PD ABE-269
ISN 67117

PEANUT
COLLABORATIVE RESEARCH
SUPPORT PROGRAM

DETAILED PROJECT
PLANS
for
1990 - 1995

Supported by USAID Grant:
DAN-4048-G-SS-2065-00

Contents

The research programs in Africa - too inclusive for the capacity!

Introduction..... i

Projects

Tx/BCP/S,BF,N - Disease-Resistant Peanut Varieties for Semi-Arid Environments..... 1

NCS/BCP/TP - Peanut Varietal Improvement for Thailand and the Philippines..... 18

GA/IM/BF - IPM Strategies for Peanut Insects in SAT Africa.. 50

NCS/IM/TP - Management of Arthropods on Peanuts in Southeast Asia..... 69

GA/PV,N,TP - Peanut Viruses: Etiology, Epidemiology, and Nature of Resistance..... 87

TX/MM/S - Mycotoxin Management in Peanut by Prevention of Contamination and Monitoring..... 99

AAM/FT/BF - An Interdisciplinary Approach to Optimum Food Utility of the Peanut in SAT Africa.....115

GA/FT/TP - Appropriate Technology for Storage/ Utilization of Peanut.....129

GA/PH/CAR - Postharvest Handling Systems for the Small Peanut Producer.....162

Resource Management.....175

Communications and Outreach.....177

Peanut CRSP Management.....179

Detailed Budgets.....183

INTRODUCTION

The Detailed Project Plans for 1990-1995 expands on information summarized in the Global Plan and Extension Proposal for 1990-1995.

The project plans include information on past accomplishments, future plans, benefits expected, justification for increased budget support to include "new thrust" proposals and budgets.

A Resource Management thrust is described which includes an expansion of some research that has been on-going in projects (for example the food consumption surveys in the food technology projects). Expansion in new areas of agronomy is described.

The Communications and Outreach thrust is a much needed area to accelerate the dissemination of information. A goal of this thrust is to demonstrate the viability of new technology to in-country outreach groups, and to make information available to U.S. policy makers and clientele.

The optimal level budget will provide funds for a much needed Communications Specialist to assist in the development of publications and other outreach materials. Some of the efforts will carry forward from present activities into an enhanced mode.

The Management Entity will continue to function in a role to assist the researchers in their programs and provide necessary programatic liaisons to USAID, universities, and host countries and be responsible to USAID for progress and management of funds.

Project Code: TX/BCP/WA

Project Title: Peanut Variety Improvement for Semi-Arid West Africa, Texas A&M University/Burkina Faso, Mali, Niger, Senegal

Olin Smith, Principal Investigator, TAMU

INTRODUCTION

Peanut is a widely distributed and economically important food crop in West Africa. Yields are historically low, and severe droughts in the two previous decades have amplified production problems. Pod and forage yields are restricted by drought, disease, arthropods, low soil fertility, and crop management practices. Short rainy seasons and intermittent periods of drought limit crop quantity and quality. Mycotoxin producing fungi flourish in the drought stressed and arthropod damaged fruit in both field storage environments. Mycotoxin production is a serious health threat to humans and livestock consumers of peanut products.

Can these problems be prioritized?

The constraints in West Africa are also important limiting factors to rainfed peanut production in Texas. Therefore, the Peanut CRSP project is mutually beneficial for the welfare of the peanut industry in West Africa and the U.S.A.

Collaborative linkages have been established with four West African countries including Senegal, Burkina Faso, Niger, and Mali.

Senegal. The project is part of the Institut Senegalais de Recherches Agricole and is linked with the Departement du Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD). The project strengthens and enhances an outgoing research program focused on breeding for agronomic adaptation, earliness, drought tolerance, and resistance to foliar diseases (leafspot and rust) and mycotoxin producing fungi. Field trials have been conducted on research station sites near Bambey and Nioro.

Burkina Faso. Collaboration is with the University of Ouagadougou, Institut Superieur Polytechnique (ISP). Advanced breeding lines and pre-selected germplasms have been introduced each year for seed increase, agronomic adaptability evaluation, and disease assessment. Breeding lines with potentially useful traits are included in multilocation yield trials. Disease assessment of breeding lines is made in the humid southwestern region of the country.

Niger. This is a collaborative yield testing program with the Institut Nationale de Recherches Agronomiques du Niger (INRAN). Advanced breeding lines, cultivars, and pre-selected germplasms are introduced annually for seed increase and observation. Potentially

useful lines are selected for advanced testing. The host country effort in selection for earliness and seed increase is also enhanced. Recently, we initiated a program of limited evaluation and selection in populations segregating for short growth duration that were developed and preselected in Texas.

Mali. A Memorandum of Understanding with the Institut Nationale Recherche Agricole (INRA) was completed June, 1989. Advanced line testing, and evaluation of landraces collected by INRA and ICRISAT researchers in 1985 are the immediate focuses of the collaboration.

ACCOMPLISHMENTS

Research

Texas. Final selection and release of two cultivars and four peanut germplasm lines have been completed. Short growth duration, 'Langley', and high grade and yield, 'Tamrun 88', were the principal attributes for release of the cultivars. Earliness (TxAG-1 and TxAG-2), and disease resistance (TxAG-4 and TxAG-5) traits were the bases for release of the germplasm lines. Selection and seed increase have been completed and a proposal for release of a spanish cultivar is planned for 1990.

Multilocation, multiyear comparisons of leafspot evaluation methods have been made cooperatively with scientists in the other major U.S. peanut growing regions for enhancement of communication and improvement of disease assessment methods.

Multiple date assessments with two or more leafspot evaluation methods have been made on 1500 peanut introductions from South America accessed through joint efforts of IBPGR, Texas A&M University, ICRISAT, and other agencies in North and South America. Elite lines have been increased and included in field trials in West Africa.

Crosses among very early maturing germplasms, and among these early maturing germplasms and high yielding and disease resistant (leafspots, rust, soilborne diseases, rosette virus, and Aspergillus flavus) parentage have been accomplished. Preliminary selection of populations, and early generation lines (F-3 nd F-4) is in progress. Transfer of preselected segregating materials to West African collaborators has been initiated.

Approximately 340 germplasm lines have been introduced to Texas from West Africa, and 230+ have been increased sufficiently for field evaluation of foliar and soilborne disease reactions. Seed are being processed for inclusion into the national germplasm system.

More than 100 elite breeding lines from ICRISAT, North

Carolina, and Florida, and numerous Texas selections were evaluated for resistance to tomato spotted wilt virus disease after extensive losses from the disease in South Texas in 1985 and 1986. Nine breeding lines with low disease incidence and reasonably acceptable agronomic traits are still under test.

Eight methods of assessing drought tolerance in other crop species have been evaluated on peanut cultivars which, according to long term field studies, have been divergent in drought tolerance. No single, rapid method differentiated the known material adequately to be employed as an effective screening tool.

Numerous breeding lines and cultivars have been evaluated for productivity under moisture stressed rainfed conditions, some for as many as five years. Significant variation in yield and quality parameters have been found in each test, but relative performances of the entries were not consistent among tests. Differential growth stages and condition of the plants when the unpredictable stress periods occur confounded interpretations on the basis of average performance. Sufficient multiyear/multilocation data are in hand to initiate analyses for interpretations on the effect of climatic and water supply patterns on the differential performance of entries.

Immunity to root knot nematode has been discovered in a Texas line derived from interspecific crosses with three wild species of Arachis. Crossing is in progress to transfer both leafspot and nematode resistance from this line into agronomically acceptable varieties.

A breeding line with moderate resistance to Aspergillus flavus/aflatoxin production has been developed.

Host Countries. Disease surveys of peanut production constraints in Senegal, Burkina Faso, and Niger reinforced the need of leafspot, rust, and rosette resistant cultivars.

Three candivars with potential for release are under expanded testing in Senegal and breeders seed increase has been initiated.

Multiple criteria selection for drought tolerance has enabled progress in breeding for drought tolerance by ISRA. A good correlation was found between temperature of plant foliage and drought tolerance that might lead to a useful selection criterion for drought tolerance.

Selections from a Sn 57-422 x Samuru 1064 cross have shown excellent adaptation and yield at Nioro during three years of testing.

Multiple location yield trials comprised of 66 entries have been conducted in five peanut growing regions of Burkina faso.

University Vs NARS
support for research work

Marked regional differences in performance have been noted.

Germplasm selected in leafspot screening trials in Texas have also shown good leafspot resistance in disease resistance trials in southwest Burkina Faso. Some entries have both leafspot and rust resistance, and one line has been introduced into the national peanut breeding program.

Three lines were advanced to off-station yield trials in Nigerien grower fields but rosette virus negated results. Seed from crosses of rosette virus resistant x early maturing parents were made in Texas and taken to Niger for seed increase and future selection in Niger.

Training

MS degree training was provided for one Senegalese student, degree conferred August, 1989, and one Burkinian is in the second year of training. Mr. N'Doye, the Senegalese student, is currently located in Senegal as a participant of the Peanut CRSP project. Partial support has been provided for two PH.D. and two M.S. students from the U.S. Three scientists, one each from Burkina Faso, Senegal, and Niger, and one technician from Senegal have received non-degree training at Texas A&M University. Support has also been provided to ISP students assisting with nursery maintenance and data collection during summer months in Burkina Faso, and to many U.S. and international students assisting with peanut research activities in Texas.

LINKAGES

IntraCRSP

Cooperative linkages have been established with projects as follows:

Mycotoxin Management Tx/MM/S identification of A. flavus/mycotoxin resistant germplasm and breeding for resistance.

Insect Management GA/IM/BF - germplasm evaluation and potentially in breeding for host plant resistance to important arthropods.

Food Technology AL/FT/BF - candivar differences in quality (chemical composition and aflatoxin content) traits of advanced lines and varieties grown in Burkina Faso.

InterCRSP

Tropsoils - soil characterization at selected peanut variety test sites in Burkina Faso and Niger to enhance understanding of crop (perhaps variety) response and adaptation.

IRC

ICRISAT - joint research on disease identification and control; surveys; publications; and germplasm collection, adaptation and utilization.

CIRAD - host plant resistance to diseases and tolerance to drought, Senegal and Burkina Faso

IBPGR - Germplasm collection, characterization, and utilization

PRIORITY CONSTRAINTS:

1. Low yields due to susceptibility to pests, low tolerance to environmental stresses and lack of adaptability to local environments, especially the short season marked with intermittent droughts.

2. Excessive use of chemicals for pest control.

3. Lack of cultivars available to meet needs for agronomic cropping systems that are resistant to pests.

GOAL

Develop and identify peanut lines adapted to important ecological areas of Sahelian West Africa and Texas that are resistant to pathogens causing economic loss and effectively utilize available water, and to identify cultural practices that will maximize the yield potential of cultivars in those environments.

RATIONALE

Drought tolerant varieties with good yield potential that are resistant to the important diseases and insects, and which produce healthful and palatable products are essential components of the solution to food deficiencies. The development of such peanut varieties for the varied ecological areas of Sahelian West Africa and Texas is a long term and ongoing effort. Many similarities exist in the growing conditions and production constraints of the targeted regions of the respective two continents. However, enhanced production by direct transfer of improved varieties from one continent to the other has shown minimal success. Significant advances in building the research capabilities of the collaborating agencies have been achieved. Useful germplasms have been identified but better parents must be developed and/or identified. Populations with potentially useful combinations of desired traits have been developed, but more and better ones are needed. In general, population sizes must be restricted because of the physical and financial resources that are required. Rapid methods

of screening for the varied constraints that are applicable to desired population sizes are being developed but must be refined and tested. Capabilities and motivation of host country researchers have been enhanced by training, communication, cooperation, equipment, germplasm exchange, and operating funds. Acquaintances, understanding, and confidence among host country and assisting organization scientists has improved. A continued and unified, cooperative effort with resources adequate to meet the challenge is needed.

OBJECTIVES

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

2. Enlarge and enhance the germplasm resources of the collaborating peanut improvement programs.

3. Encourage participants and improve the effectiveness of the peanut research programs in the collaborating host countries.

4. Assess the adaptability, stability, and acceptability of cultivars and candivars within the Sahele to ascertain the potential usefulness of current and emerging cultivars, and to identify localized differences which must be addressed in the development of peanut varieties for the region.

5. Increase the scientific expertise of current and emerging host country scientists in the development and culture of peanut.

6. Assess relative chemical quality and aflatoxin suppression characteristics of candivars and cultivars, and appropriately apply such information in the selection of new cultivars.

7. Identify and provide germplasm and populations that will facilitate the identification of useful genetic recombinants in Host-Country peanut programs.

8. Ascertain the disease reaction, drought tolerance, and agronomic characteristics of in-country and introduced varieties and breeding stocks, and assess their potential for use in cultivar development.

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

10. Develop improved disease assessment methods.

11. Develop, evaluate, and implement drought-tolerance evaluation techniques.

12. Train host-country and U.S. staff and students.

13. Monitor, in cooperation with the Insect Management Project, the reaction of advanced breeding lines and varieties to yield reducing arthropods.

PLANS PROPOSED

The number of paired "source line irrigation" experiments in Texas and Senegal will be increased. Information gained from these experiments with associated measures, such as relative water content, foliage temperature, and etcetera, will be used in the assessment of drought tolerance and in identifying reliable indicators of drought tolerance. Information gained will be examined in comparison with the relative performance of selected peanut germplasms and associated climatic, physiological, and agronomic parameters in Texas and West Africa. Multi-year, multilocation, experiments are necessary to assess the relationship of physiological variables in drought reactions of test entries.

Use, and verify or modify available crop growth and cropping systems models to expand our understanding of drought mechanisms as they relate to climatic conditions and soil factors in relation to time of the year and peanut plant phonology, morphology, growth patterns, and responses which regulate water uptake and utilization.

Continue field screening and testing 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.

Evaluate advanced lines and selections developed in ICRISAT, Texas, and Host Country programs involving intra- and inter-specific crosses, along with recent accessions from South America, China, and other sources, for better germplasm to use as parents..

Continue population development and preselection of early maturing, disease resistant (leafspot, rust, and soilborne pathogenic fungi) drought tolerant, and agronomically productive parentage for evaluation and further selection in collaborating country programs.

Collaborate with Peanut CRSP Virus, Insect Management, and Mycotoxin Management Project and ICRISAT scientists in the selection of parents and the selection of breeding lines useful in ameliorating yield limiting constraints in West Africa. Enlist the assistance of ICRISAT scientists if feasible, in the screening of early generation lines for response to rosette virus

Develop and implement an expanded regional variety testing program in West Africa in cooperation with ICRISAT and interested Host Country scientists.

Increase cooperation among and within CRSP projects, especially those active in West Africa, to increase effectiveness of research and gain information on production factors affecting important product quality characteristics in the host countries, soil factor interactions with differential variety performance, and identification of traits needed in peanut for effective resource management systems.

Continue cooperative and collaborative research with CIRAD and the newly formed CORAF Network Scientists in addressing the important constraints to peanut production in West Africa.

Assist and encourage host country scientists in achieving project goals and in peanut research program development.

Continue and increase, if possible, the advanced degree training of intelligent, energetic, and inquisitive young potential scientists in peanut science and cultivar development. Provide temporary training to host country technical staff as deemed necessary either in Texas or in collaboration with ICRISAT scientists.

Provide and instruct in the use of improved equipment, such as small plot shelling and grading, small lot seed storage equipment, and other, as possible, to increase efficiency and expedite implementation of research.

BENEFITS

Newly released or soon to be released improved varieties should benefit peanut growers substantially in the host countries and the U.S. Accurate quantification of their impact is impossible until industry acceptance is ascertained. Based on research data, yield increases of 4 to 5% on areas planted to the new varieties can be expected. Increased germplasm acquisition, characterization, recombination, and selection in the varied host country and Texas environments, coupled with improved methods for assessing and selecting superior lines, will enable the development of better varieties wtih earliness, disease resistance, and/or drought tolerance. Stability of production should be increased and risk from disease and drought losses should be reduced by proper management of the new varieties. Similar benefits should accrue to the 'developing' and 'developed' countries.

TIMETABLE

Objective (see # above)	Year 1990	1991	1992	1993	1994
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					

ORGANIZATION/PERSONNEL

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

Principal Investigator	Dr. Olin D. Smith, Department of Soil & Crop Sciences (S&CS), TAMU, College Station (CS)
Co-Principal Investigators	Dr. Charles E. Simpson, TAMU TAES Research and Extension Center, Stephenville
Cooperators	Dr. Donald H. Smith, TAMU TAES Agri. Research Station, Yoakum
	Dr. A. Michael Schubert, TAMU TAES, Agri. Research Station, Yoakum
	Dr. Robert E. Pettit, Department of Plant Pathology and Microbiology, TAMU, CS
	Mrs. Ruth A. Taber, Department of Plant Pathology and Microbiology, TAMU, CS
Research Scientist	Mr. W.J. Grichar, TAMU TAES, Agri. Research Station, Yoakum
Research Associates	Dr. Gregory B. Parker, Dept. of S&CS, TAMU, CS
	Mr. Richard Davis, TAMU PDRS, Agri. Research Station, Yoakum
	Mr. A.J. Jaks, TAMU TAES, Agric. Research Station, Yoakum
	Mr. Serafin M. Aquirre, Dept. of S&CS, TAMU, CS
Research Assistants	Mr. Mahama Ouedraogo, Dept. of S&CS, TAMU, CS
	Ms. Lisa Wildman, Dept. of S&CS, TAMU, CS
Technician	Mr. John Scherlen, TAMU TAES, Agri. Research Station, Yoakum
Budget Analyst	Ms. Marcia Walker, TAMU Research Foundation

Institutional Representatives

Dr. Dudley T. Smith, Associate Director, Texas Agricultural Experiment Station, TAMU, CS

Dr. E.C.A. Runge, Head, Dept. of S&CS, TAMU, CS

Senegal: Institut Senegalais de Recherches Agricoles (ISRA)

Directeur Generale	Dr. Mahamadou Ly, ISRA, Daker
Directeur de Departement Production Vegetales	Dr. Limamoulaye Cisse, ISRA, Daker
Project Group Leader	Mr. J.C. Mortreuil, IRHO/CNRA/ISRA, Bambey
Collaborators	Mr. D. Annerose, IRHO/CNRA/ISRA, Bambey
	Mr. Jean L. Khalfaoui, IRHO/CNRA/ISRA, Bambey

Burkina Faso: University of Ouagadougou Institut Superior Polytechnique (ISP)

Directeur des ISP	Dr. Alfred Traore, ISP, Ouagadougou
Collaborator	Dr. Phillippe Sankara, ISP, Ouagadougou

Niger: Institut Nationale de Recherches Agronomiques due Niger (INRAN)

Director Generale	Dr. Idrissa Soumano, INRAN, Niamey
Collaborator	Dr. Amadou Mounkaila, INRAN, CNRA, Maradi

Mali: Institut d'Economie Rurale (IER)

Directeur Generale	Dr. Omar Tall, IER, Bamako
Collaborator	Mr. Dielissouma Soumano, IER, Bamako
	Mr. Sadio Traore, IER, Bamako

JUSTIFICATION FOR OPTIMAL BUDGET

1. Maintain present activities at operational levels. Previous reductions and new increased indirect costs and salary adjustments in addition to increased costs of goods and services required that additional funds be provided, or project activities reduced.

2. Train one additional H.C. M.S. and one Ph.D. student, plus one U.S. Ph.D. student.

3. Provide funds for West Africa collaborators meeting with one or more U.S. Co-P.I.'s at one H.C. site per year.

4. Expand U.S. and H.C. research in breeding for mycotoxin resistance in collaboration with Tx/MM/S project. An additional screening site with irrigation capabilities for promoting fungal growth will be established in Texas, and the number of entries examined in Senegal will be increased.

