into which it is incorporated.

9. Bacterial Degradation of Aflatoxin

A spectrophotometric method for determining aflatoxin concentration in phosphate buffer was developed for use in investigating aflatoxin degradation by a bacterium, Flavobacterium aurantiacum. The technique involves determining ultraviolet absorption of buffer containing various concentrations of aflatoxin B_1 with a scanning spectrophotometer. An absorption peak at 363 nm correlated with B_1 concentration as determined by HPLC. The technique was used to quickly determine concentrations of aflatoxin B_1 in solutions by comparing peak heights (363 nm) obtained from experi-mental samples to a standard curve of peak heights constructed with known concentrations. Quantities of aflatoxin B_1 of 0.5 μg/ml or greater can be estimated in buffer by this method and compared favorably with HPLC (Fig. 9).

The influence of cell population, age and physical state of F. aurantiacum on aflatoxin degradation was determined. The number of viable cells present greatly influenced the rate and total amount of B_1 degraded. Seven $\log_{10}$ cfu/ml F. aurantiacum did not exhibit degradative activity within 72 h, whereas 9 $\log_{10}$ cfu/ml degraded about 90% of the aflatoxin B_1 in 72 h and 11 $\log_{10}$ degraded about 90% in only 24 h. Culture age is also important. A 24-h culture showed little evidence of being able to degrade B_1 whereas a 72-h culture was very effective.

The fate of ^{14}C-labeled aflatoxin B_1(^{14}C-B_1) in the presence of F. aurantiacum was determined. Preliminary results suggest that F. aurantiacum metabolizes the toxin rather than merely binding it to cell walls. F. aurantiacum was incubated at 25°C for up to 72 h in a medium containing ^{14}C-B_1. At various times during the incubation, the residual radioactivity in the cell pellet, and in the aqueous and chloroform fractions of the reaction suspension were measured. In addition, the amount of $^{14}CO_2$ evolved by the reaction mixture was determined. Results suggest that the normally chloroform-soluble ^{14}C-B_1 is rapidly converted to a water soluble degradation product (Fig. 10). Some radioactivity is initially associated with the pellet fraction but decreases at about the same rate as the water-soluble degradation product is formed. Thereafter, some ^{14}C is again gradually reincorporated into the pellet fraction. During the incubation period, a small amount of $^{14}CO_2$ is produced, suggesting that at least a portion of the ^{14C}-B_1 is metabolized.

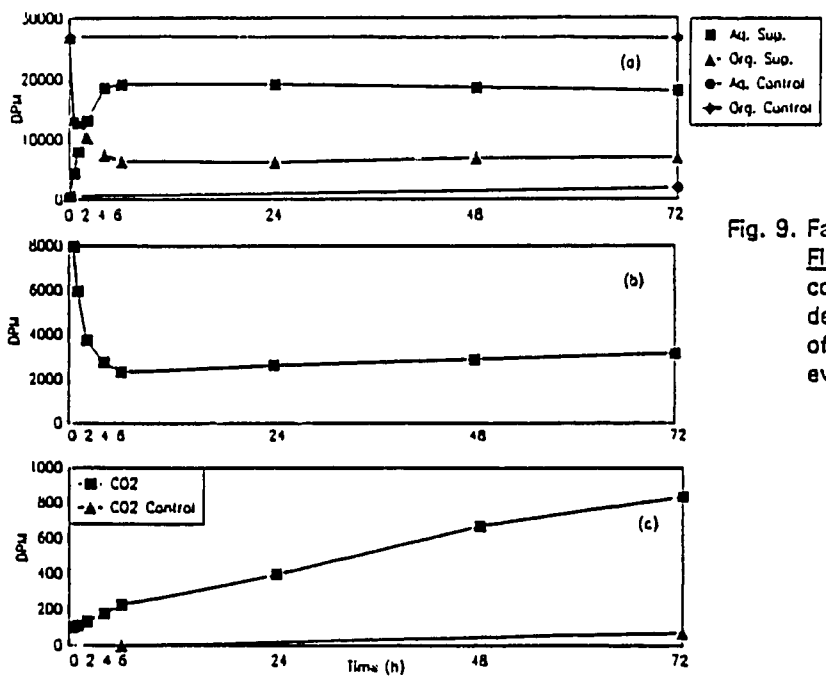

Fig. 9. Fate of ^{14}C as affected by Flavobacterium aurantiacum: (a) conversion of ^{14}C-B_1 to water-soluble degradation products; (b) association of ^{14}C with pellet fraction; and (c) evolution of $^{14}CO_2$ from ^{14}C-$_1$.

Fig. 9. Fate of ^{14}C as affected by Flavobacterium aurantiacum: (a) conversion of ^{14}C-B_1 to water-soluble degradation products; (b) association of ^{14}C with pellet fraction; and (c) evolution of $^{14}CO_2$ from ^{14}C-$_1$.