5. Strengthen intra-CRSP (GA/PV/N, Ala/FT/BF, and GA/IM/BF) and inter-CRSP (Tx/Tropsoils) collaboration capabilities.

New Thrusts

Description of two proposals that were approved for funding in the "new thrusts" follow.

PROJECT CODE: TX/BCP/WA

SUBJECT TITLE: INTROGRESSION OF GENES FOR LEAFSPOT AND NEMATODE RESISTANCE AND EARLY MATURITY FROM WILD PEANUT SPECIES INTO CULTIVATED PEANUT

INTRODUCTION

An introgression program to transfer leafspot resistance, early and late, from wild Arachis species into cultivated peanut breeding lines, and ultimately to develop varieties for release to growers was initiated in 1973. The program was extended to include resistance to two root-knot nematode species in 1987, and early maturity in 1988. All three of these efforts included crosses with the "B" genome Arachis batizocoi as a bridge species. Our work has shown that attempts at introgression will be considerably less fruitful if A. batizocoi is not included in the program.

The sources of resistance to leafspot were identified in 1974 by Abdou, Gregory and Cooper. Arachis cardenasii Krap. et. Greg. nom. nud. (GKP-10017) has a high level of resistance to late leafspot, and A. chacoensis Krap. et. Greg. nom. nud. (GKP-10602) has essential immunity to early leafspot. Nelson et.al. identified the resistance to root-knot nematodes in 1987. Arachis cardenasii and A. batizocoi Krap. et. Greg. have high levels of resistance to both Meloidogyne arenaria and M. hapla. Simpson (C.E. Simpson, unpublished data) has identified early maturity in unnamed species of wild Arachis (Arachis sp. VSGr-6416) and has verified that the species is compatible with A. hypogaea. Expansion of this effort with the involvement of a H.C. trainee will speed progress in the gene transfer and enhance the utilization of this germplasm in West Africa. Populations generated in this program can be tested and re-selected in the collaborating countries.

OBJECTIVES

1. To utilize resistance identified in wild species of Arachis for resistance to early and late leafspot to develop varieties of cultivated peanut which have resistance to both leafspot organisms.

2. To make the most of the breakthrough we have made in identifying nematode resistance in wild Arachis species by overcoming chromosome number differences, sterility barriers, and physical incompatibilities to transfer the nematode resistance into breeding lines which can be used in the breeding program to develop nematode resistant peanut varieties.

3. To circumvent incompatibility, sterility, and seed dormancy in order to transfer genes for early maturity from a wild Arachis species into cultivated peanut breeding lines.

PLANS

Plant materials available with leafspot and nematode resistance represent five generations of crossing and/or backcrossing. The next steps with this material will be to backcross again with A. hypogaea, evaluate and select BC_2F_2 progenies for resistance and agronomic characters, and continue the backcross, evaluation, and selection process for seven to eight cycles. The effort on early maturity is in more formative stages; the bridge cross has been made between the early maturing "A" genome and the bridge species A. batizocoi, and the hybrid has been evaluated and treated with colchicine. After chromosome doubling is successful, the amphiploid will be crossed to A. hypogaea. Selection and backcrossing will follow in succeeding generations. The crossing, evaluation, plant maintenance, and selection require a considerable amount of time, effort, and expense.

The transfer of excellent early and late leafspot resistance and resistance to both Meloidogyne hapla and M. arenaria are just a matter of time and effort, with a near 100% chance of success. The transfer of earliness genes will be dependent upon developing an adequate evaluation procedure and lies in the 60 to 70% range of probable success.

PROJECT CODE: TX/BCP/WA

SUBJECT TITLE: INTROGRESSION OF GENES FOR LEAFSPOT AND NEMATODE RESISTANCE AND EARLY MATURITY INTO CULTIVATED PEANUT

U.S.	1990-91	1991-92	1992-93	1993-94	1994-95
PERSONNEL					
SALARIES & WAGES	$17,500.00	$17,500.00	$17,500.00	$17,500.00	$19,500.00
TOTAL	$17,500.00	$17,500.00	$17,500.00	$17,500.00	$19,500.00
EQUIPMENT & FACILITIES					
TRAVEL & PER DIEM	$5,200.00	$5,200.00	$5,200.00	$5,200.00	$5,200.00
MATERIALS & SUPPLIES	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00
OTHER DIRECT COSTS	$3,000.00	$3,000.00	$3,000.00	$3,000.00	$2,000.00
TOTAL DIRECT COSTS	$26,700.00	$26,700.00	$26,700.00	$26,700.00	$27,700.00
INDIRECT COSTS (43%)	$15,080.00	$15,080.00	$15,080.00	$15,080.00	$17,090.00
TOTAL DIRECT & I.C.	$41,780.00	$41,780.00	$41,780.00	$41,780.00	$44,790.00
HOST COUNTRY					
SENEGAL					
RESEARCH				$2,300.00	$2,300.00
INDIRECT COSTS (30%)				$690.00	$690.00
TOTAL				$2,990.00	$2,990.00
BURKINA FASO					
RESEARCH					$2,000.00
TOTAL					$2,000.00
NIGER					
RESEARCH	$5,000.00	$5,000.00	$5,000.00	$5,000.00	$5,000.00
TOTAL	$5,000.00	$5,000.00	$5,000.00	$5,000.00	$5,000.00
MALI					
RESEARCH	$3,000.00	$3,000.00	$3,000.00	$3,000.00	
TRAINING	$20,000.00	$20,000.00	$20,000.00	$17,000.00	$15,000.00
TOTAL	$23,000.00	$23,000.00	$23,000.00	$20,000.00	$15,000.00
TOTAL H.C.	$28,000.00	$28,000.00	$28,000.00	$28,000.00	$24,990.00
TOTAL AID	$69,780.00	$69,780.00	$69,780.00	$69,780.00	$69,780.00
COST SHARE (25%)	$10,945.00	$10,945.00	$10,945.00	$10,945.00	$11,198.00
TOTAL PROJECT	$80,725.00	$80,725.00	$80,725.00	$80,725.00	$80,978.00

STATEMENT REGARDING TIME PLAN

ENHANCEMENT PROPOSAL FOR DROUGHT RESEARCH ASPECTS OF PEANUT CRSP 1990 - 1995

Initial funding levels for drought aspects of the Peanut CRSP project were based on the assumption that the scientist involved would spend much of his time in a very hands-on manner in the research with support at the technician level. The scientist has since been assigned significant administrative duties, which have reduced the hands-on involvement of the scientist. As a result, we have conducted numerous field studies which have yielded good data on relative values for a number of parameter among cultivars. But our current approach lacks the degree of basic information; integration and interpretation of results; timely communication with collaborators; testing of potentially more rapid laboratory, greenhouse, and procedures; and redesign of approaches based on results which would move the project forward as quickly as desired.

With enhanced funding, I propose that we would involve someone at the Doctoral Training level to be responsible for assisting in speeding up interpretation of results; development of new hypotheses and approaches; and expanding the level of communication and collaboration with cooperators, especially host country scientists. This will involve increased costs for personnel, materials and supplies, and travel and more time spent actually working overseas. The student would be expected to spend a 1-2 month research trip during the spring dry season, when source line irrigation studies are conducted in Senegal, in alternate years. The host country Co-P.I. and/or assistant, would participate in research and interpretation of data in U.S. during the other years.

PROJECT CODE: TX/BCP/WA

SUBJECT TITLE: ENHANCEMENT OF DROUGHT RESEARCH

	1990-91	1991-92	1992-93	1993-94	1994-95
PERSONNEL					
SALARIES & WAGES	$2,100.00	$2,100.00	$1,600.00	$1,600.00	$10,000.00
TRAINING	$11,500.00	$11,500.00	$12,000.00	$12,000.00	
TOTAL	$13,600.00	$13,600.00	$13,600.00	$13,600.00	$10,000.00
EQUIPMENT & FACILITIES					
TRAVEL & PER DIEM	$1,000.00	$6,000.00	$1,000.00	$6,000.00	$2,000.00
MATERIALS & SUPPLIES	$2,000.00	$2,000.00	$2,000.00	$2,000.00	$3,000.00
OTHER DIRECT COSTS	$2,000.00	$2,000.00	$2,000.00	$2,000.00	$2,300.00
TOTAL DIRECT COSTS	18,600.00	$23,600.00	$18,600.00	$23,600.00	$17,300.00
INDIRECT COSTS (43%)	$9,518.00	$10,668.00	$9,518.00	$10,668.00	$9,219.00
TOTAL DIRECT & I.C.	$28,118.00	$34,268.00	$28,118.00	$34,268.00	$26,519.00
HOST COUNTRY					
SENEGAL					
RESEARCH	$7,000.00	$2,000.00	$7,000.00	$2,000.00	$8,000.00
INDIRECT COSTS (30%)	$600.00	$600.00	$600.00	$600.00	$900.00
TOTAL	$7,600.00	$2,600.00	$7,600.00	$2,600.00	$8,900.00
TOTAL H.C.	$7,600.00	$2,600.00	$7,600.00	$2,600.00	$8,900.00
TOTAL AID	$35,718.00	$36,868.00	$3,718.00	$36,868.00	$35,419.00
COST SHARE (25%)	$7,030.00	$8,567.00	$7,030.00	$8,567.00	$6,630.00
TOTAL PROJECT	$42,748.00	$45,435.00	$10,748.00	$45,435.00	$42,049.00

THIS IS AN ONGOING PROJECT. HOWEVER, THE STUDENT TRAINING COULD BE COMPLETED WITHIN FOUR YEARS.

Project Code: NCS/BCP/TP

Project Title: Peanut Varietal Improvement for Thailand and the Philippines

North Carolina State University - Thailand and Philippines

Johnny C. Wynne, Principal Investigator, NCSU

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. Growing environments and cultural practices involved in peanut production vary greatly among and within peanut-producing areas. In Thailand, peanuts 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 peanuts during the dry season. Similar conditions are present in the Philippines where the duration of the rainy season can vary between 3 to 6 months over areas where peanuts are grown. The most productive growing season in the Philippines continues to be after rice but breeding efforts are needed for peanut to fit in all possible cropping systems.

The Philippines

The peanut breeding program is part of the legume crop research group at the Institute of Plant Breeding which is under the aegis of the College of Agriculture of the University of the Philippines at Los Banos (UPLB). IPB consists of a multidiscplinary team of breeders, pathologists, entomologists, physiologists, and soil scientists. Plans and programs of IPB are reviewed annually by an advisory board composed of the Minister of Agriculture, the Dean of the College of Agriculture, the Director of Research of UPLB, the Director of the Crops Research Division of the Philippine Council for Agriculture Forestry and Resources Research and Development (PCARR) and a representative of the private sector.

Peanut breeding research has been funded in part through a grant from the International Development Research Centre (I.D.R.C.) of Canada but has been significantly expanded with CRSP funding. Testing sites for yield trials have been established in the major peanut-growing areas in the Philippines.

Research Accomplishments. Of major significance during the first 7 years of the project has been the release of the cultivar UPL Pn6. During Phase I of the P-CRSP breeding project activities

included the development of peanut cultivars resistant to major pests, tolerant of stress environments and adapted to various cropping systems. Breeding efforts were directed towards combining high yield with the desired characters for upland, lowland and partial shade conditions.

During Phase I of the project, 744 new accessions were obtained mostly from North Carolina State University (NCSU) and from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). A total of 256 crosses were generated using genotypes that are high yielding, large seeded, resistant to late Cercospora leafspot, rust, leafhopper and tolerant to highly acidic soil conditions. Preliminary yield trials were conducted under upland conditions, in acid soils, under multiple insect and disease conditions as well as in drought conditions. Promising entries were identified for each trait and used for further testing and crosses.

The project was reorganized during Phase II. Studies on shade tolerance, drought tolerance and nitrogen fixation were integrated into a program designed for germplasm collection and evaluation of desired genetic traits. A new testing site for wet season yield testing and seed production of breeder seeds and elite materials was established at San Fernando, Pampanga. Studies were initiated on seed viability to partially solve the problem of inadequate viable seed for the regular dry season planting. Material from IPB and NCSU was screened for resistance to Aspergillus flavus invasion, Sclerotium wilt resistance, late leafspot and insect resistance.

Shade tolerance has become an important component of the project. Thirty shade-tolerant entries have been identified and are being evaluated in yield trials as an intercrop under coconut in selected rainfed testing sites.

Hybrid material has been generated (64 single crosses and six backcrosses) from high yielding Philippine cultivars crossed with previously identified parents for rust, leafspot, Sclerotium wilt and leafhopper resistances, high nitrogen fixation and for shade and drought tolerance.

Preliminary and advanced yield trials have continued at multiple locations. New locations of Pampanga and Mindanao have proven to be good sites for effective yield trials.

Thailand

The Department of Agriculture (DOA) and two agricultural universities (Khon Kaen and Kasetsart) have primary responsibility for peanut research in Thailand. Until recently, a coordinated peanut research program was mutually supported by the Canadian IDRC and the Peanut CRSP. As of June 1, 1989, IDRC suspended their

support, reducing the research capacity.

Breeding research is concentrated on developing cultivars with higher yields and disease resistance with emphasis on cultivars suitable for a rice cropping system under rainfed conditions. Breeding programs conduct studies through an integrated approach with plant pathologists, entomologists and microbiologists. Varietal testing is conducted at 11 locations including nine coordinated by the DOA.

Research Accomplishments. Three new peanut cultivars have been released by the program. Khon Kaen 60-1, formerly known as Moket, is a medium-seeded spanish type proposed to replace Tainan 9 and Khon Kaen 60-2 (TMV3) was released as a superior boiling-type peanut in 1987. A large-seeded virginia- type peanut derived from an NC 7 selection was released in 1988 as Khon Kaen 60-3.

Over 2800 peanut lines or populations have been introduced and screened for numerous breeding objectives. More than 300 crosses have been made locally and are in various stages of selection and yield testing. Several lines have been identified as being superior to the currently grown cultivar Tainan 9 for desirable traits such as pest resistance, stress tolerance and high yield.

Selections have been made for early maturity, rust and leafspot resistances, resistance to Sclerotium stem rot and Aspergillus sp., for boiling-type peanuts and improvement of large-seeded types. The breeding effort at Khon Kaen University has screened material specifically for different cropping systems such as the after-rice unirrigated condition and before-rice growing condition.

Work in plant pathology has focused on differential reactions of rust, leafspot, stem rot, Aspergillus crown rot and peanut stripe virus among peanut genotypes. Significant work has been conducted on yield loss assessment, symptom variations, and possible control measures for peanut stripe virus.

Surveys of incidence and severity of diseases inflicting farmers' peanut fields were conducted at over 50 locations. Screening techniques were established for leafspots, rust, A. flavus, crown rot, and stem rot. Studies on race variations for rust and leafspot pathogens were conducted. A compendium of peanut diseases in Thailand was published and distributed.

Training activities have included 10 graduate and 10 undergraduate student research assistants. Two PhD students have been conducting thesis research at NCSU and will be completed before 1990. Short-course training on peanut production has been conducted by the DOA.

North Carolina

The peanut breeding project at North Carolina State University has been able to expand research capabilities due to support from the Peanut CRSP. The breeding project is directly responsible for the development and release of improved cultivars for the farmers of North Carolina. The major objective of the program is to develop cultivars with increased yielding ability, improved quality, earlier maturity, disease (CBR, stem rot, early and late leafspot, Sclerotinia blight), insect (southern corn rootworm, potato leafhopper), and twospotted spider mite resistances.

Research Accomplishments. The increased effort has contributed to the development and release in 1985 of a high yielding cultivar, NC 9, a Cylindrocladium crotalariae- (CBR) resistant cultivar, NC 10C, and a high yielding, new release NC-V11.

The development of cultivars with greater resistance to CBR, larger seed size and early maturity has been given high priority in the program. Advanced CBR lines have shown consistently greater resistance than resistant checks. Intensive selection of segregating material under high CBR-stressed conditions has begun. Selections have been made from crosses NC 7 x Florigiant and NC 7 x NC 9 based on greater percentage of extra large kernels (ELK). These lines have shown potential for increased storage life and earlier maturity.

Genotypes have been identified and advanced that have early leafspot resistance and high yields. The most resistant lines have been used as parents to incorporate yield and resistance lines with more acceptable seed quality characteristics.

Genetic studies were performed on resistance to early and late leafspot, early maturity, dormancy and fatty acid composition. A recurrent selection breeding program has been performed for four cycles using elite germplasm. Studies on the effectiveness of convergent crossing has begun. Within the past 2 years an investigation has been conducted on isozyme patterns of the different botanical types and work has begun on genetic transformation of peanut for resistance to tomato spotted wilt virus (TSWV).

The role of plant pathology in the CRSP breeding project is to provide essential pathological information relevant to development of disease- resistant cultivars. Responsibilities have included development of disease screening methods and identification of resistant germplasm, characterization of resistant mechanisms, evaluation of environmental stresses influencing host-pathogen interactions and stability of resistance related to inoculum density and/or genetic variation within diverse pathogen populations. Studies have been completed in these areas for early leafspot (Cercospora arachidicola), late leafspot

(Cercosporidium personatum), stem rot (Sclerotium rolfsii), CBR, aflatoxin (Aspergillus parasiticus) and peanut stripe virus. In addition to identifying or confirming sources of resistance, significant advances in understanding the biology of C. arachidicola and C. personatum have been made. Physiological and morphological (phenology of plant) attributes of plants which contribute to field resistance to S. rolfsii have been identified in introduced germplasm. Physiological resistance to Aspergillus sp. has also been identified in introduced germplasm. Combination of this mechanism of resistance with previously described dry seed resistance should assist breeders in developing resistant cultivars.

The primary objective of the species portion of the CRSP breeding project is to develop interspecific hybrids for use in breeding programs in the U.S. and overseas. Numerous species of Arachis have been evaluated for leafspot resistance, CBR resistance, fatty acid composition and biological nitrogen fixation capacity. Desirable genotypes have been identified for all traits. Interspecific hybrids with 40 chromosomes which are cross-compatible with A. hypogaea and with high levels of C. arachidicola resistance have been selected. A few advanced breeding lines have been developed from interspecific hybridization with A. cardenasii that have outyielded the cultivar Florigiant. One line from this cross is being evaluated in regional yield trials. Incompatibility barriers among several species of section Arachis have been identified. The effects of gibberellic acid on peg elongation and kinetin and indole acetic acid on embryo development were investigated for crosses where the embryo aborts.

Embryo culture experiments were completed which identified growth regulator combinations useful for supporting peanut tissues in vitro and enhancing growth. Embryos of A. hypogaea can now be routinely grown to maturity and hybrid plants from an incompatible cross were obtained in vitro. Because abortion mostly occurs soon after pollination, young 1- to 20-day embryos were cultured. Growth was observed in various media tests, but cell differentiation did not occur. Attempts were made to develop in vitro regeneration methods using different media combinations and explants, with the greatest advances obtained for increasing root development.

Anther culture techniques were investigated to reduce efforts required to form pure lines. Haploid plants could also be more adaptable with diploid wild species (with lower ploidy number). Different media and stages of development were tested for initiation of embryogenesis, whereby initial cell divisions were induced.

TRAINING ACCOMPLISHMENTS:

Two Thai students (Sanun Jogloy and Surapong Charoenrath) have

received full support from the P-CRSP to earn PhD degrees at NCSU. Two Masters' students from the Philippines (Victoria Matalog and Vermando Aquino) completed work at NCSU. The P-CRSP has aided directly or indirectly 10 students from non-CRSP countries and 14 U.S. students during their graduate study. Seventeen host country scientists have received short- or long-term post-graduate training in the U.S.

Short-term training for host country technical staff and researchers has been conducted at ICRISAT in India. CRSP funds have also supported local training of undergraduate and graduate students at UPLB, Philippines and Khon Kaen and Kasetsart universities in Thailand.

LINKAGES:

ICRISAT has provided material for screening and hybridization, a training facility for host country scientists and direction for appropriate research. Coordination of projects has occurred with IDRC in Thailand throughout the history of the CRSP project. Cooperation with ACIAR has been initiated for work in the Philippines and Indonesia.

PRIORITY CONSTRAINTS TO BE ADDRESSED:

1. Low yields due to susceptibility to pests, low tolerance to environmental stresses and lack of adaptability to local environments.

2. High dependency on chemical inputs.

3. Lack of cultivars available to meet the variety of situations available in current cropping systems.

4. Reduced seed viability and seed quality from environmental conditions.

GOAL:

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.

RATIONALE:

Cultivars have been released with higher yields helping improve peanut production. Sources of resistance to some pests have been identified and incorporated into adaptable material.

However, yields remain low and chemical inputs high in Thailand and the Philippines. Fungicide and insecticide use is still extensive in North Carolina. Further research is needed to continue to improve yields, gain greater pest resistance, identify resistant sources to other pests that cause economic loss and then combine these desirable traits. Most agronomic traits and the occurrence of specific disease and insect pests are common between peanut-growing areas of North Carolina, Thailand and the Philippines. The cooperative nature of work that has occurred during the first two phases of the project provides the background for more efficient use of time and space to accomplish the goals. Tolerance to extremes in environment as well as resistance to pests are evaluated in natural settings among the collaborative institutions. Greater understanding of the mechanisms of yield constraints can also be gained.

OBJECTIVES:

Philippines

Long-term:

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.

Short-term:

1. Improve seed viability and stability through cultural practices.

2. Select for increased seed viability among crosses using adapted parents.

3. Coordination of seed increases of released cultivars by farmers/ cooperators in Pampanga, Tarlai, Balangas and Cavite.

4. Crossing and selection for a large-seeded cultivar to replace UPL
Pn 2.

5. Initial screening and breeding for good boiling-type peanut.

6. Conduct on-site testing of shade-tolerant lines on coconut farms.

7. Characterize effects of acid soils on susceptible and tolerant material.

8. Screening for acid tolerance.

9. Genetic studies on shade and acid tolerance.

10. Initiate crosses and backcrosses for resistance to rust and leafspot and subsequent selection.

11. Multi-location yield testing.

Thailand

Long-term:

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, TSWV, stripe virus, and insects and drought tolerance would be incorporated for specific growing seasons.

2. Develop cultivars for the boiling-type market.

Short-term:

1. Characterize soil requirements for better management use of fertilizer and rhizobia inoculum.

2. Crossing of high yielding adapted lines with sources of resistance to leafspot, rust and insects.

3. Crossing of early maturity and large seed material with adapted lines.

4. Develop a field screening technique for A. flavus.

5. Screen parental material and begin breeding for A. flavus resistance.

6. Use alternative breeding technique for incorporation of rust and leafspot resistances in adapted material.

7. Elucidate biological reasons for plant resistance to rust and leafspot.

8. Determine details of biology of wilt bacteria (Pseudomonas solanacearum).

9. Continue attempts for biological control of rust and

leafspots.

10. Gain further understanding of peanut stripe resistance that would lead to control measures (cross-protection).

11. Determine importance of yellow spot virus and bud necrosis virus in the disease complex.

12. Evaluate the competitive ability of Rhizobium used in commercial inoculum versus native strains.

13. Use competitive rhizobial strains for selection in breeding traits.

14. Expand and strengthen regional yield trials of advanced breeding material.

15. Test drought-tolerant lines from ICRISAT under after-rice unirrigated conditions.

16. Breeding for drought tolerance.

North Carolina

Long-term:

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.

Short-term:

Breeding

1. Intensive selection of large-seeded adapted lines with CBR resistance.

2. Breeding for resistance to early leafspot in early generation lines of large-seeded adapted x high yielding leafspot-resistant lines.

3. Selection of early maturing large-seeded virginia peanut

with good storability.

4. Incorporate TSWV resistance in adapted lines through use of genetic transformation techniques.

5. Study genetics and continue breeding attempts toward incorporation of multiple mechanisms of resistance to aflatoxin production.

6. Test leafspot-resistant lines at multiple locations (Thailand, Philippines, U.S.).

7. Convergent crossing between genotypes with individual components of leafspot resistance.

8. Study genetic resistance incorporated through cultivated x wild Arachis crosses.

9. Test current advanced material with variation in storability for chemical and market quality.

Plant Pathology

10. Study plant-pathogen mechanisms of resistance to Sclerotium rolfsii and Sclerotinia minor.

11. Study effects of partial nematode resistance on response to root and stem pathogens.

12. Identify environmental factors that alter mechanisms of resistance to aflatoxin accumulation.

13. Screen levels of root-knot nematode resistance in interspecific crosses.

14. Identify host specificity of TSWV.

15. Screen transgenic plants for resistance to TSWV.

Cytogenetics

16. Document ploidy level and species identification of Arachis germplasm resources.

17. Determine genomic relationships among section Arachis species, including intra- and interspecific variation.

18. Identify isozyme and seed protein markers in Arachis species for use in introgression studies and possible linkages with useful agronomic traits.

19. Characterize barriers to interspecific hybridization for

species closely related to A. hypogaea.

20. Develop adapted and high yielding germplasm pools for cultivar improvement by utilizing populations of interspecific hybrids.

21. Develop nematode and TSWV-resistant breeding populations by interspecific hybridization.

22. Evaluate the inheritance and mechanisms of resistance of Cercospora arachidicola in diploid species of Arachis.

23. Evaluate media to induce rooting in vitro and then enhance embryo rescue capabilities.

24. Develop C. arachidicola-resistant breeding lines.

RESEARCH PLANS PROPOSED:

Philippines

A. Cultivar development:

1. Evaluation and selection will continue for high yield, large seeds, pest resistance and tolerance to marginal growing conditions. Greater emphasis will be placed on large-seeded genotypes to replace UPL Pn2. Efforts to increase disease resistance will continue with emphasis on late leafspot, rust, Sclerotium wilt and aflatoxin. Screening and selection will also be initiated for stripe virus resistance.

Evaluation and selection will continue for drought, shade and acid tolerance as well as higher biological nitrogen fixation. Crosses will be made specifically for the incorporation of shade and acid tolerance for genetic study and later selection.

2. A multidisciplinary evaluation will be initiated of promising materials for desired traits (yield, pest resistance, stress tolerance).

3. Greater emphasis will be placed on screening germplasm for improved seed viability and storability. Improvements must be made in this area for increased germination in field tests for other traits.

4. Screening and selection for improved boiling-type peanuts will be initiated.

5. On-farm testing of advanced material for shade

tolerance will be initiated by distributing material to coconut farmers in various areas of the Philippines and other countries (Malaysia).

B. New or improved breeding techniques:

1. Two types of shade cloths will be tested and shade tolerance screening of material will be conducted under full sunlight and partial shade conditions in an attempt to improve selection techniques.

2. Field testing for tolerance to acidity, aluminum and manganese will be performed. Genotypes will be characterized for their growth, nodulation, nutritional status and root growth.

3. Evaluation of seed quality of selected materials will be performed in cooperation with food science personnel.

C. Seed production and purification of improved varieties and promising materials: Farmers/cooperators will be identified for the purpose of increasing seed of released and recommended cultivars. This would aid in the disbursal of seed to rural farmers in many areas of the country.

Thailand

A. Breeding:

1. Initial screening of segregating materials introduced from NCSU, ICRISAT, and the local crossing programs will be performed at Khon Kaen University for high yields, earliness, resistance to Aspergillus flavus, resistance to rust and leafspot, and resistance to Sclerotium stem rot.

2. High yielding adapted lines will be crossed to insect-resistant sources and promiscuous nodulating lines for biological nitrogen fixation to initiate breeding activities in these areas.

3. Emphasis will be placed on backcrossing programs to transfer rust resistance into high yielding adapted lines and convergent crosses among high yielding adapted lines and leafspot-resistant sources.

4. Promising breeding lines will be evaluated under before-rice and after-rice conditions.

5. The Department of Agriculture will take greater responsibility in testing of advanced material. At the standard yield trial and regional yield trial stages, the lines will be merged into four series (regular medium-seeded types, boiling types, large-seeded types, and early lines) of trials.

6. DOA will also coordinate wider on-farm trials of the most promising lines.

B. Plant pathology:

1. Studies on improving methodology for screening for resistance to Aspergillus sp. infection in the field.

2. Field nurseries for foliar diseases will continue to be established for screening for disease resistance.

3. Monitoring of peanut diseases in farmers' fields will become a routine program with emphasis on the incidence of bacterial wilt.

4. More detailed studies of the leafspot and rust pathogens including pathogenesis and biological control will be conducted.

5. The biology and epidemiology of the wilt bacteria (Pseudomonas solanacearum) will be studied in more detail.

6. Work with peanut stripe will emphasize strain interaction (cross protection) and biology and epidemiology of particular strains. Biology of yellow spot and bud necrosis viruses will also be studied.

C. Rhizobium research:

1. The competitive abilities of the Rhizobium strains currently used in commercial inoculum production against the native strains will be evaluated. Studies will also be conducted to evaluate the competitive abilities of good native strains with other native strains. Selection of strains under nonsterile media will be undertaken and the results compared with those derived from sterile media. The strains that perform well in nonsterile media will be tested under field conditions.

2. An attempt will be made to determine indicators for potential response to Rhizobium inoculation. The population of native legumes will be monitored in a number of selected fields throughout the year. The native Rhizobium population of native legumes will also be monitored. Soil type will be taken into account, and the rhizosphere effect of some important nonlegume crops such as cassava, kenaf, rice, and sugar cane will be studied. Inoculation trials will be conducted in some fields once the monitoring is completed.

3. The promiscuous peanut lines already identified will be multiplied and crossed to high yielding adapted lines. The progenies will be evaluated for both yield and nitrogen-fixing

ability. This work will be done in cooperation with the breeder.

D. Soils: To effectively derive appropriate fertilizer recommendations for peanut production in different zones, a soil fertility map will be constructed for areas of peanut production. A base map indicating peanut growing locations, season grown, and the cropping systems involved in the different areas will be developed. This will be done in collaboration with extension by gathering information on peanut-growing areas and season grown by subdistrict. Visits to different provinces will be made to meet with local extension personnel to have them locate the exact peanut production area on the map. The production area map will be superimposed on detailed soil maps, which are available for all the provinces, to determine the soil types in which peanut is grown. Soil analysis data are also available for most of the major soil types in Thailand. These will be used to develop a preliminary zoning for peanut soil fertility research. Additional soil and plant analyses will be done to determine the level of soil fertility in each soil group. Further fertility trials will be conducted as needed.

North Carolina

A. Breeding:

1. Cultivar development

(a) Breeding and selection for yield, early maturity, drought tolerance, quality, and diseases and insect resistances will continue. Material identified as potentially useful will be sent to Thailand and the Philippines.

(b) The fifth and sixth cycles of recurrent selection will be performed and evaluated for yield and market grades. Elite lines will be identified for regional evaluation.

(c) Segregating material produced through a convergent crossing program will be evaluated for yield, early maturity, drought resistance, CBR resistance, and leafspot resistance by screening in multiple environments in the U.S., Thailand, and the Philippines.

(d) Large-seeded genotypes generated through crosses of locally adapted material (NC 7 x NC 9, NC 7 x Florigiant) and through a large 50- parent crossing program using exotic lines will be evaluated for early maturity and shelf-life. Selections for early maturity will be made and sent to Thailand and the

Philippines for further evaluation and use.

(e) Selections made for increased nitrogen fixation in cooperation with G. H. Elkan will be evaluated for their ability to fix nitrogen.

(f) Select for high and low O/L fatty acid and determine effects on chemical quality and taste.

2. Disease resistance

(a) Crossing, evaluation and selection for resistance to CBR will be intensified through direct screening of early generation segregating material. Cycles of crossing and testing will be initiated annually.

(b) Selections made for resistance to late leafspot, early leafspot and rust will be evaluated in multiple locations (U.S., Puerto Rico, Thailand, Philippines) for further use. Crosses between genotypes identified as being superior on individual components of resistance to the diseases will be made and selection will be practiced for multiple components of resistance.

(c) Selections from a recurrent selection program for early leafspot will be evaluated and the most resistant and highest yielding lines will be used for the second cycle.

(d) Genetics of multiple mechanisms of resistance to aflatoxin will be continued. Selections will be tested in Thailand and the Philippines and further crossing will be performed to incorporate greater overall resistance through multiple mechanisms and improved agronomic performance.

3. Molecular genetic studies: Genetic transformation for resistance to tomato spotted wilt virus (TSWV) will be performed by Dr. A. Weissinger. The first two steps (isolation of required viral capsid genes and development of a reliable transformation protocol for peanut) will be conducted in the laboratory. Greenhouse and field screening will then be performed through a coordinated effort between breeding and plant pathology (M. K. Beute). Advanced material will be sent to Thailand, the Philippines, and India (ICRISAT) for further screening.

B. Plant pathology:

1. Leafspot pathogens

(a) Investigation will focus on efforts to increase levels of Cercosporidium personatum and Cercospora arachidicola resistance in agronomically superior genotypes. Techniques need to be improved (domestically, foreign testing) to ensure adequate

levels of resistance to both leafspot pathogens irrespective of environments occurring during testing.

(b) Efforts will be increased to characterize the current pathogenic variability in both pathogens. Potential for selection of "super" pathogenicity strains of each pathogen will be evaluated on the basis of the best host resistance currently available.

(c) Studies will be initiated to compare the effectiveness of genetic resistance factors which have become available through cultivated x wild Arachis crosses. Both stability (variable environments) and durability (pathogen variability) factors will be evaluated over subsequent years.

2. Stem and root rot pathogens

(a) Field tests will be initiated to identify additional germplasm which has potential to contribute to increased levels of (currently recognized) mechanisms of resistance, as well as providing additional resistance factors (Sclerotium blight, Sclerotinia blight, Cylindrocladium root rot).

(b) Tests will be done to verify the contribution of both metabolic resistance and plant phenology (morphological traits) in diverse environments and geographic locations (Sclerotium rolfsii, Sclerotinia minor). Potential selection for increased pathogenicity of locally occurring pathogen strains will be examined in context of resistance mechanisms being employed in problematic sites.

(c) Increased emphasis will be placed on performance and "ecological consequences" of utilizing genotypes containing multiple pathogen resistance. The role of partial resistance toward endoparasitic nematodes in the variable effectiveness of responses (physiologically) to root and stem pathogens of peanut will be examined.

3. Resistance to Aspergillus sp. and aflatoxin accumulation

(a) Additional research is planned to elucidate the heritability of preharvest infection, postharvest (dry seed) and toxin-formation "types" of resistant factors in peanut. The goal of this initiative is to develop a superior peanut genotype containing adequate levels of all three resistances that can be utilized by domestic and foreign collaborators and serve as a parent for further cultivar development.

(b) The role of abiotic (temperature, moisture, etc.) and biotic (disease severity, insects, nematodes, etc.) on stability of the three types of resistances, alone or in combination, must be determined. Breeding priorities will be

developed based on the complexity of interactions (negative, positive) which are discovered.

(c) Molecular phenomena involved in induction of toxin metabolytes by the pathogen will be studied using physiological and biotechnology (genetic) techniques. Procedures used currently in aflatoxin studies on corn will be modified to study peanut problems. Role of environmental stress (high temperature, low moisture) as it affects the pathogen directly, as well as stress metabolytes (host molecules) produced by plants are implicated in stimulating aflatoxin production by the fungus. Potential to alter the host pathogen interaction (for disease control) may be possible through plant breeding for stress resistance when metabolic systems are understood more completely.

4. Nematode resistance

(a) Studies have been initiated to quantify the level of available resistance to root knot nematodes in our root rot breeding program. Results of recent studies indicate that some genotypes inhibit reproductive abilities of both M. hapla and M. arenaria species. Also, certain genotypes do not appear to respond physiologically to nematode infection; resistance to soilborne fungal pathogens is not altered.

(b) Complex hybrids between wild Arachis sp. x cultivated peanut have been made wherein the parent species are reported to possess high levels of resistance or immunity to both M. hapla and M. arenaria. Studies have been initiated to determine whether resistance factors can be transmitted to progeny at adequate levels during backcrossing which is necessary to improve agronomic characteristics of peanut. Understanding the genetics of this resistance is essential to improve breeding strategies.

5. Virus resistance

(a) Concern about TSWV in peanut is increasing throughout the world. Studies have been initiated to elucidate the serious problems in the serological and molecular characterization of the pathogen. Host specificity of pathogen strains may occur both domestically and in foreign countries. Fundamental understanding of the biology of disease is essential to breeding and management strategies.

(b) Efforts have been initiated to incorporate viral capsid- protein genes into peanut. If this effort succeeds, extensive epidemiological research is necessary to determine the potential for using "cross protection" mechanisms of resistance (similar to that being utilized in solanaceous crops for TMV) for management of TSWV epidemics of peanut with transgenic plants.

C. Cytogenetics:

1. Characterization of Arachis germplasm

(a) Arachis species are continuing to be collected in South America and distributed to research institutions. As new germplasm becomes available for investigation, it will be initially analyzed for ploidy level, evaluated morphologically for sectional identification and seeds increased for additional evaluations.

(b) Genomic characterization of section Arachis species has been an on-going project and will continue as long as new taxa are being introduced from South America. Genotypes will be crossed with A, B and D genome testers and the F_1 hybrids cytologically analyzed to determine meiotic chromosome relationships. Unique taxa will also be crossed with the cultivated peanut to establish base populations for exploiting useful traits and to identify potential barriers to utilizing germplasm sources.

(c) Because few markers are available for genetic studies or as aids in breeding programs to select desirable genotypes, at least 20 different isozymes will be evaluated for polymorphism in the species of Arachis. More than 100 accessions plus cultivated types will be used to identify intra- and interspecific variation. Species-specific markers will then be used to identify recombinational products of interspecific hybrids. Linkage relationships between isozymes and disease and insect resistances will then be investigated.

(d) Protocols for analyzing seed storage proteins have been determined and techniques will be applied to accessions of section Arachis to evaluate variation among and within species. Protein banding patterns have been associated with blanching characteristics, and the inheritance of individual protein bands will be determined. In addition to biosystematic analyses, attempts will be made to associate unique bands with other agronomic traits which will aid in the identification of interspecific hybridization products and selection for desirable genotypes in peanut breeding projects.

(e) Advanced generation interspecific hybrids will be evaluated for leafspot, nematode, and TSWV resistances. Selections are already available for early and late leafspot resistances, but most are with poor agronomic quality. Efforts are thus needed to increase productivity. Resistant genotypes will be used in crossing programs with commercially acceptable cultivars with the objective of producing large seeded types with high yields. Evaluations of advanced generation interspecific hybrid plants will be made for nematode and TSWV resistances. The inheritance of these resistances will then be determined so that the germplasm can be used for cultivar development.

2. Introgressing germplasm from Arachis species to A. hypogaea

(a) Interspecific hybrids have been made between approximately 20 species of section Arachis and the cultivated peanut. Fertility has been restored at the hexaploid level for most of the hybrid combinations and generations are being increased to enhance recombination to the A. hypogaea genome. After selfing for at least five generations, the interspecific hybrids will be backcrossed to A. hypogaea to reduce the ploidy level to 2n = 40. Progenies can then be used in breeding programs for increased yield and improved quality.