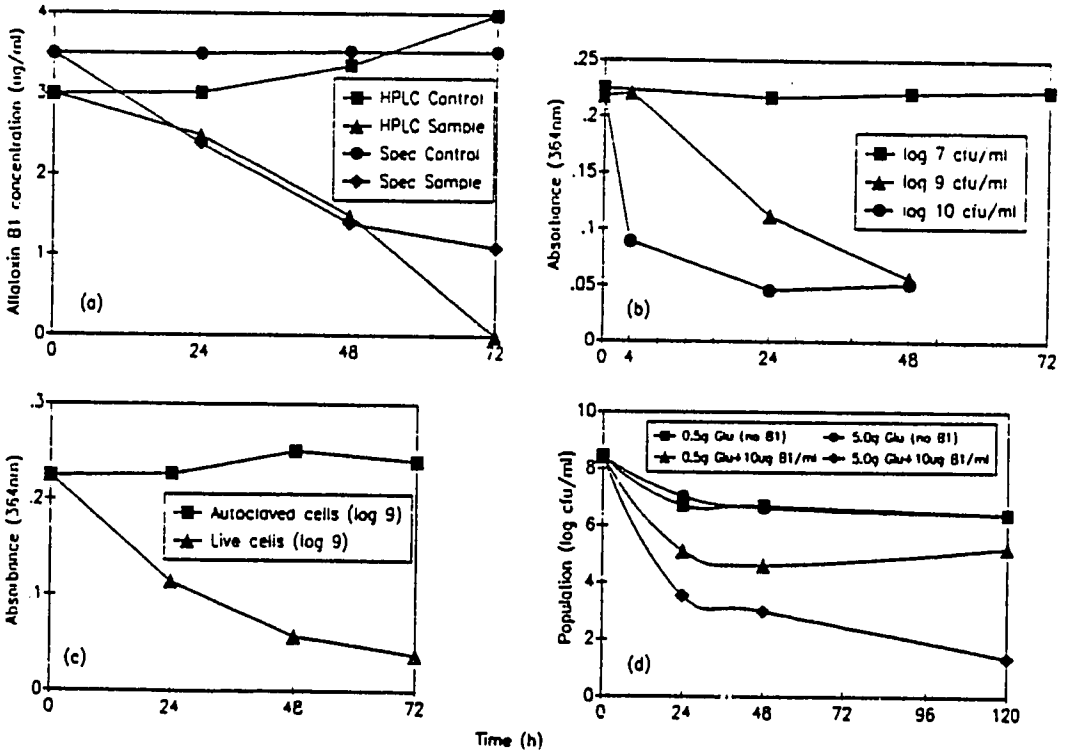

Fig. 10. (a) Comparison of spectrophotometric and HPLC methods; (b) influence of cell population on degradative activity by Flavobacterium aurantiacum; (c) influence of autoclaving on degradative activity of F. aurantiacum; (d) influence of glucose on survival of F. aurantiacum in the presence of 10 μg B_1/ml.

10. Separation of Aflatoxin-Contaminated Seed from Sound Seed by H_2O_2 Treatment

The objective of this study was to evaluate the feasibility of using H_2O_2 solutions for the purpose of separating aflatoxin-contaminated seed from sound seed. The development of a model for predicting the hydrogen peroxide concentration and treatment time required for a given lot with known initial aflatoxin content to obtain maximum yield and low aflatoxin content in a segregated fraction was also investigated.

Medium-sized Florunner peanut seed naturally contaminated with aflatoxins were blended with sound seed in ratios of 0:1, 1:3, 1:1 and 3:1 by weight. Each blend (750g) was evenly deposited in a 28 x 10 x 11.5 cm plexi-glass box containing 3 L of 0, 0.075, 0.150 or 0.225% hydrogen peroxide solution. Peanut that floated (floaters) after 1, 2 and 3 min were collected using a wire screen. Peanut that did not float (sinkers) after 3 min were collected by decanting the hydrogen peroxide solution. To obtain the weight distribution after each treatment time, floaters and sinkers were dried in a forced-air oven at 39°C to 8-9% moisture. Three replicate experiments were conducted for each concentration of hydrogen peroxide solution and for each ratio of the contaminated and sound seed blends. Dried peanut were weighed and the yield, defined as the percent (by weight) sinkers after any given treatment time, was calculated. The aflatoxin content in various functions was determined by standard HPLC procedures. The RSREG procedure of the Statistical Analysis System was used to fit second order polynomial equations. Response surface methodology (RSM) with a four-level by three-factor design was used to identify the hydrogen peroxide treatment condition for obtaining a maximum yield and low aflatoxin content of seed in the sinker fraction segregated from a lot containing a given initial aflatoxin content.

A significant reduction in aflatoxin content in the sinker fraction was achieved by treating blends of aflatoxin contaminated and sound peanut seed in solutions containing various concentrations of hydrogen peroxide for 1 min (Fig. 11a). A concentration of 0.075% hydrogen peroxide was sufficient to reduce the amount of aflatoxin in the sinker fractions of blends containing ratios of 1:3, 1:1 and 3:1 (contaminated: sound) seed by 91.8%, 89.9% and 90.5%, respectively. No further reduction in aflatoxin content in the sinker fraction of the various blends treated with 0.075% hydrogen peroxide was observed with increased treatment time (Fig. 11b). This observation is significant because effective treatment could be achieved in a short time, hence, minimizing the extent of uptake by seed.

At any given hydrogen peroxide concentration, lots containing a high initial aflatoxin concentration yielded sinker fractions containing high concentrations of aflatoxin. This indicates that treatment of peanut seed blends containing a contaminated to sound peanut seed ratio of 3:1 or higher (approximately 200 ppb or higher) will yield a sinker fraction with an aflatoxin content greater than the FDA action level of 15 ppb. In this case, the hydrogen peroxide treatment could still be applied but the treated peanut could only be marketed as an animal feed.

Yield, expressed as percent recovery in the sinker fraction, decreased as hydrogen peroxide concentration and ratio of contaminated seed in blends increased (Fig. 11c). Blends containing high ratios of aflatoxin-contaminated seed presumably exhibit a higher catalase activity, such that evolution of oxygen gas due to the action of catalase on hydrogen peroxide would be more rapid. This would results in a lower yield of sinkers.