(b) Most attempted interspecific hybrids in Arachis fail to produce hybrids because embryos abort or hybrids are weak and die. Studies will thus be made to determine both the timing and mechanisms of incompatibilities, especially between A. hypogaea and diploid members of section Arachis. Data thus far indicate that abortion may occur at different times, depending on the specific cross combination, from a few days after pollination to more than 30 days later. Future experiments will concentrate on taxa which should hybridize based on known genomic relationships, but which have been difficult or impossible to obtain. Results from the investigations will allow logical programs to be developed to introgress useful germplasm to the cultivated species.

(c) Environmentally adapted elite germplasm lines have been widely used for many crop species as the primary resources for cultivar improvement. Selections from an A. hypogaea x A. cardenasii cross are high yielding and agronomically acceptable, but have slightly lower economic value than recently released cultivars. A crossing program will be conducted to induce recombination among these unique elite germplasm lines to select for increased yields and quality characteristics. Progenies will then be hybridized with cultivars to introduce useful agronomic qualities for increased production.

3. In vitro culture

(a) Most potential interspecific hybrids abort within 6 days after pollination when the embryos are very small and undifferentiated. Young reproductive tissues of A. hypogaea will be used in experiments to develop a better understanding of the mechanisms controlling embryo growth and differentiation in peanuts. Experiments will concentrate on answering specific questions concerning the effects ethylene, light, cytokinins, gibberellins and auxins have on the peanut embryo. Information will then be used to develop protocols for rescuing interspecific hybrids.

(b) Peanut embryos excised from the parental tissues

at 1 to 2 days after pollination have been cultured in vitro and growth has been induced from single cells to globular embryos. However, differentiation beyond the globular stage is extremely rare and nonrepeatable. Methods will be investigated to stimulate cell differentiation in vitro. Techniques will then be applied to obtain interspecific hybrids from otherwise incompatible hybrid combinations.

(c) Because initiation of rooting on peanut tissues is a major obstacle to recovering interspecific hybrids, experiments will be conducted to increase the frequency of roots on explants and callus. The effects of cytokinins and auxins will be determined on numerous A. hypogaea genotypes to obtain optimal levels of root initiation and growth. Results will then be applied to recovering interspecific hybrid plants.

TRAINING PLANS PROPOSED:

One PhD candidate involved with fungal pathology will be identified from Thailand and one PhD student in breeding and/or plant pathology may be identified for training in the United States. Support will be provided to Master's level students trained in host countries. These are needed due to the high turnover in positions brought about in part to low wages.

Short-term post-doctorate training at ICRISAT of personnel from host countries (Jogloy, Montein from Thailand) would enhance the collaborative nature of the project with ICRISAT. Other in-country short-term training and conferences among staff of Thailand and the Philippines will help pool resources and add to efficiency of projects.

BENEFITS EXPECTED:

<u>In host country</u>: Productivity increases through improved cultivars and increased acreage resulting from identification of new cultivars to specific cropping systems will allow for an increased market and new peanut products in the country. Human nutrition should be improved in poverty areas of rice- based agricultural areas of Thailand and the Philippines. With increased resistance to pests, yields will increase, input costs will decrease, and the environment will be less polluted with agricultural chemical residue.

<u>In United States</u>: Peanut cultivars are needed by farmers that have increased resistance to CBR and leafspot to increase yields, reduce input costs, and improve quality of peanuts. Larger seeded cultivars will accommodate the current market demands and early maturity will reduce risk of late season frost damage. Improved quality and reduced contamination will ensure market acceptance and increase potential for exports.

ORGANIZATION/PERSONNEL:

Philippines

Institute of Plant Breeding (IPB):

Dr. Ricardo Lantican, Coordinator of Project
Dr. Remedios Abilay, Senior Breeder
Dr. Lina Ilag, Senior Pathologist
Ms. Araceli Pua, Pathologist
Dr. Ocampo, Entomologist
Dr. Henry Samonte, Soil Scientist

Isabela State University:

Dr. Rustico Santos, Agronomist

Cagayan State University:

Mr. Silvino Tejada, Agronomist

Bureau Plant Industry, Tupi Experiment Station:

Ms. Delia Concepcion, Agronomist

Thailand

Department of Agriculture:

Dr. Vichitr Benjasil, Director, Field Crops Research Institute,
Coordinator
Dr. Montien Sompee, Director, Khon Kaen Field Crops Research Center,
Assistant Coordinator
Mrs. Somjintana Toomsan, Breeder
Mr. Surapong Charoenrath, Breeder
Mr. Anon Watayanont, Agronomist
Mr. Preecha Surin, Plant Pathologist
Mr. Voothisak Buthanu, Plant Pathologist
Mr. Sopone Kitisin, Plant Pathologist
Dr. Duangchai Choopunya, Plant Virologist
Mr. Samnao Phetchawee, Soil Scientist
Mr. Suwapan Ratanarat, Soil Scientist

Khon Kaen University:

Dr. Aran Patanothai, Breeder
Dr. Sanan Jogloy, Breeder
Dr. Banyong Toomsan, Microbiologist
Dr. Sopone Wongkaew, Plant Pathologist

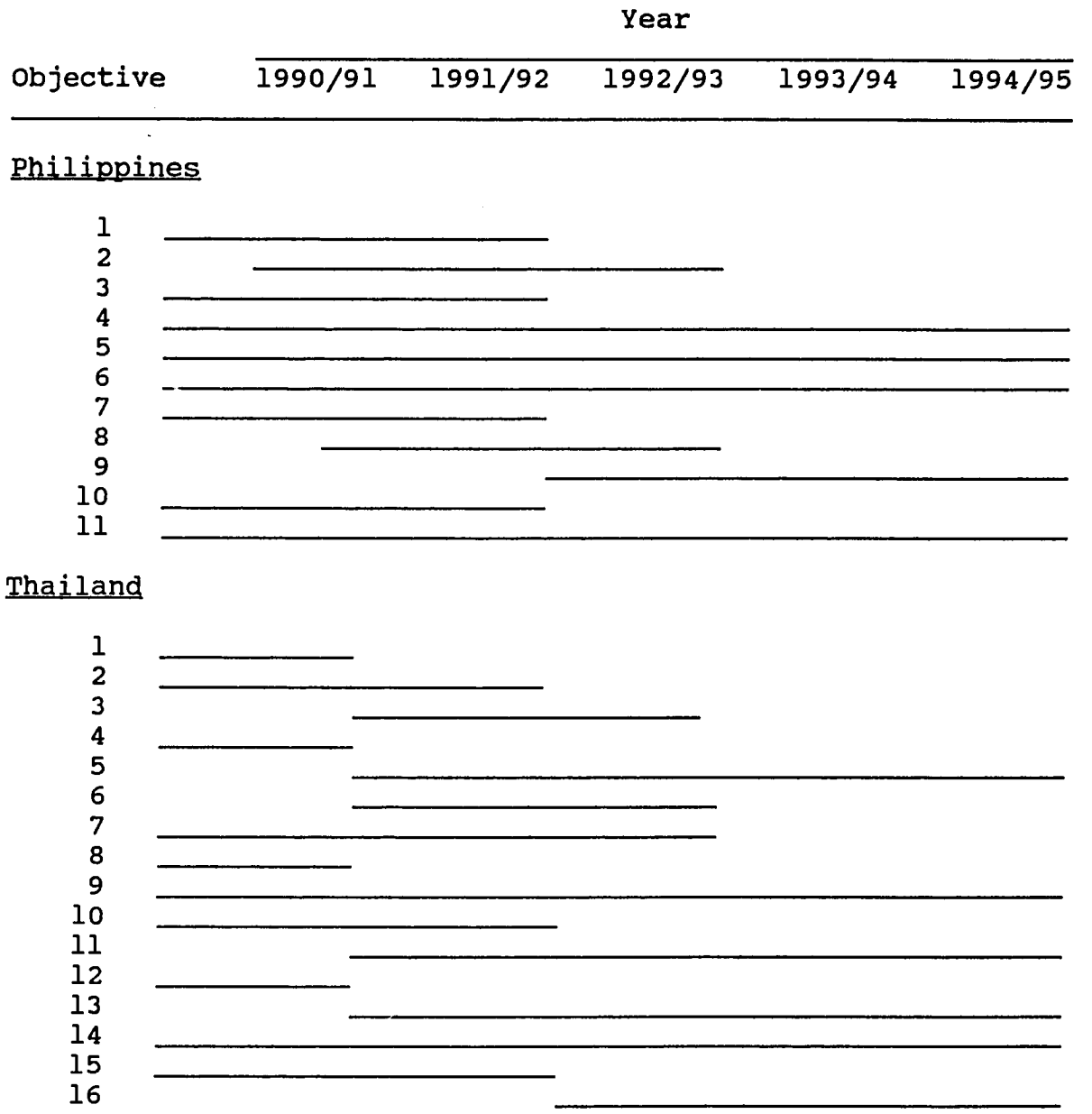
Kasetsart University:

Dr. Thammasak Sommartya, Plant Pathologist

North Carolina State University

Dr. Johnny C. Wynne, Dept. of Crop Science, Principal Investigator, Breeding
Dr. Marvin K. Beute, Dept. of Plant Pathology, Co-Principal Investigator, Plant Pathology
Dr. H. Thomas Stalker, Dept. of Crop Science, Co-Principal Investigator, Cytogenetics
Dr. W. F. Anderson, Dept. of Crop Science, Research Associate, Breeding
Dr. W. V. Campbell, Dept. of Entomology, Cooperator, Entomology
Dr. G. H. Elkan, Dept. of Microbiology, Cooperator, Nitrogen Fixation
Dr. Randy Wells, Dept. of Crop Science, Cooperator, Plant Physiology
Dr. A. Weissinger, Dept. of Crop Science, Cooperator, Molecular Biology
Dr. Barbara Shew, Dept. of Crop Science, Research Associate, Plant Pathology
Mr. Michael Fitzner, Dept. of Crop Science, Technician
Ms. Joyce Hollowell, Dept. of Plant Pathology, Technician
Ms. Tracy Jones, Dept. of Crop Science, Technician
Ms. Jerry Phillips, Dept. of Crop Science, Technician
Mr. Philip Rice, Dept. of Crop Science, Technician

TIMETABLE:


Year
Objective
1990/91
1991/92
1992/93
1993/94
1994/95
Philippines
1
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8
9
10
11
Thailand
1
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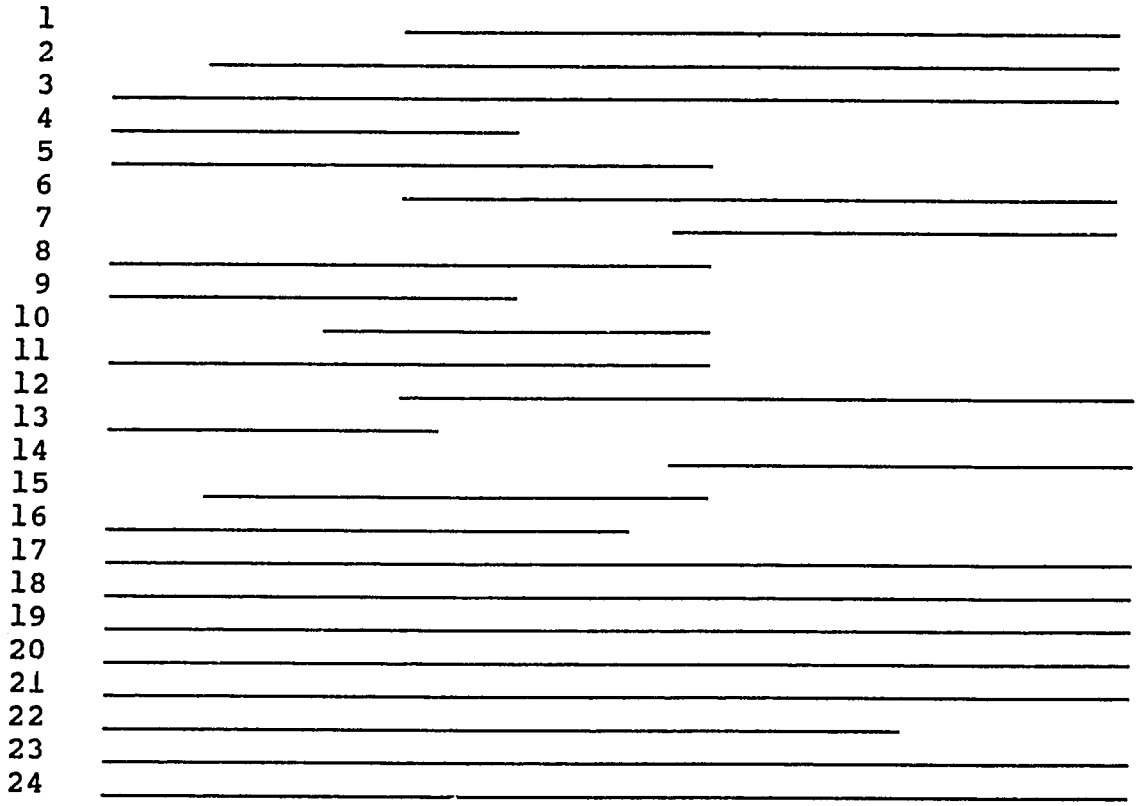
15
16

Year

Objective	1990/91	1991/92	1992/93	1993/94	1994/95

North Carolina State University:



JUSTIFICATION FOR OPTIMAL BUDGET

1. Maintain present activities at operational levels because of salary adjustments and inflation.

2. Train two additional PhD students from the host countries.

3. Allow for short-term training at ICRISAT of technical staff from host countries for disease screening techniques, environmental stress assessment and seed storage technologies.

4. Train personnel involved with seed multiplication and dissemination of newly released cultivars in the host countries. Greater efficiency is needed in Thailand and the Philippines for supplying seed to farmers.

5. Expand breeding and research involved with shade tolerance, acid tolerance, rust and leafspot resistance, and improved boiling-type peanuts in Thailand and the Philippines. These have been identified as priority traits.

6. Increase emphasis on breeding for A. flavus resistance via field screening techniques in Thailand. Field infection is an important source of aflatoxin contamination in peanut products.

7. Increase on-farm field trials using minimum inputs for the most promising lines in the host countries. Tests in Thailand would become country- wide.

8. Additional disease surveys of farmers' fields will be conducted in both Thailand and the Philippines to stay abreast of changes in yield constraints.

9. Intensify efforts in screening and advancement of CBR and aflatoxin resistance in the United States. These remain high priority diseases in North Carolina.

10. Expand isozyme research and seed storage protein analysis to aid in identification of factors responsible for peanut seed quality.

11. Intensify studies on effects of current accomplishments in disease resistance within lines developed in North Carolina. It is important to know the economic benefits of resistance to leafspot and CBR for determination of whether a cultivar release with these traits will be acceptable.

12. Travel of principal investigators and research personnel to international peanut conference at ICRISAT in 1991 to enhance understanding and communication within the P-CRSP and among linkage organizations.

13. Supply a consultant (Dr. S. Buol) concerning the soil survey work in Thailand. Dr. Buol is a member of the Tropical Soils CRSP with soil survey experience in Thailand and other S.E. Asian countries.

New Thrusts

A description of three proposals that were approved for funding under "new thrusts" follow.

Project Code: NCS/BCP/TP

Title: **Increasing Seed Viability and Quality in the Philippines and Thailand**

Introduction

Low germination of peanut grown in the field has been attributed to poor seed quality from improper curing and storage or from lack of tolerance to the environmental conditions at the time of planting. Inadequate seedling vigor has led to poor stands which have resulted in inadequate seed stocks of newly released varieties for distribution in the Philippines and Thailand. Thus, more accurate tests are needed to evaluate overall seed quality and then to estimate field performance. To be competitive in the market place, good quality characteristics are essential. Because the seed is largely comprised of oil and protein, favorable profiles are essential to assure superior products. Further, specific proteins may be useful as indicators of injury or viability. The goal of this project is to eliminate mediocre seeds which result in low viability, poor seedling emergence and inferior marketable products. Improving seed quality will have significant positive impacts on the peanut industry at all production, processing and marketing levels.

Objectives

1. Identify the problems associated with low seed viability and emergence.

2. Develop appropriate curing, storage, and planting techniques to avoid mechanical damage of seeds.

3. Develop laboratory tests to predict field emergence.

4. Initiate breeding efforts to improve seed vigor by evaluating storage proteins as indicators of viability and vigor.

Research Plans

A survey of the seed industry will be coordinated by seed specialists at NCSU to evaluate specific needs for improving seed quality. Physiological aspects of low germination and emergence

will be investigated and procedures to conduct germination tests on a routine basis will be established. Tests such as the accelerated aging, cool germination, and seedling growth rate will be used to evaluate peanut seed vigor. Training at ICRISAT in seed processing techniques will be made available. Laboratory tests will be developed to predict field emergence and breeding lines will be evaluated to improve cultivars. Seed proteins of peanut varieties will be analyzed electrophoretically to identify variability. Storage and injury experiments will be conducted to evaluate changes in seed protein banding patterns over time.

Added Personnel

Drs. Janet Ferguson and Robert Keys, both specialists in seed technology, will be added as cooperators to the project. Students will also be identified for training in seed storage and quality processes.

Seed Viability and Quality

Budget

NCSU	1990/91	1991/92	1992/93	1993/94	1994/95
Personnel: Wages	0	0	0	0	0
Graduate student & part-time labor	13,000	13,000	13,000	13,000	13,000
Travel	0	0	0	0	0
Materials & Supplies	3,000	3,000	3,000	3,000	3,000
Total Direct	16,000	16,000	16,000	16,000	16,000
Indirect costs (25.5%)	4,080	4,080	4,080	4,080	4,080
TOTAL NCSU	20,080	20,080	20,080	20,080	20,080
Host Country					
Personnel: Wages	9,000	9,000	9,000	9,000	9,000
Graduate student	10,000	10,000	10,000	10,000	10,000
Travel (foreign)	4,000	4,000	4,000	4,000	4,000
Materials & supplies	1,920	1,920	1,920	1,920	1,920
TOTAL	24,920	24,920	24,920	24,920	24,920
Overall Total	45,000	45,000	45,000	45,000	45,000

Timetable

A survey of the seed industry will be conducted the first year along with identification of graduate students for advanced training. Seed evaluations will be initiated and continued throughout the funding period. Technical personnel will be trained at ICRISAT during year 2. By the third year a seed testing facility will be in place and NCSU personnel will visit the host country. The usefulness of seed proteins will be determined in years 1 and 2 and applications made to seed quality during years 3-5.

Project Code: NCS/BCP/TP

Title: **Interspecific Hybridization and Transfer of Desirable Germplasm into the A. hypogaea Genome**

Introduction

Introgressing genes to cultivated peanuts from Arachis species which condition disease and insect resistances will significantly increase production at a reduced cost. However, genetic transfers are nearly impossible for most species, and introgression is difficult even for "compatible" crosses because of hybrid sterility, difficulties in manipulating ploidy levels, and problems in obtaining crossing-over between the cultivated and wild species genomes. The probability of incorporating foreign chromatin into A. hypogaea is unknown at any particular ploidy level or during any hybrid generation. The goal of the proposed research is to utilize genetic markers to enhance germplasm introgression to the cultivated species and at the same time utilize two Arachis species which together have very high levels of disease and insect resistances for problems common to both the Philippines and the USA. Contacts prior to CRSP budget reductions established the potential for cooperative cytogenetic and interspecific hybridization research. This proposal will establish a viable linkage between the cytogenetics prorams in the Philippines and NCSU and produce valuable genetic resources.