Under treatment conditions of 0.075% hydrogen peroxide for 1 min, yield in the sinker fraction was 83.5, 79.8, 73.9% for blends containing ratios of 1:3, 1:1 and 3:1 aflatoxin-contaminated:sound seed), respectively. A yield of only 70.5, 68.7 and 73.1% for blends containing ratios of 1:3, 1:1 and 3:1 (aflatoxin-contaminated:sound peanut seed), respectively was achieved when the hydrogen peroxide concentration was increased to 0.15%. Yield was further reduced to 61.0, 57.1 and 60.2 when the respective blends were subjected to 0.225% hydrogen peroxide. An increase in treatment time from 1 to 3 min in 0.75% hydrogen peroxide solution also resulted in a reduction in yield (Fig. 11d). For peanut blends containing ratios of 1:3, 1:1 and 3:1 (aflatoxin-contaminated:sound seed), yield decreased from 83.5 to 62.2%, 79.8% to 59.% and 73.9% to 55.8%, respectively, as treatment time was increased from 1 to 3 min. For any given peanut blend, further reduction in yield occurred as the concentration of hydrogen peroxide solution was increased. Only 15.4, 16.7 and 13.6% yields were obtained when 1:3, 1:1 and 3:1 blends were subjected to treatment in 0.225% hydrogen peroxide solution for 3 min. This indicates that prolonged exposure of peanut in solution containing a high concentration of hydrogen peroxide results in a substantial loss of sound seed, i.e., segregation of sound seed to the floater fraction. A loss in yield also occurred when 100% sound peanut (0:1 blend) were subjected to hydrogen peroxide treatment. This suggests that excess hydrogen peroxide and prolonged treatment time caused a reduction in yield as a result of the reaction of peanut catalase with hydrogen peroxide. The hydrogen peroxide treatment therefore needs to be optimized to obtain maximum yield and low aflatoxin content in the sinker fraction.

Analysis of variance revealed that the models appear to be adequate for predicting the responses, given the hydrogen peroxide concentration, treatment time and initial aflatoxin content. R^2 values for yield and residual aflatoxin were 0.98 and 0.80, respectively. Further statistical analysis revealed that all treatment variables had a significant overall effect on both responses.

Using the predictive models of yield and residual aflatoxin, computer-generated response surfaces were obtained within the experimental region. For peanut containing 50 ppb aflatoxin, the shaded region in Fig. 12a indicates optimum conditions which result in a yield higher than 85% with less than 5 ppb residual aflatoxin in the sinker fraction. The optimum conditions consist of a 0.08% hydrogen peroxide treatment for 0.7 min. This procedure results in a maximum yield of 85.5% of the original lot and an aflatoxin content of 5 ppb in the sinker fraction. Under the same treatment conditions, peanut containing 100 ppb

aflatoxin also resulted in approximately the same yield (84%) (Fig. 12b); however, the aflatoxin content in the sinker fraction was much higher (35 ppb) than the FDA action limit. To achieve a sinker fraction with a lower aflatoxin content, then, the hydrogen peroxide treatment time must be increased. The shaded region in Fig. 12 indicates optimum conditions for peanut containing 100 ppb. Results indicate that optimum conditions consist of treatment in a 0.1% hydrogen peroxide solution for 1 min. This condition resulted in a yield of 73% and an aflatoxin content of 10 ppb. Additional experiments will be required to determine the usefulness of this treatment for separating contaminated and sound seed of other peanut cultivars. The efficacy of the method as affected by seed size and temperature of the hydrogen peroxide solution must also be investigated.

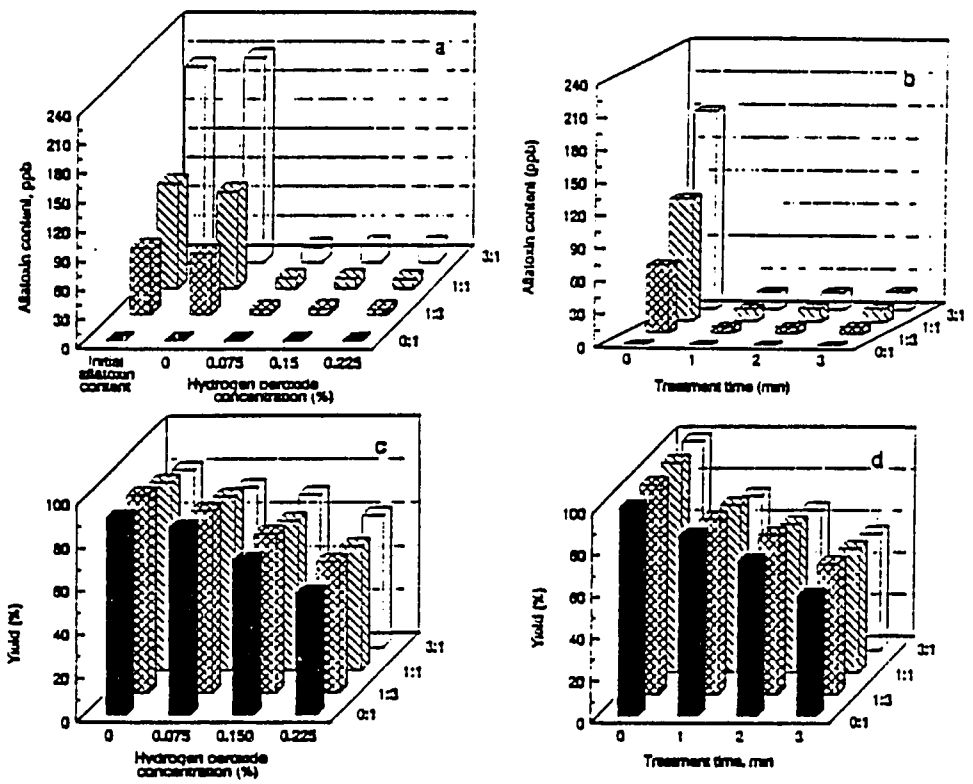

Fig. 11. Aflatoxin content in the sinker fraction of blends of aflatoxin-contaminated and sound seed (0:1, 1:3, 1:1, 3:1) treated with (a) various concentrations of hydrogen peroxide for 1 min and (b) 0.075% hydrogen peroxide for 0, 1, 2 and 3 min. Yield, expressed as percent recovery in the sinker fraction from seed blends (0:1, 1:3, 1:1, 3:1) treated with (c) various concentrations of hydrogen peroxide for 1 min and (d) 0.075% hydrogen peroxide for 0, 1, 2 and 3 min.