Objective

The objective of this proposal is to analyze interspecific hybrid populations cytologically and with molecular markers to (1) better understand the cytological relationships among cultivated and wild Arachis species, (2) determine the most efficient pathway for germplasm introression from Arachis species to the cultivated peanut and (3) utilize two species with high levels of disease (Cercospora arachidicola, Cercosporidium personatum, peanut rust) and insect (thrips, corn earworm, potato leafhopper and nematode) resistances for cultivar improvement.

Research Plan

Interspecific hybrids will be made between A. hypogaea (A-B genomes) and the diploid species A. stenosperma (A genome) and A. batizocoi (B genome) by: (1) directly hybridizing the diploids with A. hypogaea, (2) producing autotetraploids before making interspecific hybrids and (3) by producing amphiploids between the diploids and then producing crosses. After restoring fertility, plants will be selfed and backcrossed to A. hypogaea during successive generations and then analyzed for disease resistances, cytological relationships and for profiles of amino acids and seed storage proteins using electrophoretic techniques. Analyses will indicate linkages, the relative amounts of introgression, estimate the most efficient pathway for incorporating resistance genes to cultivated peanuts and produce progenies with multiple resistance.

Interspecific Hybridization (page 2)

Added Personnel

Dr. R. Barba previously expressed an interest in cooperative research and contacts will initially be made to establish him as a cooperator. Students at both locations will be involved in the research program.

Budget

NCSU	1991/92	1992/93	1993/94	1994/95	1995/96
Personnel: Wages	0	0	0	0	0
Graduate student & part-time help	11,000	11,000	11,000	11,000	11,000
Travel	0	0	0	0	0
Materials &	2,000	2,000	2,000	2,000	2,000
Total Direct	13,000	13,000	13,000	13,000	13,000
Indirect Costs (25.5%)	3,315	3,315	3,315	3,315	3,315
Total NCSU	16,315	16,315	16,315	16,315	16,315
Host Country					
Personnel: Wages	9,685	9,685	9,685	9,685	9,685
Travel	0	0	0	0	0
Materials & supplies	2,000	2,000	2,000	2,000	2,000
Total Host Country	11,685	11,685	11,685	11,685	11,685
TOTAL BUDGET	28,000	28,000	28,000	28,000	28,000

Timetable

Interspecific hybrids and backcrosses will be made during each year of the grant. Linkages of disease and insect resistances with seed storage proteins and isozymes will be evaluated during the first 2 years and interspecific hybrids analyzed during years 3 to 5. Resistant genotypes will be selected by the fifth year of the proposal.

Project Code: NCS/BCP/TP

Title: **Molecular Approaches to Study the Regulation of Aflatoxin Biosynthesis in Aspergillus flavus**

Introduction

The overall goal of this research project is to clone genes coding for aflatoxin and to determine the factors that regulate its biosynthesis which could ultimately lead to genetic transformation of genes able to block aflatoxin production. Although intermediates in the aflatoxin pathway are known, little is known about the regulation of biosynthesis. The ability to clone genes for aflatoxin biosynthesis through techniques of molecular biology provides a new approach for studying pathway regulation. For example, a cloned gene can be used as a probe to monitor changes in levels of gene-specific mRNAs and thus provide a direct measure of gene expression. This technique provides a way to study regulation of the pathway without isolation of pathway enzymes. This technique also allows the expression of specific genes to be measured directly; therefore, one can study the effects of compounds and culture conditions on the aflatoxin pathway without interference from other pathways.

The objectives outlined in this project are aimed at developing a better understanding of the factors that regulate aflatoxin biosynthesis in the fungus and will permit us to identify compounds that are either stimulatory of inhibitory to biosynthesis. The research approach will allow us to examine the effect of plant products and other potentially inhibitory compounds on the regulation of aflatoxin biosynthesis. Such information may lead to efficient selection of resistant genotypes and to the identification of genes that can be expressed in plants to totally block aflatoxin production.

Objective

1. To isolate and clone genes involved in aflatoxin biosynthesis.

2. To determine and analyze the nucleotide sequence of the aflatoxin genes.

3. To use these cloned genes to study factors that regulate aflatoxin biosynthesis.

Research Plan

We have developed a genetic transformation system for A. flavus that allows us to isolate genes by complementation for function. Twenty-five distinct aflatoxin-negative mutants will be transformed and selected for aflatoxin production. We will also construct a cDNA library using cascade hybridization and isolate genes by complementary DNA hybridization. Isolated genes will be

characterized and sequenced, and their sequence compared to the sequence of other genes for possible common gene function. Isolated genes (radioactively labeled) will also be used as probes to measure gene-specific mRNA isolated from cultures at various times and under several cultural conditions. This procedure will provide a direct measure of the effect of culture conditions and selected compounds on the biosynthetic pathway.

Added Personnel:

Dr. Gary A. Payne, Plant Pathology, NCSU

Budget (U.S.)	1991/92	1992/93	1993/94	1994/95	1995/96
Personnel: Wages research associate)	24,000	25,680	27,478	29,401	31,459
Fringe benefits (22.8%)	5,472	5,855	6,265	6,703	7,173
Travel	3,000	2,000	0	0	0
Materials & supplies	17,000	15,937	15,729	13,368	10,840
Total Direct	49,472	49,472	49,472	49,472	49,472
Indirect Costs (25.5%)	12,615	12,615	12,615	12,615	12,615
Total	62,087	62,087	62,087	62,087	62,087

Timetable

The genes will be isolated and cloned during the first three years. Analysis of nucleotide sequence regulation studies will be conducted after the second year. Travel in the first two years will allow for conferences to gain knowledge in techniques.

Project Code: GA/IM/BF

Project Title: IPM Strategies for Peanut Insects in SAT Africa

University of Georgia-University of Ouagadougou

Principal Investigators: R. E. Lynch, Principal Investigator, UGA

INTRODUCTION

Food production in the developing nations, especially those of Semi-Arid Tropical (SAT) Africa, fluctuates widely from year to year. These fluctuations in crop productions have resulted in subsistence farming and inadequate food supplies. Thus, stability in crop production has been designated the priority need for SAT Africa. SAT Africa has vast areas of arable land suitable for increased crop production. However, to attain this goal for stable food production, improved cropping procedures, better crop varieties, and improved methods for control of insects and diseases are needed.

Arthropod pests in developing nations have been estimated to reduce or destroy over 30 percent of the food production. Recent reviews by Amin and Mohammad (1980), Wightman (1985), and Lynch et al. (1986) have identified the major arthropod pests of groundnut in SAT Africa. These include the groundnut aphis (*Aphis craccivora* Koch), jassids (*Empoasca dolichi* Paoli and *E. facialis* Stal.), a termite (*Microtermes thoracialis* Sjostedt), an armyworm (*Spodoptera littoralis* (Boisduval), the groundnut hopper (*Hilda patruelis* Stal.), the groundnut bruchid (*Caryedon serratus* (01.), the "Wang" (*Elasmlomus sordidus* (F.), and millipedes (*Peridontopyge* spp.). In developing nations, control measures for these important pests are essentially nonexistent or woefully inadequate to prevent serious losses when outbreaks occur. Of equal importance to the direct losses due to arthropods are the plant pathogens that these pests often transmit. Rosette is transmitted by *A. craccivora* and is credited for the enormous loss in production in SAT Africa in 1975 (Gibbons 1977). Similarly, termite damage to groundnut pods not only reduces yeield by up to 50 percent (Feakin 1973; Johnson et al. 1981; Sudhakar and Veeresh 1985) but enhances invasion of pods by *Aspergillus flavus* (Link) and formation of aflatoxin in kernels (McDonald and Harkness 1963, 1964; McDonald et al. 1964; McDonald 1969; pollet and Decleret 1987; Lynch et al. 1989). The importance of aflatoxin contamination of a major protein source, groundnuts, for the people of SAT Africa may supercede the importance of direct food losses since aflatoxin has been associated with liver cancer in both man and his livestock.

The realization of the goal for stabilized food production in SAT Africa will require coordinated, interdisciplinary research in plant breeding, agronomy, entomology, plant pathology, and food science. The research must develop alternatives that will fit

within the socio-economic frame for the developing nations. In entomology, host-plant resistance to insects, insect damage, and/or aflatoxin along with cultural methods and indigenous products for control of insect pests fit within these guidelines. They are also major components for sustainable agriculture since they have no deleterious effects on food, soil, groundwater, and human or animal health. Prior research by scientists participating in the Peanut CRSP programs has developed an understanding of the problems associated with groundnut production in SAT Africa and an insight into means to alleviate these production constraints. Additional interdisciplinary research will provide accelerated progress in reaching the goal for stabilized and/or improved food production for SAT Africa.

MAJOR ACCOMPLISHMENTS:

Burkina Faso:

The initial objectives of the entomology program in Burkina Faso were to identify the major arthropod pests throughout the major growing regions, determine their abundance in relation to groundnut developmental phenology, determine the amount of yield loss caused from damage by these insects, and determine the relationship between level and type of arthropod damage with aflatoxin contamination in groundnut. With an extension of the project, groundnut cultivars from ICRISAT-India with resistance to termites were evaluated in Burkina Faso, and neem, an indigenous tree in much of Africa and Asia with known insecticidal properties, was evaluated for insect control.

The major arthropod pests and phenological stage of groundnut when most susceptible to damage were identified (Lynch et al. 1986). Termites, millipedes, groundnut aphids, jassids, and thrips are potential economic threats to stability of groundnut production in Burkina Faso. Populations of these insects tend to reach extremely high numbers during critical growth stages of groundnut, i.e., during pod fill, throughout most of the groundnut growing regions in Burkina Faso. Resistance to other species of these insects has been identified (see Lynch 1989 for a review of resistance in groundnut to insects), but the germplasm has not been evaluated against the species most threatening to groundnut production in West Africa.

The most serious potential pests in West Africa are the groundnut aphid and termites. Aphids transmit rosette, which can devastate groundnut yield when infection is initiated early in the development of groundnut. Infection appears to occur first in the southern part of Burkina Faso, the major groundnut growing area, and then spread to other groundnut producing areas in the country. Resistance to the virus has been identified (see Lynch 1989 for a review) in several cultivars such as RMP 12, RMP 91, KH-149 A, KH-241 D, and RG 1. Resistance to rosette infection or to feeding by

aphids is the most promising avenue for reducing losses to this insect/virus.

Termite damage tends to occur during the latter portion of the growing season when soil moisture is low. Groundnut is more drought tolerant than most crop plants, and during periods of inadequate soil moisture, groundnut plants and especially pods are both attrative and susceptible to feeding by termites. This problem tends to be aggravated by lack of rainfall during both the planting and harvest of groundnut. When inadequate rainfall occurs early in the season, groundnut planting is delayed until adequate moisture is available for seed germination and plant establishment. Delayed planting requires that farmers allow the plants to remain in the field as long as possible for pod maturity. Likewise, normal planting with an early cessation of rain results in the same type of problem; farmers do not know exactly when the rains are finished and allow the groundnuts to remain in the field in an attempt to optimize maturity. However, Lynch et al. (1989) determined that only two weeks past optimum harvest are required to increase termite damage to groundnut pods by 50 percent.

Termite damage to groundnut pods, along with drought that often occurs during the latter part of the growing season, has been identified as one of the major causes of A. flavus invasion of pods and aflatoxin formation in kernels (Lynch et al. 1989 and unpublished data). Groundnuts harvested at 70, 90, or 110 days had minimal termite damage on pods and little or no aflatoxin. Delayed harvest to 125 days, however, resulted in almost 60 percent damage to groundnut pods (55.2 percent pod scarification and 4.6 percent pod penetration), 27 percent kernel infection with A. flavus, and a 14.6 X increase in the aflatoxin level in kernels (Lynch 1988).

Yield losses to insects in Burkina Faso have been estimated by comparing yield when insects were not controlled with yield when insecticides were used to control certain types of insects. Over aa 4-year period, yield losses have ranged from 10.1 to 30.1 percent and averaged ca. 20 percent. No one group of insects was responsible for the yield loss. Control of early-season insects such as thrips and jassids increased yield by an average of 7.9 percent, while control of mid-to-late-season soil insects such as termites increased yield by an average of 9.0 percent. However, season-long control of both foliar and soil insects increased yield by an average of 20.7 percent.

Preliminary research with neem seed, kernels, and leaves has been conducted to determine activity, especially against soil insects. Neem leaves and seed were ground into a fine powder, mixed with corncob granules, and applied over the row with a granular applicator. To dat, only minor insecticidal activity has been observed, but the research is continuing with increased dosages. Unpublished research from the Southern Regional Research Center in New Orleans has also indicated possible activity of neem

in the inhibition of A. flavus growth and/or aflatoxin formation.

Eleven groundnut cultivars with resistance to termites in India were evaluated in Burkina Faso. Two harvest dates, normal harvest and delayed harvest, were used to enhance termite damage. On the most susceptible cultivar, termite damage increased from 17.6 percent to 49 percent with a two-week delay in harvest. Several of the termite-resistance cultivars showed reduced termite damage even under delayed harvest.

Georgia

Peanut stripe virus (PStV) was introduced into the U.S. in peanut seed from the People's Republic of China and was detected in germplasm being grown on experiment stations in 1982. The virus is a potyvirus transmitted by aphids and by seed. Prelininary research in the greenhouse on the effects of this virus indicated a 20 percent yield loss and an amount of seed transmission of up to 37 percent. Restrictions were placed on the exchange of germplasm among plant breeders, and several research plots infected with the virus were destroyed in an attempt to prevent the spread of the virus into commercial peanut fields.

Research to determine the influence of PStV on yield, quality, and seed transmission of 'Florunner' grown in the field was conducted in 1985 and 1986 (Lynch et al.1988). In 1985, plants were grown inside screened cages and artificially inoculated with PStV at 20, 40, or 60 days after plant emergence. Uninfected controls included an uninoculated control grown inside the cages and an uninfected control grown without the cage. Infection was monitored by ELISA analysis of leaf samples collected every 20 days throughout the growing season. No significant differences were noted in orthogonal comparisons between the inoculation treatments and the uninoculated, caged control for plant weight, pod weight, top weight, root weight, seed weight, number of seed, or yield. However, shading reduced peanut yield by 27 percent, and an interaction between shading and maximum expression of the virus could not be ruled out.

In 1986, the experiment was conducted both with and without the screened cages utilizing the same treatments. As in the previous year, few meaningful differences were detected between inoculated and uninoculated treatments grown under the same environmental conditions. In both tests, seed transmission averaged less than 5 percent regardless of the plant age at inoculation. Thus, PStV had minimal detrimental effect on yield or quality of 'Florunner' peanut. As a result of this research, restrictions by many peanut-growing states on exchange of germplasm were rescinded.

Laboratory research on the lesser cornstalk borer (LCB), one of the most important soil insect pests, indicated that larvae were

an excellent vector for A. flavus and preferred to feed on peanut pods in stages 1-3 of development. Older pods, pods in which the mesocarp had developed structural rigidity, were often skeletonized, but were not penetrated. Field research indicated that kernels from pods penetrated by LCB larvae contained significantly more aflatoxin than did kernels from undamaged or externally damaged pods. Kernels from externally damaged pods had higher levels of A. flavus infection than did kernels from undamaged pods, but there were no differences in aflatoxin levels.

The ability to rear insects is important to a research program, both for laboratory and field tests. Research was conducted on the fall armyworm, Spodoptera frugiperda, to determine the most economical, efficacious diet for laboratory production. Major diet ingredients evaluated were pinto beans (the standard diet), peanut, peanut meal, soybean meal, bermudagrass pellets, and alfalfa pellets. Bermudagrass pellets, alfalfa pellets, and peanut meal were suitable substitutes for pinto beans in the meridic diet for rearing the fall armyworm. Diets containing these ingredients promoted rapid larval weight gain and development, pupae of normal weight, excellent survival to adults, and excellent fecundity. Insects reared on raw peanut as a diet ingredient had reduced larval survival, and insects reared on soybean meal had reduced fecundity.

Training of Burkina Faso Personnel With GA/IM/BF

Name/Training	Status	Date/Description
	Degree Training in U.S.	
Idrissa Dicko Ph.D.	Completed degree in 1989 Co-PI	Seasonal Abundance of Selected Pest and Beneficial Insects in Relation to Peanut Phenology, Irrigation and Insecticides. Sept. 1985-July 1989 Peanut CRSP supported research at ca. $7,000/year
	Training by the University of Ouagadougou*	
Daguina Mahonte IDR3		2.5 month, 1984
O. Elie Dianda ITDR3		6 months, 1985
Jean Ngamine IDR3		2.5 months, 1987
Barce Kabore IDR3		2.5 months, 1988

Daouda Thiam IDR3/5	2.5 months, 1988
A. Florent Ngaroun ITDR3	6 months, 1986
Olle Frank Kam ITDR3	6 months, 1988

*Students at the University of Ouagadougou were trained in the GA/IM/BF project by assisting in the conduct of the research. Each wrote a paper from the research, presented it to his/her advissor at the university, and received credit toward the 3rd cycle degree for the research.

Short-Term Training

Albert Patoin Ouedraogo	Co-PI for GA/IM/BF	July 17-28, 1984 - Research review and planning, review research at the IBPMRL on peanut, attend the APRES annual meeting, and attend Peanut CRSP planning session. July 14-28, 1987 - Research review and planning, training in rating peanut for insect damage, and attend APRES annual meeting. August 21-26, 1985 - Participate in the Agrometeorology of Groundnut Symposium and discuss peanut research with other SAT colleagues at Niamey, Niger. Sept. 13-16, 1988 - Participate in the Groundnut Production in West Africa Symposium, attend Peanut CRSP planning session, and discuss research with SAT colleagues at Niamey.
Solibo Some	Co-PI in Burkina Faso	June 6-Sept. 4, 1984 - Conduct lab and field

		research on peanut. Research supported by the Peanut CRSP at a cost of ca. $3,000.
Phillip Sankara	PI TX/BCP/BF	July 14-28, 1987 - Review peanut research at the Coastal Plain Experiment Station. Attended APRES annual meeting and met with Dr. Olin Smith.

LINKAGES:

University of Ouagadougou, Institute Superion Polytechnique, ISN/IDR, Ouagadougou, Burkina Faso

Peanut CRSP Breeding Project (TX/BCP/S,BF,N), Texas A&M University, College Station, TX

Peanut CRSP Food Science Project (AAM/FT/S,BF), Alabama A&M University, Normal, AL

Peanut CRSP Peanut Virus Project (GA/PV/N,TP), University of Georgia, Griffin, GA

ICRISAT, International Center, Andhra Pradesh, India

ICRISAT, Sahelian Research Center, Niamey, Niger

Mycotoxin and Tobacco Laboratory, University of Georgia, Tifton, GA.

PRIORITY CONSTRAINTS TO BE ADDRESSED:

1. Low yields as a result of arthropod damage during the growing season.

2. Increased incidence of A. flavus infection and aflatoxin contamination as a result of termite damage to pods.

3. Rosette transmitted by A. craccivora which reduces yield.

GOAL:

Reduce losses due to arthropod damage, diseases transmitted by arthropods, and aflatoxin through development of resistant varieties and pest management procedures applicable to West Africa.