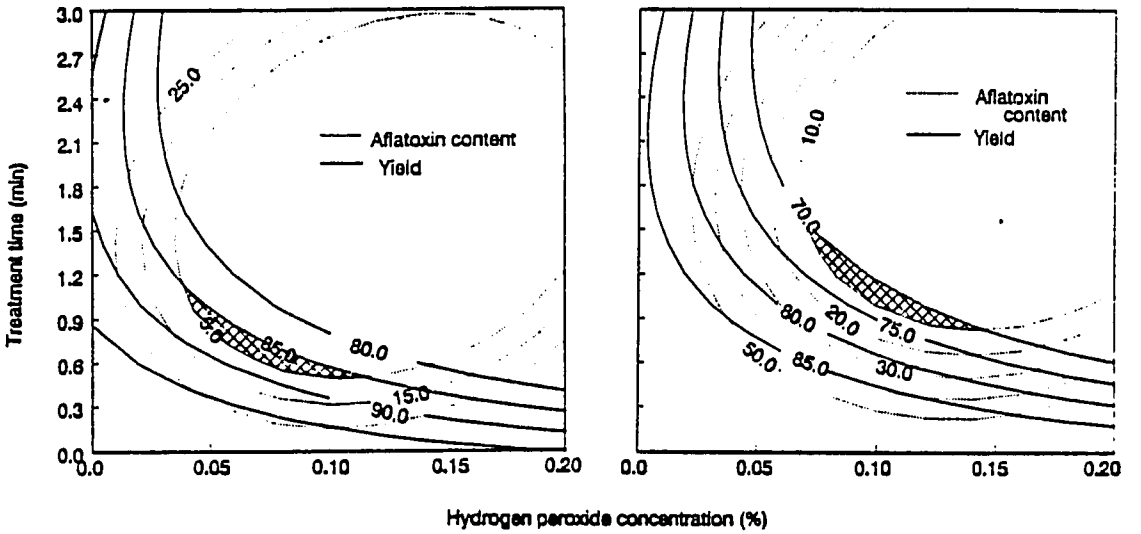

Fig. 12. Superimposed contour plots of aflatoxin content (ppb) and yield (%) in the sinker fraction for peanut with an initial aflatoxin content of 50 ppb (left) and 100 ppb (right).

TRAINING

Mr. Thongchai Suwonsicho and Ms. Sujinda Suwannakij finished their M.S. degrees at KU. Mr. Thongchai accepted a teaching position a Prince Songkla University and Ms. Sujinda resumed her work at Udonthanee Agricultural College.

Mr. Wiwat Wattanatchariya, Mr. Chaiwat Tipsuk, Ms. Sumet Amnuaysirisuk, and Ms. Sirin Pussayapaiboon are making good progress toward meeting the requirements of their M.S. degree at the Department of Product Development.

In August, 1991, UPLB Investigators assisted small scale industries in peanut product development and in making peanut processing equipment operational in Isabela, Cagayan.

UPLB investigators organized a short course on peanut processing which was conducted April 3-5, 1992 at the Institute of Food Science and Technology (UPLB) for the purpose of disseminating technology to small scale producers, teachers and housewives. Those not able to attend were provided with leaflets describing processes for making peanut products. In addition, consultation and information was provided to two M.S. degree students from Isabela State University, two representatives of the Department of Agriculture (Region 5, Naga City) and private entrepreneurs from Calamba and Sta. Rosa, Laguna.

The project provided partial support for thesis research work for three undergraduate students, Emilia T. de Castro, Rhoda L. Natividad and Arlene M. Villena, at the Institute of Food Science and Technology, UPLB.

Dr. Luthgarda S. Palomar from the Department of Agricultural Chemistry and Food Science, Visayas State College of Agriculture, Baybay, Philippines arrived at UGA in June, 1992 for 2 months training in methods for modeling and optimizing peanut formulations for product development.

Ms. Therese M. M. Malundo (Filipino) and Ms. Rocelle S. Clavero (Filipino) completed their requirements for the M.S. degree at UGA. Mr. Witoon Prinyawiwatkul (Thai) and Ms. Rudeepan Wattanapat (Thai) are making good progress toward their M.S. degrees at UGA. Mr. Eric Line (American) is working toward his Ph.D. at UGA.

Ms. Rocelle Clavero won the Student Scientist Award from the Food Science and Human Nutrition Section of the Southern Association of Agricultural Scientists at the annual meeting in Lexington, KY. Ms. Clavero also was Third Place in the Z. John Ordal Graduate Student Award competition (Food Microbiology Division) for

the paper she presented at the June 1992 annual meeting of the Institute of Food Technologists in New Orleans, LA. A third award was given to Ms. Clavero in FY92. She was a co-winner of the UGA E. Broadus Brown M.S. Graduate Student Research Paper Award. Ms. Therese Malundo was a finalist in the Rose Marie Pangborn Graduate Paper Award (Sensory Evaluation Division) at the 1992 IFT meeting.

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PLANS FOR 1992-93:

A. Kasetsart University

1. Improve the quality of traditional peanut products. Systematic development of tuub taab will be done. Shelf-life and consumer acceptance will be evaluated.

2. Research will continue to investigate the use of peanut tempeh in Thai foods. Vegetarian and non-vegetarian foods will be tested for consumer acceptability. Snacks containing peanut tempeh flour will be developed and tested for Thai consumers.

3. Research to determine consumer acceptability of nutritious snacks containing defatted peanut flour will continue. Texturized protein from defatted peanut flour will be prepared using a village texturizer. Optimization of a process for obtaining good quality texturized protein will be done. Uses of texturized protein for vegetarian as well as non-vegetarian foods will be investigated.

4. Formulation of animal feed using good quality undersized peanut will be done. Testing for acceptance by animal will be made.

5. Peanut press cake will be used for production of flavoring sauces by acid hydrolysis. Quality characteristics of such sauce will be analyzed.

6. A Workshop on Peanut for the Industry will be organized to commemorate the 10th Anniversary of Peanut CRSP in Thailand and the 50th Anniversary of KU.

B. University of the Philippines

1. Studies on utilization of peanut for snacks, sauces, curds and fermented products will continue.

2. Studies on the characterization of the compound(s) produced by *Cladosporium fulvum* which is inhibitory to *Aspergillus parasiticus* will continue.

3. Technical assistance to small industries producing peanut products will continue.

4. Quality characteristics of peanut cultivars developed by the Institute of Plant Breeding will be determined upon request.

C. University of Georgia

1. Research to determine the feasibility of replacing protein sources in coffee/tea whiteners with peanut extract will continue. Evaluation of the performance of new formulations compared to commercially available products will be done.

2. Investigations to determine the usefulness of chromatographic analysis of headspace gas to develop prediction equations for flavor of roasted peanut and peanut products will be initiated.

3. The use of peanut fermented with the tempeh mold (*Rhizopus oligosporus*) as an ingredient in extruded peanut-based snack foods will be investigated.

4. Investigate utilization of chemically hydrolyzed peanut sauce in food formulations.

5. Stabilization of peanut butter emulsions against microbial and colloidal instability will be investigated.

6. The efficacy of using liquid ammonia and bisulfite to degrade aflatoxin and the consequent effects of treatments on functional and nutritional properties will be evaluated.

7. Metabolism of ^{14}C-labelled aflatoxin by Flavobacterium aurantiacum will be further investigated.

8. Sensory characteristics of peanut treated with H_2O_2 when used in a confection formula will be evaluated.

9. Constraints associated with various segments of postharvest handling systems used by small peanut producers in Thailand will be identified through the use of survey questionnaires.

INTERNATIONAL TRAVEL

Drs. Garcia, Haruthaithanasan and Beuchat attended the Second International Groundnut Workshop held at the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India, November 25-29, 1991. Six papers reporting project activities were presented. Dr. Beuchat visited project investigators at Kasetsart University and Cheingmai University in conjunction with travel to the ICRISAT Workshop.

Drs. Chompreeda, Paiboon, Mabesa, Resurreccion and Beuchat attended the Fourth ASEAN Food Conference held in Jakarta, Indonesia, February 17-21, 1992. Five papers reporting project activities were presented. Drs. Resurreccion and Beuchat visited project investigators at UPLB in conjunction with travel to the conference. Discussions were also held with food scientists at UP-Dilliman concerning additional financial support which might be available from non-PCRSP sources, which would enhance project activities.

GA/PH/C

POSTHARVEST HANDLING SYSTEMS FOR THE SMALL PEANUT PRODUCER

University of Georgia
Manjeet S. Chinnan

Caribbean Agricultural Research and Development Institute
Brian Cooper (Project Coordinator), A. K. Sinha (PI-Belize),
Joe Lindsay (PI-Jamaica)

INTRODUCTION

It is a well documented fact that the 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 peanuts after they are harvested can be a primary factor associated with the reduction of market value and decrease in probability of consumption. Another factor affecting the probability of consumption of indigenously grown peanuts is their cost, which in turn is influenced by the cost 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. Initial emphasis will continue in the Caribbean region, whereas possible collaboration will be sought in Thailand and/or The Philippines into the later years of the project for an improved system of postharvest operations and providing linkage with the production and utilization aspects of peanuts.

ACCOMPLISHMENTS

Host Countries

1. Belize

Harvester: Based on the drawings provided by Mr. Urvan Wilson, Agricultural Engineer, Jamaica, a harvester is being locally fabricated for testing in Belize. As graduate student he has designed the harvester and tested in Jamaica. Once it works in Belize's heavy soils it will be a breakthrough in reducing cost of harvesting.

Mechanical thresher: Locally fabricated PTO driven thresher has been further modified in terms of the size of the feeding tray and slope of the discharge screen. This equipment is being used by a number of farmers.

Dryer: Members of the San Antonio Cooperative as well as non-members of the village are utilizing the dryer for drying of peanut and corn. Thus, it is serving as a multi-purpose dryer. Other cooperatives are also interested to have their own dryer.

Aflatoxin: Aflatoxin level is being monitored at the farm level in storage and exporting peanut. 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%.

2. Jamaica

This year, the focus on developing post harvest technology for small farm peanut producers continued. Experiments were conducted to determine drying characteristics of peanuts dried using traditional methods. Construction of the storage facility at Newton, St. Elizabeth continued as far as funds were

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available. A Peanut CRSP team consisting of Dr David Cummins and Dr. Dudley Smith visited Jamaica during October 1-4, 1991. Dr. Brian Cooper of Antigua and the late Dr. Gordon Muller of Trinidad also visited Jamaica during that period. Mr. Urvan Wilson travelled to Georgia Experiment Station, Thailand and India. In India he attended the Second International Groundnut Workshop at ICRISAT. A workshop planning meeting was held during February 17-21, 1992; however, adequate funding commitment could not be obtained to hold the workshop, so a scaled down version was scheduled for the next year.

U.S. Institution - University of Georgia

Thresher: Modifications to improve the performance of the engine-driven thresher were made including appropriate changes in all drawings. Manual to evaluate the costs involved with fabrication of the peanut thresher is under development.

Dryer: A prototype arrangement to be used with the large one ton dryer was designed to dry small samples (one pound samples) of peanuts. Preliminary drying tests were conducted with the one ton capacity dryer built in Jamaica.

Storage: A manual to design different size storage facilities and estimating cost is under development.

Pedal-operated sheller: Design for incorporating cleaning and separating device is continuing.

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 and/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 peanuts and associated materials.