RATIONALE:

Under the present socio-economic conditions in West Africa, resistance in groundnut to arthropod damage, diseases, and

aflatoxin contamination, along with cultural procedures and indigenous products with insecticidal properties, offers the greatest potential for reducing losses. Research addressing these constraints has been initiated to: 1) evaluate germplasm from ICRISAT-India for termite resistance in Burkina Faso; 2) determine the effects of cultural practices on termite damage and subsequent aflatoxin contamination of groundnut; and 3) evaluate neem products for insecticidal properties.

OBJECTIVES:

Burkina Faso

Long Term:

1. Identify germplasm with resistance to termites, aflatoxin formation and/or rosette that can be utilized for development of breeding lines with insect and disease resistance with acceptable yield and quality for use in West Africa.

2. Identify the major mechanisms and interrelationships between termite damage to peanut pods, *A. flavus* invasion, and aflatoxin formation in kernels and develop cultural methods that will limit aflatoxin formation.

3. Develop integrated pest management strategies utilizing resistance to insects, cultural practices, and indigenous plant products with insecticidal activity to reduce peanut losses to arthropods.

Short Term:

1. Evaluate germplasm from ICRISAT with resistance to termites and aflatoxin for resistance in Burkina Faso. Cooperate with the Breeding CRSP in the evaluation of progeny from resistant lines.

2. Determine the influence of soil moisture on termite damage to groundnuts and subsequent aflatoxin formation, and develop cultural methods to reduce the extent of damage and contamination. Cooperate with the Food Science CRSP in the determination of the influence of these variables on nutritional quality and aflatoxin concentration.

3. Evaluate neem kernels for insecticidal activity against groundnut insects, *A. flavus* and aflatoxin.

4. Establish a screening program for identifying rosette resistance and assist breeders in screening germplasm.

5. Provide short-term training for host country scientists that will assist in their conduct of research.

Georgia

Long Term:

1. Evaluate germplasm from ICRISAT with resistance to termites and aflatoxin for resistance to soil insects.

2. Study the interrelationships between damage to peanut pods by soil insects, invasion by *A. flavus*, and aflatoxin formation.

3. Identify resistance in peanut to the major insects; i.e., thrips, leafhoppers, defoliating insects, and soil insects.

4. Provide germplasm with resistance to insects to peanut breeders and assist in the development of breeding lines with insect resistance.

Short Term:

1. Develop artificial infestation techniques to evaluate peanut against the lesser cornstalk borer, southern corn rootworm, and peanut wireworm.

2. Evaluate ICRISAT germplasm with resistance to termites for resistance to the lesser cornstalk borer, southern corn rootworm, and peanut wireworm.

3. Study the interrelationships between lesser cornstalk borer and rootworm damage to peanut pods with drought and aflatoxin formation utilizing rain shelters.

4. Evaluate peanut germplasm from ICRISAT, multiple insect resistant germplasm, and plant introductions for resistance/susceptibility to major peanut insects.

RESEARCH PLANS PROPOSED:

Germplasm with resistance to termites and aflatoxin has been obtained from ICRISAT or Texas A&M through Dr. Olin Smith and is presently being multiplied at Tifton to provide sufficient seed for evaluation in both Ouagadougou and Tifton. Research will be conducted in Burkina Faso to evaluate this germplasm using a delayed harvest to accentuate termite damage to pods. Data will be collected on plant damage, pod damage, and aflatoxin content (coordinated with Drs. Bharat Singh and Alfred Traore, Food Science CRSP). With a minimum of two years' research, lines with resistance will be provided to Dr. Olin Smith, Peanut Breeding

CRSP, for crossing with adapted germplasm. Progeny from these crosses will then be re-evaluated for resistance. Other lines developed by the Breeding CRSP will also be evaluated for resistance/susceptibility to major insects.

Research on the influence of groundnut harvest date and soil moisture on termite damage and aflatoxin formation will be continued to determine the interrelations between these variables. Groundnuts will be harvested at various intervals and soil moisture estimates will be taken along with data on extent of termite damage. Samples from these research plots will be analyzed for aflatoxin and provided to Dr. Alfred Traore for determination of food quality.

Crude preparations of neem kernels, comparable to those that can be prepared by farmers, will be prepared by grinding dried kernels into a fine powder, mixing with corncob granules, and applying the granules over the row for control of insects and/or aflatoxin. Concentrations will be increased 100 X over those used in previous research. Data will be collected on insect population levels, damage, yield and grade from treated and untreated plots with normal and delayed harvest. In cooperation with the Food Science CRSP, selective media will be used to determine the incidence of A. flavus contamination of hulls and kernels, and aflatoxin concentration.

Pending increases in the budget, techniques will be developed to maintain A. craccivora in the greenhouse on rosette-infected plants, similar to those used by ICRISAT-Malawi. Plants with aphids and infected with rosette can be increased in the greenhouse, transplanted to the field in plots with plants that will be evaluated for rosette resistance by the Breeding CRSP, and a disease epidemic will be initiated early in the growing season. This procedure will provide a more uniform infection and greatly expedite selection for resistance among crosses and segregating populations. This research will be in cooperation with Drs. Olin Smith, Phillip Sankara, and Jim Demski and will greatly expedite the development of improved groundnut lines with resistance to rosette.

The research in Burkina Faso is of such nature that extensive cooperation and coordination will be necessary between Peanut CRSP projects (GA/IM/BF; TX/BCP/S,BF,N; AAM/FT/S, BF; and GA/PV/N,TP). Groundnut lines with resistance to insects will be provided to Dr. Olin Smith of the Breeding CRSP for crossing with rosette resistance or more agronomically-acceptable lines, and the entomology project will assist in the evaluation of progeny for insect resistance. Likewise, interdisciplinary research involving the Entomology CRSP, Food Technology CRSP, and Peanut Virus CRSP will be utilized in research on aflatoxin and rosette. Close coordination will also be maintained with the ICRISAT Sahelian Center, Niamey, Niger, to share research findings, update

techniques, and initiate cooperative research.

Research is presently underway in Georgia to study the interrelations between insect damage and aflatoxin formation in kernels. 'Florunner' peanut was planted in small plots with an automated rain-out shelter. Two tests are being conducted, one with the lesser cornstalk borer and the other with the southern corn rootworm. During peak pod production, plots will be artificially infested with either lesser cornstalk borer larvae or rootworm eggs. At ca. 90 days, drought will be initiated in selected plots while others will be irrigated throughout the season. Data will be collected on percentage of undamaged, externally damaged, and penetrated pods, yield, grade, A. flavus contamination of hulls and pods, and aflatoxin content from control, drought, and insect-damaged drought plots.

Peanut germplasm with previously identified resistance to related species of insects will be evaluated in Georgia for insect resistance/susceptibility. Germplasm with resistance to thrips, jassids (leafhoppers), leaf miners, Heliothis, and Spodoptera has been obtained from ICRISAT, Thailand, Philippines, or North Carolina State University and are presently being seed increased. Several of these accessions have been reported to have multiple insect resistance. Identification of resistance, especially multiple pest-resistant lines, can then be used in a breeding program to reduce losses in the U.S.

Peanut germplasm will be evaluated for resistance/susceptibility to the peanut wireworm, Conoderus scissus. In cooperation with Dr. W. D. Branch, peanut breeder at Tifton, several lines with different pod characteristics will be evaluated by artificially applying wireworm larvae during peak pod production. Wireworms will be bait-trapped with germinating corn and wheat, and the wireworm larvae will be used to artificially increase populations in the test plots. Data will be collected on the percentage of undamaged, externally damaged, and penetrated pods, yield, and aflatoxin content for the various pod damage categories.

Crosses have been made between A. hypogaea x A. villosa, a line identified as resistant to the fall armyworm (Lynch et al. 1981), and F_1, and F_2 progeny will be evaluated in laboratory feeding assays for resistance to the fall armyworm. Plants will be grown in the field, and terminals and newly expanded leaves will be brought into the laboratory and fed to neonate fall armyworm larvae. Data will be collected on establishment, larval weight at 10 days, days to pupation, pupal weight, percent survival to pupation, days to adult emergence, and percentage survival to adults to identify progeny with resistance.

TRAINING

Training will be provided for host country researchers

periodically at the Insect Biology and Population Management Research Laboratory, Coastal Plain Experiment Station, Tifton, Georgia. Collaborators will observe and actually participate in the conduct of laboratory bioassays for resistance to insects and in-field evaluation of insect damage. Techniques for artificially rearing insects artificially infesting field plots with insects, rating individual plants or plots for insect damage, and determining yield and quality components for peanut grade will be demonstrated.

Training will also be provided to host country researchers and the U.S. principal investigator through a visit to ICRISAT facilities in Malawi to observe techniques for rearing Aphis craccivora and maintaining rosette infection in the greenhouse. This training will be necessary for the utilization and/or modification of techniques to rear Aphis craccivora in the greenhouse, transplant groundnuts infected with rosette and aphids in field plots, and screen for rosette resistance, in cooperation with the Peanut Breeding Project, in Burkina Faso.

Additional training at ICRISAT-India on techniques and methods used in the evaluation of peanut for resistance to insects, especially termite resistance to pod damage, would benefit host country scientists. Dr. P. W. Amin, Research Entomologist, in India has developed techniques to enhance damage by thrips, leafhoppers, and termites. These techniques have been used successfully in India to identify germplasm with resistance to insects. Observation and training on the use of these procedures would be very beneficial to both the principal investigator and host country collaborators.

BENEFITS EXPECTED:

Stabilized food production to support the population is the primary goal for West Africa. Important constraints to groundnut production include poorly adapted varieties with low yield potential, losses to insects and diseases, and aflatoxin contamination. Identification of germplasm and development of breeding lines with resistance to insects and aflatoxin, development of cultural methods and/or indigenous products with insecticidal properties to control or limit insect damage and aflatoxin formation will greatly aid in stabilizing agricultural production. In addition, training of scientists will probably be the most notable contribution, since they will remain in the country with greater expertise to address constraints.

Access to germplasm with resistance to insects and aflatoxin offers tremendous potential benefits to the U.S. peanut industry. This germplasm has been obtained primarily through contacts made while working in the Peanut CRSP program. Evaluation of this germplasm against U.S. insects will identify sources of resistance that can be used in U.S. breeding programs for the development of

insect-resistant cultivars, thus reducing losses to insects and reducing the quantity of insecticide used for their control. Probably as important is the intellectual stimulation of developing control measures that fit within the socio-economic conditions of a developing nation. This stimulation will carry over to research being conducted in the U.S.

ORGANIZATION/PERSONNEL:

Principal U.S. Investigator:	Dr. Robert E. Lynch Insect Biology and Population Management Research Laboratory USDA/ARS/University of Georgia Tifton, GA
Technical Support, U.S.:	Mr. Jamie Day, Technician Department of Entomology University of Georgia, Tifton, GA
Principal Investigator: Burkina Faso	Dr. Albert Patoin Ouedraogo Entomologist, ISN/IDR, University of Ouagadougou, Ouagadougou, B.F.
Collaborating Scientists: Burkina Faso	Dr. Idrissa Dicko Entomologist, ISN/IDR, University of Ouagadougou, Ouagadougou, B.F. Dr. Solibo Some, Entomologist ISN/IDR, University of Ouagadougou Ouagadougou, B.F.
Technical Support: Burkina Faso	Mr. Mahonte Daguina, Technician Peanut CRSP Entomology Project University of Ouagadougou, B.F.
U.S. Cooperators:	Dr. Olin D. Smith (TX/BCP/S,BF,N) Plant Breeder Department of Soil and Crop Sciences Texas A&M University College Station, TX Dr. Bharat Singh (AAM/FT/S,BF) Food Scientist Department of Food Science Alabama A&M University Normal, AL
Cooperating Scientists: Burkina Faso	Dr. Phillip Sankara, Phytopathologist ISN/IDR, University of Ouagadougou Ouagadougou, B.F.

Dr. Alfred Traore, **Food Scientist**
ISN/IDR, University of Ouagadougou
Ouagadougou, B.F.

ICRISAT:

Dr. John Wightman, Entomologist
ICRISAT, Andhra Pradesh, India

Dr. P. W. Amin, Entomologist
ICRISAT, Andhra Pradesh, India

Dr. Maurice Lukefahr, Entomologist
ICRISAT, Sahelian Center
Niamey, Niger

Optimal Budget (Expanded)

JUSTIFICATION:

For the past several years, research in both Burkina Faso and the U.S. has been reduced due to budget cuts and increased operating costs. In particular, gasoline is so expensive in Burkina Faso that research in the southern part of the country had to be dropped due to excessive costs (525 CFA/liter; $1.00 = 300 CFA) and insufficient funds. Entomological problems tend to be more severe and occur earlier in Southern Burkina Faso. Therefore, research needs to be conducted in both major groundnut growing regions.

ICRISAT-India has developed several techniques for enhancing infestation levels of insects that are applicable to the resistance program in Burkina Faso. Training at the ICRISAT Center for host country scientist would be provided with an increase in funding.

Previously, groundnut samples for aflatoxin analysis have been shipped from Burkina Faso to the U.S. for analysis. This process is not only very expensive (>$3,000 for 1988 samples) but extremely slow. In addition, analysis in the U.S. fails to provide expertise for host country scientists. Several ELISA techniques are available for rapid determination of aflatoxin concentration at a relatively low cost. The increased funding will be used to purchase needed equipment and supplies (in cooperation with the Food Science CRSP) for host country analyses of aflatoxin.

For the last two years, entomological research in the U.S. to support the programs in Burkina Faso has experienced tremendous funding problems as a result of the budget cut, increased indirect costs, and inflation. Part of the new money would be used to alleviate these problems.

TIMETABLE:

Burkina Faso

Year during which activity will occur:

Short Term	1990/91	1991/92	1992/93	1993/94	1994/95
Objective 1	---------->				
Objective 2	---------->				
Objective 3	---------->				
Objective 4	---------->				
Objective 5	---------->				

Year during which activity will occur:

Long Term	1990/91	1991/92	1992/93	1993/94	1994/95
Objective 1	---------->				
Objective 2	---------->				
Objective 3	---------->				

Georgia

Year during which activity will occur:

Short Term	1990/91	1991/92	1992/93	1993/94	1994/95
Objective 1	---------->				
Objective 2	---------->				
Objective 3	---------->				
Objective 4	---------->				

Year during which activity will occur:

Long Term	1990/91	1991/92	1992/93	1993/94	1994/95
Objective 1	---------->				
Objective 2	---------->				
Objective 3	---------->				
Objective 4	---------->				

New Thrusts

Description for a proposal that was approved for funding in the "new thrusts" follow.

Project Code: GA/IM/BF

Title: Enhanced Research for Integrated Pest Management Emphasizing Millepede Problems and Aphid Vector for Rosette Virus.

Rosette is the most important viral disease of groundnut in West Africa. The 1975 epidemic of rosette in West Africa reduced groundnut yields by an estimated 60-75%. As a result, groundnut production, the primary cash crop for many West African countries, was devastated and hectarage planted to groundnut was greatly reduced in subsequent years. Even today, the quantity of land planted to groundnut in West Africa is far below that planted prior to the 1975 epidemic of rosette. Thus, the impact of this disease had and continues to have a tremendous impact on the economics of the developing nations and is one of the primary constraints for stability in food production.

Rosette is transmitted to groundnut by the **groundnut aphid**, Aphis craccivora. A. craccivora is polyphagous, with a marked preference for the Leguminosae. It is a known vector of over 30 viral diseases including both nonpersistent and persistent viruses, such as rosette. In Nigeria, both the aphid and virus are thought to overwinter during the dry season in alternated hosts along the coastal areas and/or adjacent to water reservoirs. Alate aphids (winged) are capable of migrating long distances and are easily carried by wind currents. Climatic conditions and the availability of suitable hosts seems to determine their abundance from year to year.

Rosette infected plants are noticed shortly after the arrival of alate aphids in the groundnut crop, an indication that aphids are infective before arriving. These adults that migrate to groundnut fields act as a nucleus for propagation of both the aphid and the virus. Aphids then reproduce parthogenetically on the groundnut plants and subsequent apterous (without wings) and alate aphids become infected and spread the disease to adjacent plants or to plants in uninfected fields.

Resistence to both the aphid and to rosette have been identified (see Lynch 1989 for a review). RMP 12, RMP 91, KH-149, KH-241 D, and RG 1 are resistant to rosette and have been used in breeding programs for West Africa. Resistance to the virus is recessive and is governed by two genes (Nigam 1987).

Techniques for rearing the aphid on groundnuts in the greenhouse and maintaining rosette-infected plants have been developed by

ICRISAT in Malawi. These techniques can be employed or modified to establish a groundnut screening program for rosette in Southern Burkina Faso in cooperation with the Breeding CRSP. Facilities would have to be constructed and equipped, and money would have to be provided for operation and travel. However, such facilities would greatly expedite the selection for resistance to rosette in segregating populations through rapid identification of resistant germplasm. In addition, the development of a rosette screening program would provide needed expertise to host country scientists.

Both rosette and A. craccivora are endemic to West Africa and occur every year in various locations. The extent and time of infection, however, depend on seasonal weather patterns, populations of alternate hosts for both the aphid and virus, and aphid migration. Thus, in many years, the extent of natural rosette infection in a given location is insufficient for dependable evaluation of groundnut germplasm for resistance to rosette. Artificial infestation in groundnut plots will provide a dependable source of both aphids and rosette. Since the disease is endemic and dependent on aphid migration for movement, artificial infestation in field plots would account for only a minute quantity of increased inoculum relative to that already present in nature. Furthermore, artificial inoculation in the field would not affect the general incidence of rosette; if conditions are favorable for spread of the virus, it will occur naturally from feral sources; if conditions are not favorable, the aphids and rosette will not spread from the area that was artificially infected.

Similar techniques have been used extensively in the U.S. over many years to artificially infest with insects without any discernible increase in natural populations of the insect pest. In all of these programs, artificial infestation techniques have been credited with increasing the incidence of insect damage, avoiding escapes and loss of research time due to inadequate natural insect populations, and greatly expediting research progress. The success of a screening program for groundnut rosette in West Africa will also be dependent on an adequate and dependent source of inoculum.

Millipedes were identified in the early phase of the project as a major insect problem. The damage can be detrimental to stand establishment due to attack on young seedlings. Constraints on budget has led to less emphasis on millipedes and more on termite and aphids. Extra funds will allow more attention to this important problem. IPM strategies are needed to enhance control measures for millipede. Work to be developed under this special proposal will aid in this development.

OBJECTIVES:

Therefore, the objectives of this proposal are to develop

facilities for rearing A. craccivora on rosette-infected groundnuts and to cooperate with the Breeding CRSP in the evaluation of segregating populations for rosette resistance through artificial infestation with rosette and aphids. The colony will also provide aphids and rosette for laboratory research and/or other field research on rosette. IPM strategies to control millipedes will be developed.

RESEARCH PLANS:

Facilities will be constructed in Southern Burkina Faso for maintaining A. craccivora on rosette-infected groundnuts throughout the year. The host country and U.S. Principal Investigators will visit ICRISAT-Malawi to observe techniques for rearing A. craccivora and rosette in the greenhouse and techniques to artificially infect plants in the field. Prior to field planting of research plots, plants will be increased in the greenhouse and infected with aphids and rosette. These infected plants will then be transplanted into field plots shortly after groundnut emergence to provide a source of inoculum. The research will be coordinated with Drs. Sankara and Smith of the Breeding CRSP to determine the number of infected plants required for transplant and to establish rating procedures for rosette infection.

Field studies will be enhanced to develop cultural control including naturally occuring pesticides (neem) for control of millipede.

ADDED PERSONNEL:

Two technicians will be required in the host country to produce aphids, plants, and to develop rosette infection. Additional part-time labor will be required to assist during the growing season.