7. Identify the input and output parameters of all the components of the 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. Tal Oz-Ari, Research Agricultural Engineer I
Mr. Glen D. Farrell, Laboratory Technician III
Mr. Anil Sharma, Graduate Student

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)

Antigua
Dr. Brian Cooper, Project Coordinator
Ms. Pat Shoy, Accountant

Belize
Mr. A. K. Sinha, Principal Investigator
Mr. B.O. Enriquez, Sr., BFAC, Santa Elena
Mr. Martin Lindo, Technician
Mr. T. Serrut, Technician
Mr. Mr. J. Lisbey, Agronomist

Jamaica
DR. Joe Lindsay, Principal Investigator
Dr. Janice Reid, Country Representative
Mr. Urvan Wilson, Project Research Engineer
Mrs. Barbara Black, Coordinator CARDI Projects
Mr. Morris Taylor, Research Assistant
Ms. Heather Gray, Biometrician
Mr. M. Montague, Executive Ag. Officer, RADA/MOA (Rural Agricultural Development Authority/ Ministry of Agriculture
Mr. B. Saunders, Extension Officer, RADA/MOA
Mrs. C. Wilson, Extension Officer, RADA/MOA

Trinidad
Dr. Gordon Muller, CARDI Cooperator
Dr. Clement Sankat, Department of Agricultural Engineering, University of West Indies

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. The drawing was acquired from him for local fabrication. Initially, there was problem in getting materials specified in Mr. Wilson's report but later some alternatives were looked into, and parts of an old disc plough were acquired to make the main frame/structure of the lifter. Thus, the main body was completed, further work needs to be done for the fabrication of the mould board plough.

Mechanical Thresher

Locally fabricated PTO driven thresher was used by a number of farmer cooperatives. Approximately 50 acres of peanut crop was threshed with this equipment. The demand for the use of the thresher was more but all at the same time.

The thresher has been further modified in (i) lengthening the feeding tray by 30 cm to increase the efficiency of the feeding rate, and (ii) increasing the slope of the discharge screen so that peanut could flow better for bagging.

The longer plants especially at high moisture severely wrapped the threshing cylinder at all speeds. Under these conditions, the threshing effectiveness was low. The thresher performed best on peanut plants that were exposed to four or more days of uninterrupted sun drying. Increasing the cylinder speeds for the dryer crop increased the feeding rate. When peanut pods were too dry then cylinder speed had to be decreased to prevent losses from shelling of pods.

Dryer

The dryer installed in San Antonio, CAYO has been continually utilized by the 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.

On the request of PRODERE (UNDP - United Nations Development Program) CARDI provided services of drying peanuts to the farmers serviced by them. This group has realized the importance of the dryer for the expansion of agricultural development in the community. The design and cost of construction and equipment for the dryer was provided to this group.

Varietal Screening

Although varietal screening is not the major thrust of this project, there is an ongoing effort in this area under CARDI's own program. Several cultivars which are better than Tennessee Red have been identified and some other improved varieties have been examined. The factors which are most

important in this screening process are resistance to rust and leaf spot disease (to ensure good yields), red testa (since consumers prefer this for all ball park nuts), large seed size (for salted nuts). Selected varieties are being tested on the farmers field plots in Toledo and Cayo Districts. Selected large seeded varieties were blanched using laboratory model peanut blancher. Salted nuts were given to various people to judge consumer acceptability. Consumer tests were done on a very preliminary basis. There is need for conducting modern scientific consumer testing methods in evaluation of value-added peanut products.

Aflatoxin Monitoring

Aflatoxin level in peanuts was monitored at the farm level in storage facilities and also for peanuts for export. Fifteen samples were checked. To date aflatoxin level has not been detected above the tolerance level of 20 part per billion.

2. Jamaica

Mechanical Drying

A low cost kerosene dryer was installed on the Ministry of Agriculture, Rural Agricultural Development Authority (RADA), property in Newton, St. Elizabeth. Permission to install this facility on the Ministry's property was expedited by the efforts of Mr. D. B. Irving, Deputy Executive Director of RADA and Mr. Mervyn Montague, Parish Agricultural Manager, RADA, St. Cruz.

The dryer was designed by Tal Oz-Ari, of the Georgia Experiment Station. It consists of a drying bin of capacity of 800 kg of wet peanuts, a blower and a heat generator (fuel burner). The surface of the fuel in the fuel chamber of the burner is ignited . The resulting flame consisting of a mixture of air which is drawn into the heat exchanger chamber. This heated air is then drawn into the blower and forced out into the drying bin and up through the peanuts.

The dryer was tested using 590 kg of CARDI-PAYNE peanuts of 30% moisture (wet basis). The fan was set to operate at 1200 rpm and the plenum temperature at 30 deg C. The depth of peanuts in the bin was 110 cm and the static pressure was limited to a maximum of 250 Pa. Accurate determination of fuel consumption was not possible at the time of testing. The peanuts were dried to approximately 9% moisture wet basis, in eight hours.

Storage Facility

Construction work continued on the storage building adjacent to the mechanical dryer. The facility was designed jointly by Mr. Wilson and Mr. Oz-Ari to store peanuts for up to six individual farmers and such has six compartments each of 900 kg capacity. Using available funds, construction progressed to the covering, partitioning and ventilating of the building. After shutters have been installed and the metal work has been weather-proofed, the facility will be ready for use. Delay in completion of the facility, and undue delay by the postal service in delivering the shipment of lab supplies from the Georgia Experiment Station caused a postponement of the start of storage experiments till early in the next fiscal year.

Barbecue Drying Curve Determination

Barbecuing or Bar-B-Queing in Jamaica refers to drying peanuts under sun when spread in a thin layer on a concrete slab. An experiment described below was conducted to determine the drying curve for peanuts dried under

the farmer's traditional drying method.

CARDI-PAYNE variety was chosen, peanuts were harvested 118 days after planting. Except for taking periodic samples for moisture analysis, farmer's practice was followed. They were put out to sun dry at approximately 8.00 am and gathered and bagged at 3.00 pm each day during the test. At the end of the day, the peanuts were gathered, and packed into bags and stored for the night. The test were carried out using 200 kg of peanuts. Samples were taken each morning just after the peanuts were spread out to dry. This timing of sampling was done to ensure equalization of moisture contents in the peanuts after they have been dried during the previous day. Five samples weighing approximately 130 g were taken at random from five different locations of the peanuts on the Bar-B-Que. The time of sampling was recorded. The samples were put into separate paper bags, carefully labelled, and were weighed within 20 min after being collected. Following which the samples were dried in oven, held at 75 deg C, for at least 48 hours. The samples were removed and weighed again to calculate the initial moisture content of the peanut samples.

During the drying test period, there was good sunlight and negligible precipitation. On three evenings after the peanuts were collected, there was light rainfall for a short duration. Daily variations of temperature and humidity were recorded on the hygrothermograph, the recorded charts are on file.

Initial moisture was 39.02% which reduced to 27.66%, 20.73%, 16.34%, 11.61% and 8.10% at the end of first, second, third, fourth and fifth day of drying, respectively. The results show that with an average daily temperature of 35 deg C and humidity ranging from 25 to 40%, the moisture content reduced from 39.02% to 8.1% in five days. Thus, given good sunny weather conditions, the barbecuing method can reduce the moisture content of peanuts to a safe level for storage. Drying by this method although effective under favorable weather conditions, is risky, and involves human labor over a longer period of time than mechanized drying. It may be useful therefore to sun dry when weather conditions are favorable and use mechanical drying in unfavorable weather conditions.

B. U.S. INSTITUTION - UNIVERSITY OF GEORGIA

Threshers

Modifications to improve performance of the engine-driven thresher were made and all drawings and specifications modified accordingly. The main modifications were to increase the slope of the collecting screen and improve the engine base. Manual to help evaluate the costs involved with fabrication of the peanut thresher is under development, which should be published in the next fiscal year. The document includes the cost evaluation based on the Belizian market. This document also includes detailed shop drawings, instructions and specifications for two different threshers: a tractor P.T.O driven , and a gasoline engine-powered thresher. It also includes a test procedure to aid in determining performance evaluation of the threshers.

Dryers

A prototype arrangement was developed to be used with a larger scale capacity dryer to be able to dry several one pound samples of peanuts simultaneously. The prototype arrangement basically consisted of a four inch dia PVC tube which could be fitted with a screen on one side; the tube arrangement is then to be mounted on the existing dryer in such a way so that the air from the dryer passes through this tube holding a small peanut sample. The purpose of this design was to allow drying of any experimental

storage samples to low moisture content to arrest growth of any *Aspergillus* mold. These samples could be then held for few days before taking to the laboratory for aflatoxin analysis. Detailed instructions and drawings to duplicate such a tube were prepared and shipped to Jamaica.

The batch dryer of 800 kg capacity previously designed, was built in Jamaica with the coordination provided by Mr. Tal Oz-Ari. The dryer uses the modified radiant heater fueled with kerosene oil and the blower powered with a small gasoline engine. Preliminary results from the drying tests were satisfactory.

Preliminary work on developing a manual for a batch dryer cost and fabrication has been done, and all related drawings, specifications and most other information were collected. This manual will provide guideline to organizations and groups interested in building a low-cost dryer for peanuts.

Storage

A manual to design different size storage facilities and estimating cost is under development.

Pedal Operated Sheller

The present pedal operated sheller only cracks the peanut pods, it does that job efficiently. However, a separate cleaning step has to be followed, whether it is mechanical or manual. Design for incorporating cleaning and separating device is being pursued.

Physical Properties

Work on mechanical properties of peanut shells and in-shell peanuts was continued. Additional data was taken to identify suitability of different probes to puncture and compress peanuts using the Universal Instron Testing Machine. Test were also conducted to reveal the rupturing of whole peanut pod when the pods oriented in different positions were subjected to compression forces. The quantification of the rupturing forces, which could lead to improved design of current shelling devices, was found to be very difficult using the uniaxial compression testing approach.

Density Distribution of Aflatoxin Contaminated Peanuts

Previous studies had shown that it is possible to statistically model the density distribution of aflatoxin contaminated peanuts. Further analysis showed that it is possible to estimate the percentage of peanuts that will fall into specified range of density. However, more work has to be conducted to establish the presence or absence of a 'critical' aflatoxin level required to effect a significant and known amount of depression of kernel density. At this time the results obtained do not seem to be very promising to develop an efficient and effective separation scheme based on density differences.

II. Training

U. S. Institution Personnel: Tal Oz-Ari visited Jamaica during the period of June 23 and July 6 of 1991, to assist in the installation of the dryer and provide training to operate the dryer. Dr. Chinnan also travelled to Jamaica in July of 1992 to assist in the installation of the dryer and the training aspects of the operation of the dryer. Mr. Urvan Wilson spent few days with Mr. Oz-Ari at Georgia in November of 1991 to get familiar with personal computer software for word processing and spread-sheet work. This trip was made during Mr. Wilson's travel to Asia via Atlanta.

CARDI-Jamaica Personnel: Mr. Urvan Wilson travelled to Asia in November of 1991. During that trip he visited Khon Kaen University and Asian Institute of Technology in Thailand to obtain information on postharvest handling of agricultural materials including peanuts. He also visited several institutes in India to gather information on small scale farming equipment including animal drawn equipment. These institutes are Central Institute of Agricultural Engineering, Bhopal; Indian Agricultural Research Institute, Delhi; and the International Crops Research Institute for Semi-Arid Tropics, Patancheru.

Morris Taylor, and Dr. Joseph Lindsay offered technical assistance to two of the large peanut growers in Jamaica. These are Sevens Estate and Thethford Farms.