SHORT PROPOSAL #1

GA/IM/BF
SHORT PROPOSAL #1 BUDGET

PROPOSED BUDGET

UGA	1990/91	1991/92	1992/93	1993/94	1994/95
A. Salaries & Wages Technician Student workers	0	0	0	0	0
B. Fringe benefits Technician (32.0%) Students (7.51%)	0	0	0	0	0
C. Equipment	0	0	0	0	0
D. Supplies	0	0	0	0	0
E. Travel	8,000	5,000	4,000	4,000	4,000
F. Publications	0	0	0	0	0
G. Total (A-F)	$8,000	$5,000	$4,000	$4,000	$4,000
H. Indirect costs (32.5%)	2,880	1,800	1,400	1,400	1,400
I. Total (G+H)	$10,880	$ 6,800	$ 5,400	$ 5,400	$ 5,400

University of Ouagadougou	1990/91	1991/92	1992/93	1993/94	1994/95
A. Salaries & Wages	$ 2,000	$ 4,000	$ 8,000	$ 8,000	$ 8,000
B. Equipment	14,927	10,636	2,000	2,000	2,000
C. Supplies		6,000	11,909	11,909	11,909
D. Travel	5,500	5,000	5,000	5,000	5,000
E. Total (A-D)	21,927	25,636	26,909	26,909	26,909
F. Indirect costs (10.0%)	2,193	2,564	2,692	2,691	2,691
G. Total (E+F)	$ 24,120	$28,200	$29,600	$29,600	$29,600
GRAND TOTAL	**$ 35,000**	**$35,000**	**$35,000**	**$35,000**	**$35,000**

Project Code: NCS/IM/TP

Project Title: Management of Arthropods on Peanuts in Southeast Asia

William V. Campbell, Principal Investigator, NCSU

INTRODUCTION:

Insects and other arthropods cause direct losses and indirect losses by transmitting viruses to peanuts. Yields of peanut in the Philippines and Thailand may be reduced 40-60% by the complex of insects. To prevent this loss insects should be managed by environmentally safe, economical methods that are compatible with local farm management practices and existing pest management systems. Fortunately many of the same genera of insects occur in Thailand and the Philippines that occur in North Carolina. This permits standardization of sampling and damage evaluation for selected pests. Pilot pest management programs have been initiated in the Philippines and Thailand. These need to be refined with emphasis on the use of insect resistant germplasm, natural control agents and thresholds.

The Philippines

Ten major pests of peanuts were identified in surveys for insect abundance and their natural enemies. The complex of pests feed on the pods, stems and foliage. Tests to manage the pest complex have been located at the National Crop Protection Center at Los Banos, at Isabella State University in the Cagayon Valley, Quirino Provence and the island of Negros Oriental in the south.

Entomologists in the Peanut CRSP cooperate with the breeders at the Institute of Plant Breeding in evaluation of peanut genotypes for resistance to pests.

Natural control factors were investigated as a means of managing pests with non-chemical methods. The parasite *Trichogramma* spp. was found effective parasitizing eggs of the cutworm *Spodoptera litura* and the corn earworm *Heliothis armigera*. More virulent strains of *Bacillus thuringiensis* were selected and used against lepidopterous larvae. Nuclear polyhedrosis virus (NPV) reduced *S. litura* in the laboratory and field.

A diverse collection of 250 genotypes were tested at two locations during two growth cycles. The four tests identified genotypes with multiple insect resistance to thrips, leafhopper, defoliators and pod damage. This same experiment was planted in multiple locations in Thailand and North Carolina.

The cutworm Spodoptera litura is a major defoliator in Southeast Asia. Peanut CRSP Entomologists reported on the relationship of damage to yield loss, the effect of time of leaf loss on yield and then developed an economic threshold level (ETL) for S. litura on peanut.

Pilot IPM package developed from CRSP research was compared with farmer pest management methods. CRSP IPM resulted in less insect damage and higher yield than farmer pest management methods.

Thailand

Eighteen species of insects, mites and millipedes cause damage to the peanut crop that is grown in northeast, north and eastern Thailand. In the south peanuts are intercropped with young rubber trees. The subterranean ant, white grub and millipedes bore into pods and cause a direct loss. Leafhopper, leafminer, corn earworm and cutworm feed on the foliage and thrips and aphids transmit viruses.

Seasonal history records were plotted for leafhopper, leafminer, thrips and the subterranean ant in Khon Kaen. Biological/ecological studies were made for the white grub Maladera sp. in northern Thailand. These biological and ecological studies provide information on time of peak occurrence for insect monitoring and pest management.

The thrips that transmits peanut yellowspot virus (PYSV) in Thailand was identified as Scirtothrips dorsalis. Direct relationship was found between thrips number, percent yellowspot virus and yield.

A diverse collection of peanut germplasm was screened in multiple locations in Thailand for resistance to the pest complex and yellowspot virus. Part of the collection, 250 genotypes, were also tested in the Philippines and North Carolina. Genotypes were selected for resistance/tolerance to thrips, leafhopper, leafminer, Heliothis armigera, aphid and the subterranean ant. Some genotype yields were higher than local cultivars.

Several high yielding genotypes were incorporated into a pilot pest management program for conparison with local cultivars for pest damage and yield. NC7 (KK 60-3) a newly released cultivar in Thailand exhibited less insect damage and higher yield than local cultivars in multiple locations.

Advances were made in soil insect management. Coconut halves are used as bait to attract the subterranean ant. Pesticides are being tested in the baited area as a method of selective control of the pod-boring ant. Damage from another soil pest, the white grub, may be reduced by early harvest.

North Carolina

Peanut CRSP research provided the necessary support to expand and refine the insect pest management program. Research was designed to explore the effect of cultural practices on the pest complex, population sampling with pheromones, development of insect population/damage thresholds and to select peanuts with resistance to the pest complex and to be developed and incorporated into IPM.

Cultural practices utilized in the research included planting date, seeding rate and cultivar interaction. Planting date was more important than seeding rate and in general early planted peanuts had less insect damage and higher yield. Minimum tillage studies with peanuts planted in wheat stubble revealed that peanuts planted in wheat stubble had less insects and less foliage damage than conventionally planted peanuts.

Insect population/damage thresholds are important for pest management decisions. Threshold information was obtained for tobacco thrips Frankliniella fusca and the potato leafhopper Empoasca fabae. Pheromones are now being used to monitor the adult population of the southern corn rootworm for possible action threshold. Sampling for the destructive larval stage is difficult since they live in the soil and feed on the pods. Preliminary data have shown that an average weekly trap catch during June of 100 adults will result in economic damage to pods. No treatment decisions are confounded by cultivar susceptibility, soil type and soil moisture.

The IPM program has been tested utilizing the developed thresholds. A weak point is the lack of information on insect complex threshold. Threshold decision may be further confounded by integrated pest management using established weed, disease and insect thresholds.

The most economical and permanent method of managing the pest complex is the identification and development of pest resistant/tolerant cultivar - NC6 was developed in cooperation with Dr. J. C. Wynne. It has high resistance to the southern corn rootworm Dabrotica undecimpunta howardi, moderate resistance to corn earworm Heliothis zea and potato leafhooper, Empoasca fabae and low level resistance to thrips Frankliniella fusca. It is one of the major cultivars grown in North Carolina and Virginia. Wild species of peanut tested prior to the peanut CRSP and in cooperation with Dr. H. T. Stalker exhibited resistance approaching immunity to thrips, potato leafhopper and the corn earworm. Breeding techniques including biotechnology can make use of these valuable sources of pest resistance.

Improvement is needed in the pest resistant cultivar and higher levels of resistance are needed for the entire pest complex. Therefore the search continues to find more and improved sources

of pest resistant germplasm through selection and breeding for use locally, in Southeast Asia and internationally.

A diverse collection of 250 germplasm lines selected in tests conducted in North Carolina was packaged for testing in four locations in the Philippines, four locations in Thailand and two locations in North Carolina. This research was conducted during my sabbatic leave with collaborators in Thailand and the Philippines.

Genotypes with multiple pest resistance were identified in multiple locations in the Philippines, Thailand and North Carolina. The test was reduced to 150 genotypes for retesting in Southeast Asia and North Carolina.

Uniform Insect Nursery Test was established from some of the multiple insect resistant genotypes and are being sent back to Thailand (two sets) and the Philippines. In addition, the test was distributed to cooperators in Georgia, Florida and Virginia. Additional distribution is needed in the U.S. and internationally.

Leafhopper resistant genotypes were crossed with NC 7 by Dr. J. C. Wynne and some of the progensis show good leafhopper resistance and should be tested also in Thailand, Philippines and other locations.

TRAINING

Ph.D. training was funded for one Thai student. Two U.S. students received M.S. degrees from Peanut CRSP funds. Technical training on peanut pests and pest management was obtained at ICRISAT for two trainees each from University of Philippines (UPLB), Department of Agriculture (Thailand) and Khon Kaen University (Thailand). Entomology host country collaborators Dr. Eliseo Cadapan (Philippines), Dr. Manochai Keerati-Kasikorn (KKU, Thailand), and Dr. Sathorn Sirisingh (DOA, Thailand) all attended APRES meeting and received non-degree training in pest management in my research program.

LINKAGES

ICRISAT Entomology pest management and peanut breeding.

Priority Constraints to be Addressed

Insects and other arthropods damage peanuts and transmit viruses that reduce peanut yields.

GOAL

Identify and manage the pests responsible for economic damage by developing an environmentally safe and economically sound pest

management program that is compatible with production practices for the country.

RATIONALE

Major peanut insects have been identified and information is available on their biology and seasonal history but information is still needed on the impact of specific pests on yield. Progress has been made in identifying genotypes with pest resistance. Additional selection for higher levels of resistance is needed and resistant genotypes need to be incorporated into breeding programs. Some basic research has been conducted on natural or biological control, including parasites, microbials and botanicals. This research needs to be expanded into more field research experiments and multiple methods of biological control incorporated into existing IPM programs. Pilot IPM programs have been conducted in host countries. Growers need to be made aware of IPM principles through on-farm tests and other extension activities. IPM strategies need to be refined and expanded to develop pest management programs suitable for the existing farming system.

OBJECTIVES

Philippines

Long-term

1. Evaluate peanut genotypes for resistance to the insect complex and cooperate with the breeder (IPB) in the development of cultivars with pest resistance.

2. Incorporate effective management strategies into the IPM package including pest resistant genotypes, biological control, cultural practices and threshold and evaluate IPM package in multiple locations at research stations and farmer fields.

3. Expand cooperative research to find more efficient methods and techniques of managing the pest complex with microbials, parasites botanicals and other biological control agents.

Short-term

1. Determine the effect of shade on the insect complex in cooperative intercropping research.

2. Refine and expand thresholds including plant phenological relationships.

3. Determine the critical time of protection against the major insect pests of peanuts.

Thailand (Khon Kaen University)

Long-term

1. Select peanut genotypes for resistance to the insect complex. Cooperate with the plant breeder to transfer insect resistance to agronomically suitable genotypes for development of pest resistant cultivars.

2. Cooperate with the virologist in a study of insect vector/virus/yield relationship. Select peanut genotypes with nonpreference (antixenosis) resistance to insect vectors of viruses.

3. Refine the IPM pilot pest management program incorporating pest resistant genotypes and other management strategies at experiment stations and farmers fields.

Short-term

1. The subterranean ant causes economic damage to peanut pods. More information is needed on the management of this destructive soil pest including biology, ecology and use of poisoned bait traps.
p

2. Conduct cooperative research with the biological control specialist at KKU to explore the use of biocontrol agents and networking with Dr. Ocampo (UPLB) for exchange of natural control agents.

Thailand (Department of Agriculture)

Long-term

1. Continue to screen genotypes from the North Carolina collection and select for multiple pest resistance and agronomic potential for use in a cooperative breeding program.

2. Introduce additional insect resistant genotypes into the IPM program to assess the effect on insect population, damage and pest management.

3. Conduct IPM tests incorporating all management strategies available at multiple locations, including farmer fields.

4. Determine crop loss assessments for major pests of peanuts and refine threshold for major pests.

Short-term

1. Cooperate with the virologist in research on thrips population/damage/ yellowspot virus and yield relationship.

2. Study the importance of soil insect pests and their management with emphasis on the white grub.

North Carolina

Long-term

1. Evaluate peanut accessions and breeding lines for multiple insect resistance. Transfer genotypes to Thailand and Philippines for testing for multiple insect resistance. Cooperate with the project NCS/BCP/TP for developing pest resistant cultivars.

2. Test IPM program incorporating most important local cultivars. Test will include insect pest management only and integrated pest management (insects, weeds and disease).

3. Confirm thresholds established for thrips, leafhopper and corn earworm. Determine thresholds for foliage insect complex.

4. Continue research on the use of pheromones for southern corn rootworm (SCR) monitoring and management decisions.

Short-term

1. Initiate research on the use of biological control agents to manage the major soil pests.

2. Simulate corn earworm damage by flower removal and depodding for effect on yield.

RESEARCH PLANS PROPOSED

Philippines

1. Plant Resistance to Insects

A collection of 150 genotypes and a Uniform Insect Nursery Test of 24 genotypes was sent to Dr. Abilay (IPB) for seed increase and cooperative research to select and develop peanuts with pest resistance. These will be planted in multiple locations and evaluated for resistance/tolerance to thrips, aphids, leafhoppers, *Spordoptera* *Heliothis* and leafminer.

2. IPM Package

Local and selected genotypes will be compared with susceptible cultivars for management of this pest complex using thresholds established at UPLB and from North Carolina. Tests will compare genotype and cultivar, insect population, damage and yield when subjected to: (a) preventive management program (b) as needed based on threshold established and (c) untreated check. Local farmer practices will be compared with CRSP managment practices. This

should be expanded to include agircultural extensions demonstration and training in IPM at the farmer level.

3. Biological Control

Progress has been made on the use of *Trichogramma* spp. parasites, *Bacillus thuringiensis* strains and nuclear polyhedrosis virus (NPV) in reducing pests of peanuts. Tests will be established in cooperation with biocontrol specialists to improve techniques and field development of biological control. Extracts from the Neem plant and other botanicals will be included in this biocontrol program.

4. Cultural Practices (intercropping)

Peanuts are intercropped with corn and tree crops resulting in shade. What effect does intercropping and shade have on the insect complex? This will be a cooperative program with IPB and agronomy.

5. Thresholds

Progress has been made in developing economic threshold level for *Spodoptera litura*. This needs to be confirmed under varying field condition. Also, thresholds developed in North Carolina need to be confirmed and refined for agricultural conditions in the Philippines.

Thailand (KKU)

1. Plant Resistance to Insects

Genotypes collections from ICRISAT and North Carolina have been evaluated for resistance to the pest complex. Multiple pest resistant genotypes have been identified from this diverse germplasm collection. The addition of Sanan Jogloy, peanut breeder, should permit closer cooperation by Entomologist and Peanut Breeders in the development of pest resistant cultivars for Thailand.

2. Insect Vector/Virus Relationship

Aphids and thrips transmit viruses to peanut. Opportunities exist for close cooperation between the Entomologist and Virologist to study pest behavior, ELISHA techniques for viruliferous vectors, trapping methods and identification of virus tolerant plants or peanut plant exhibiting nonpreferences for feeding (antixenosis) by the insect vectors.

3. Pilot IPM Program

Genotypes with pest resistance will be incorporated into IPM programs and tested in multiple locations at the farm level. At some point when the IPM program is developed the Agricultural Extension needs to be incorporated into the programs for education and promotion of the principles of pest management.

4. Subterranean Ant

Coconut halves will attract the ant. This technique shows that the ant is not present in the field until 8 weeks after planting. Pesticide baited coconut may prove effective in reducing pod damage. This technique will be tested.

5. Biological Control

Collaboration with a specialist in biological control at Khon Kaen University and networking with Dr. Ocampa from UPLB will provide information on the importance and use of biocontrol methods in the Thai pest management program. Also "No-Bait" sticky traps may be effective in reducing small insects such as aphid, leafhopper, leafminer and thrips. These will be shipped to cooperators in Thailand for testing.

Thailand (DOA)

1. Plant Resistance to Insects

Uniform Insect Nursery and a collection of genotypes will be shipped to Thailand for testing and selection of pest resistant genotypes. These will be planted initially at the experiment station at Tha Phra, Mahasarakom and/or Rayong.

2. IPM Research

Insect resistant genotypes will be incorporated into the IPM program and evaluated at experiment stations and private farms. Existing thresholds will be used for treatment decisions that will include (a) preventive (b) as needed and (c) untreated checks. This research will be coordinated with and compliment research conducted at Khan Kaen University.

3. Crop Loss Assessment

Peanuts will be treated to maintain insect damage-free plants. Other plots will not be treated to allow the buildup of insects and damage. Plots will be sampled weekly for the entire season maintaining pest population and damage records. Data will be analyzed by multiple regression to identify pest and phenological plant stage contributing damage and yield loss.

4. Yellowspot Virus/Thrips Relationship

Preliminary data were obtained on thrips effect on PYSV and yield reduction. More precise information is needed on numbers of thrips, phenological plant stage, pest control increments and yield relationship to arrive at potential pest/damage/PYSV thresholds.

5. White Grub

The white grub is a soil inhabiting pest that damages pods. It is found close to the plant and just under the soil surface. Early harvest will reduce damage. More information on its habits and possible cultural practices effects on this grub will be useful in managing this elusive pest. Soil insects present a special problem because of sampling and distribution. They are not easily monitored.

North Carolina

1. Diverse germplasm collection will be retested in North Carolina. Seed will be sent for cooperative research to the Philippines and Thailand. Progenies from NC7 cross with leafhopper resistant genotypes will be selected. Promising progenies will be made into a UNIFORM LEAFHOPPER RESISTANCE NURSERY and distributed to Cooperators.

2. IPM Program

Information is needed on effect of new cultivar releases and any adjustments required in the established thresholds. Tests needs to be expanded to include weeds, diseases and insects.

3. Threshold Complex

Insects occur as a complex. Thresholds have been established for specific insect. Information is needed on the compounding effect of multiple pest damage compared with specific pest damage. Thresholds need to be reconfirmed with new cultivars utilizing a range of thresholds above and below those now established to confirm and refine thresholds.

4. Pheromones/Insect Monitoring

Pheronomes are used to monitor pest insects. The southern corn rootworm, a soil pest, is difficult to monitor and sample in the soil but the adult is attracted to pheromones. Information indicates that a weekly trap catch in June of 100 or more adults will result in economic damage to pods by larvae in August and September. More information is needed to determine confounding problems such as cultivar difference, soil type and soil moisture. The problem now lies in the decision of when not to treat rather than the need to treat.

5. Biological Control of Soil Pests

The southern corn rootworm is potentially the most destructive pest of peanut in North Carolina. Biocontrol agents have not been tested against this pest in North Carolina. Microsporidia, parasitic nematodes, and beauveria will be evaluated against the pest under controlled laboratory conditions then tested under field condition for potential on farm management.

6. Heliothis zea Flower and Peg Damage

H. zea most often damages the foliage but it has been observed feeding on the flowers and pegs. Test will be conducted to simulate the damage by precentage removal of the flowers and depodding by cutting the gynophore. Observation and cage tests will be used to study flower and pod loss with known larval populations.

BENEFITS EXPECTED

Host Countries

Provides funds to develop a pest management program compatible with local agriculture and needs of the farmers. It has encouraged cooperation among agencies and will expand interdisciplinary research.

United States

Peanut CRSP will permit an expansion and acceleration of pest management research. It provides test sites for genotype evaluation with diverse environments, diverse pests and the opportunity to study cross insect species resistance among peanut genotypes in cooperative tests with collaborators in Thailand and the Philippines.