CARDI-Belize Personnel: They provided training to one extension officer of the Ministry of Agriculture and Fisheries, two extension officers of Belize Federation of Agricultural Cooperatives and three group of farmers. The training was given on how to operate a dryer and on the uses of threshers and shellers.

PUBLICATIONS AND PRESENTATIONS

Sinha A. K. 1992. A guide for peanut Production in Belize. CARDI Belize Pamphlet, pp9.

Ganasekharan, V., M. S. Chinnan. 1992. Density distributions of aflatoxin contaminated peanuts in naturally and laboratory infected peanuts. Transactions of ASAE. 35:631-637.

Ganasekharan, V., M. S. Chinnan and J. W. Dorner. 1992. Methods for characterization of kernel density and aflatoxin levels of individual peanuts. 19:24-28.

Chinnan, M. S., B. R. Cooper and U. Wilson. 1991. Handling and processing of peanuts in Americas. (Abstract) Second International Groundnut Workshop, International Crops Research Institute of Semi- Arid Tropics., Patencheru, AP, India, 25-29 November.

Cooper, B. R., M. S. Chinnan, A. K. Sinha, U. Wilson and G. Muller. 1991. Development of threshing and shelling systems appropriate for small groundnut farmers in the Caribbean. (Abstract) Second International Groundnut Workshop, International Crops Research Institute of Semi- Arid Tropics., Patencheru, AP, India, 25-29 November.

Wilson, U., A. K. Sinha, T. Oz-Ari, M. S. Chinnan and B. R. Cooper. 1991. Development of drying and storage systems appropriate for small groundnut farmers in the Caribbean. (Abstract) Second International Groundnut Workshop, International Crops Research Institute of Semi- Arid Tropics., Patencheru, AP, India, 25-29 November.

PLANS FOR 1992-1993

U.S.

A. Identification of the segments of the postharvest handling system and various constraints.

Efforts from FY 91-92 will continue in this area. Cooperation with a faculty member from the Department of Agricultural Economics at Georgia and Department of Social Sciences at the University of West Indies at Mona, Jamaica, will be sought.

B. Evaluation of economic value of individual postharvest handling operation or segment.

Qualitative relationships in thrust A will be transformed into quantitative relationships. This information will be obtained in coordination with the host country cooperators and agriculture economists as needed.

C. Adaptation or modification of existing or developed technologies.

A thresher developed at the Khon Kaen University, Thailand, will be obtained and protocol for testing under the Jamaican conditions will be coordinated. Cost of fabrication and adaptation of that thresher in the Caribbean will be evaluated.

D. Evaluation of technologies identified for functionality and economic value.

Cost of building and operating a dryer and a storage facility will be evaluated.

E. Evaluate the anticipated change in quality loss.

Work on systems approach for quality evaluation will continue.

F. Determine physical properties of peanuts.

Feasibility of coating shelled and unshelled peanuts with starchy, cellulosic, and/or proteinaceous materials for enhanced storage life will be conducted.

G. Identify input and output parameters of all the components to build a global model.

Some progress has been made in FY 91-92, further emphasis will be given in FY 92-93.

H. 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 utilization of peanuts.

I. Workshop in January 1993 in Jamaica. Enhancing Peanut Production and Quality for Small Producers: Development of Improved Postharvest Handling Systems.

1. Planning Activity

2. Holding the Workshop

Host Country

<u>Jamaica</u>

A. Evaluate developed/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

A. Economic evaluation of various postharvest handling operations or segments

1. Efficiency and operation cost of locally fabricated peanut threshers will be further evaluated.

2. Artificial driers of two different sizes will be evaluated for effectiveness and cost.

3. One or two additional peanut threshers will be fabricated in Belize based on the design and the drawings developed through this project. The funding for these additional threshers will be sought form non-CRSP sources.

4. A lifter will be fabricated in Belize or in Jamaica for use in Belize.

B. Assessment of Aflatoxin levels at different time periods of storage.

1. Also, see Objective E under University of Georgia thrusts.

Project Redirection Proposed

Research on postharvest handling aspects of peanuts will be enhanced in the Southeast Asia region by shifting emphasis from the Caribbean region. Initial focus on postharvest handling will be in Thailand providing linkage between the peanut production and utilization research. Manjeet Chinnan who is the Principal Investigator of the GA/PH/C project will become one of the cooperators on this GA/FT/TP project. Future increase in postharvest activities in Thailand will depend upon the increase in the availability of funds and any further shift of Peanut CRSP funds from the Caribbean and Central America region.

This project (GA/PH/C) will also 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.

INTERNATIONAL TRAVEL

U. S. Participants

July 1991: Tal Oz-Ari and M. S. Chinnan visited Jamaica to assist in the installation of the dryer, training of the operation of the dryer, and review the project activities.

October 1991: Drs. David Cummins and Dudley Smith visited Belize and Jamaica to review Peanut CRSP project activities.

November 1991: Manjeet Chinnan travelled to Asia. Visited Khon Kaen University, Kasetsart University, Chiang Mai University, and Asian Institute of Technology in Thailand to develop possible collaboration to conduct research in postharvest handling of peanuts in Southeast Asia. During the same trip, he also travelled to ICRISAT, Patencheru, India to participate in the Second International Groundnut Workshop.

February 1992: Chinnan travelled to Jamaica to plan a workshop on peanut production and postharvest handling aspects.

Host Country Participants

July 1991: Mr. Anil Sinha from CARDI Belize, visited ICRISAT, India during his vacation period. The objective was to observe various peanut production and postharvest handling equipment developed or adapted and investigate the possibilities of collaboration.

November 1991: Mr. Urvan Wilson accompanied Chinnan to Thailand and India. Dr. Brian Cooper travelled to India to participate in the Second International Groundnut Workshop.

February 1992: Dr. Cooper from Antigua travelled to Jamaica and joined Dr. Chinnan to plan a workshop in Jamaica.