ORGANIZATION/PERSONNEL

Philippines

Program
Coordinator: Dr. Ricardo Lantican - Coordinator of Project

Principal
Investigator: Dr. Virginia Ocampo, Entomologist

Cooperator: Dr. Candida Adalla, Entomologist

Cooperator: Mr. R. V. Ebora, National Institite of Biotechnology

Cooperator: Dr. Edwin A. Benigno, Insect Biological Control

Cooperator: Mr. Dante R. Santiago, Insect Biological Control

Research
Assistant: Ms. Evelyn A. Bergonia, Entomologist

Technician: Mr. M. V. Navasero

Thailand (Department of Agriculture)

Program
Coordinator: Dr. Vichitr Benjasil, Director Field Crops

Principal
Investigator: Dr. Sathorn Sirisingh, Entomologist

Cooperator: Dr. Turnjit Satayavirut, Entomologist

Cooperator: Mr. Pisit Sepswasdi, Entomologist

Cooperator: Dr. Duangchai Choopunya, Virologist

Cooperator: Ms. Srisamon Pitak, Entomologist

Technician: Mr. Punya Pooksoon

Thailand (Khon Kaen University)

Principal
Investigator: Dr. Manochai Keerati-Kasikorn, Entomologist

Cooperator: Dr. Aran Patanathai - Peanut Breeder

Cooperator: Dr. Sanon Jogloy - Peanut Breeder

Cooperator: Dr. Sopone Wongkaew, Plant Pathologist/Virologist

Technician: Mr. Preecha Singha

N.C. State University

Principal
Investigator: Dr. W. V. Campbell, Entomologist

Cooperator: Dr. J. C. Wynne, Peanut Breeder

Cooperator: Dr. Wayne Brooks, Insect Pathologist

Cooperator: Dr. Harold Coble, Weed Scientist

Cooperator: Dr. J. C. Bailey, Plant Pathologist

Justification

1. Adjustments in inflationary cost

2. Initiate research on biological control of soil pests in peanuts and expand cooperative research on biological control in the Philippines and Thailand.

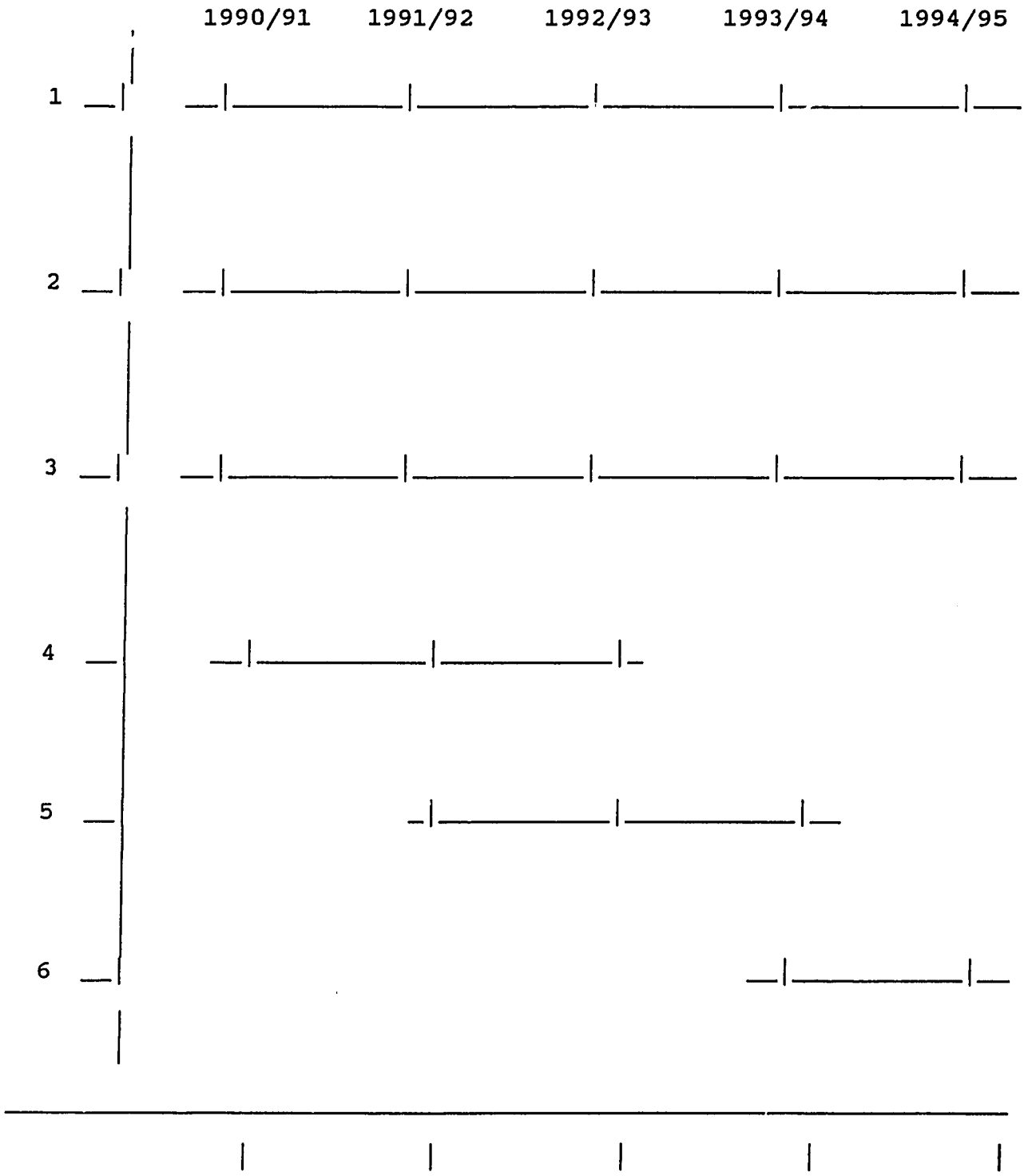
3. Provide MS degree training in IPM at the host country university.

4. Expand IPM pilot programs in Thailand and Philippines and investigate the use of no-bait traps for reducing insect and virus vectors.

5. Prepare manuals on insect pests of peanuts with colored plates of principal pests and beneficial insects for both Thailand (Thai language) and Philippines (English)

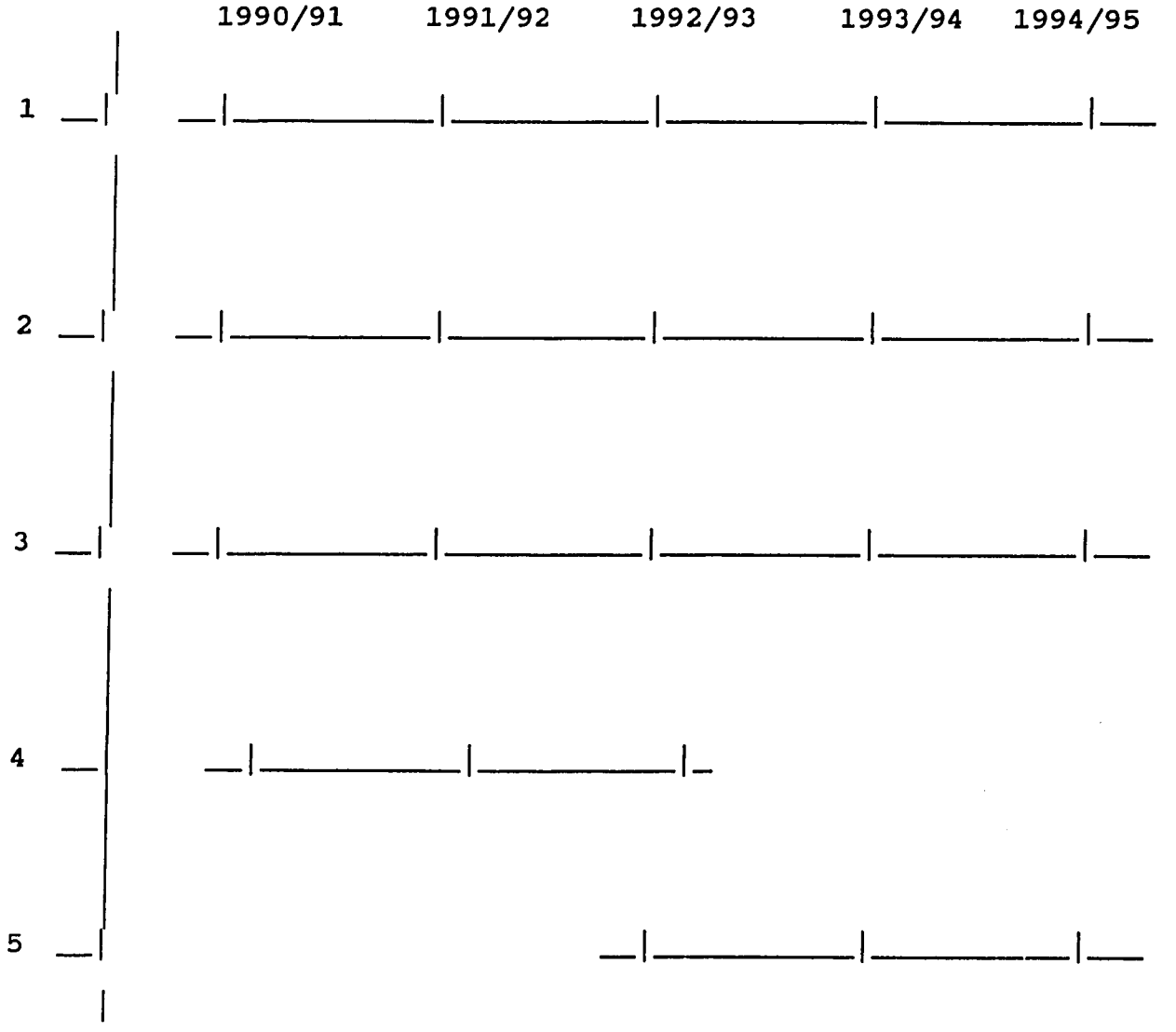
TIMETABLE
Philipines

Objective No.

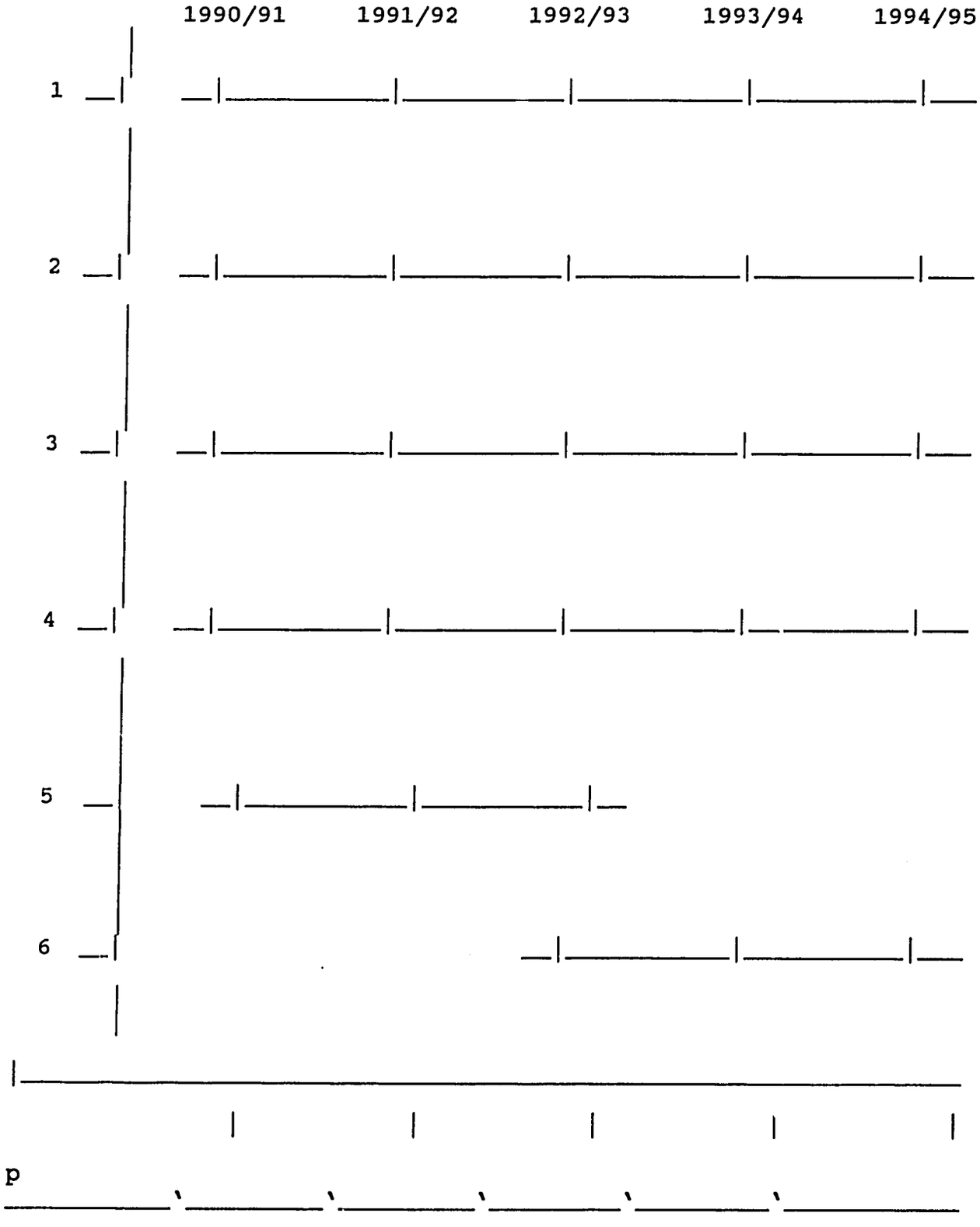


TIMETABLE
Thailand (KKU)

Objective No.



TIMETABLE
Thailand (DOA)



TIMETABLE
North Carolina

Objective No.

	1990/91	1991/92	1992/93	1993/94	1994/95
1					
2					
3					
4					
5					
6					

New Thrusts

A description of a proposal approved for funding under "new thrusts" follows.

Project Code: NCS/IM/TP

Title: Uniform Insect Nursery Test

Introduction

Peanut genotypes have been identified with known resistance to specific insect and to multiple insects. Since many of the same genera of insects occur in Southeast Asia, Africa and the United States, it would be beneficial to subject the genotypes to more pest and environmental stresses. Breeding lines with resistance to the leafhopper *Empoasca* exhibit a wide range in leafhopper hopperburn and these lines should be tested in other regions of the United States, Africa and Southeast Asia for potential use in breeding programs.

Objective

1. Select genotypes with resistance and susceptibility to insect for inclusion in a Uniform Nursery.

2. Distribute genotypes to cooperators in the U.S., Africa (Via Dr. Bob Lynch) and Asia.

Research Plan

Genotypes will be evaluated in replicated plots in areas endemic to insect pests. Plots will be rated on percentage damage and compared with selected checks and local cultivars. Promising lines will be retested with yield data.

Budget (US)	1990/91	1991/92	1992/93	1993/94	1994/95
Salaries & Wages	$12,000	$ 4,400	$ 4,600	$ 4,900	5,300
Graduate Students		10,500	11,000	11,500	12,000
Travel	3,000	2,000	2,100	2,200	2,279
Materials & Supplies	2,000	2,000	2,145	2,237	2,300
Other Direct Costs	1,000				
TOTAL DIRECT COSTS	$18,000	$18,900	$19,845	$20,837	$21,879
Indirect Costs	4,590	4,819	5,059	5,312	5,577
TOTAL	$22,590	$23,719	$24,904	$26,149	$27,456

Peanut CRSP Project Code: GA/PV/N,TP

Project Title: Peanut Viruses: Etiology, Epidemiology and Nature of Resistance

Introduction:

Numerous virus diseases of peanuts have been found in the peanut producing areas of the world. At least three virus diseases were previously shown to be significant and require research programs.

Peanut mottle virus (PMV) is the most wide-spread peanut virus. Although PMV induces relatively low yield losses, the high incidence of the disease, and its wide dissemination in the world, make it responsible for the largest economic loss in peanuts on a world-wide basis.

Groundnut rosette (GR) causes devastating losses in peanut in Africa and is a limiting factor in the production of peanuts on that continent. The disease has been reported only in Africa.

Epidemics of GR in 1975 virtually destroyed peanut production in Nigeria. Regional epidemics in 1983, 1985 and 1988 have been a major influence on growers deciding to plant other crops instead of peanuts. Although peanuts have better nutritional values than alternative crops, farmers plant crops that have better chances of survival. In areas below the Sahara desert where it does not rain from September to May, crop dependency is a major concern. Thus GR is a limiting factor for both production and crop selection.

Tomato spotted wilt virus (TSWV) causes bud necrosis in peanuts and is probably the most important peanut virus disease in India. Early infection can cause up to 100% yield loss.

In the mid 1980's TSWV infection of peanut became a major problem in South Texas. Some fields had over 80% of the plants infected with severe yield losses. Additionally the virus causes some seed to be darker in color and misshapened which reduces the marketing value of the seed. In 1988, TSWV could be detected in the majority of the peanut fields in south and west Georgia; however, the percentage infected remained far below one percent. In 1989, incidence of TSWV on peanuts dramatically increased. Several fields were identified with over five percent TSWV infection. Although some cultivars appear to have a lower percentage infection than others, a high level of resistance in peanut to infection with TSWV is lacking.

In Thailand a disease of peanut known as yellow spot (YS) is common and in some fields epidemic. YS is caused by a virus whose particle resembles TSWV and is transmitted by thrips like TSWV.

However the YS particles are restricted to the local area of infection on a peanut leaflet producing a yellow spot. YS particles are not serologically related to TSWV and further virus characterization is needed.

Peanut stripe virus (PStV) was discovered and named in 1982. This virus has many of the same characteristics as PMV. Both are flexuous rods, seed transmitted in peanuts, transmitted by aphids and infect numerous legumes. Like PMV, PStV may cause relatively low yield losses. In the U.S., PStV did not cause significant yield losses in several field trials. However, all yield loss trials with PStV indicate the average loss is greater than 5%. Recent reports presented at the Second Peanut Stripe Virus Coordinators Meeting (August 1-4, 1989 at ICRISAT) indicated that yield loss trials in Thailand, the Philippines and Indonesia gave highly variable results. Between 5 and 60% losses were reported for PStV. In the S.E. Asian environment, PStV disease symptoms persist throughout the growing season, infected plants exhibit stunting and in general the disease reaction is more severe than in the U. S.

PStV has a higher seed transmitted rate than PMV, is more efficiently transmitted by aphids and induces a more severe disease reaction in S.E. Asia. If PStV is permitted to spread unchecked throughout the world, it has the potential to cause the greatest economic loss in peanut.

Both PStV and PMV are known to occur naturally in peanuts from northern China to Indonesia and fields with greater than 80% incidence of PStV have been observed in these countries. The basic PStV disease reaction in peanut in S.E. Asia is some stunting of infected plants, dark green spots or blotches on paler green leaflets with the symptoms persisting until plant maturity. This contrasts to the PStV isolates in the U.S. which induce little or no stunting with milder symptoms which generally fade as the peanut plant matures.

Accomplishments

Research

In Nigeria, two agents involved with GR have been identified; groundnut rosette virus (GRV) (the symptom inducing agent) that does not appear to have a protein coat and a luteo virus that has been called the groundnut rosette assistor virus (GRAV) (causes no symptoms). GRV can be mechanically transmitted but not GRAV; thus separation of the two viruses can be effected. GRAV is aphid transmitted but not GRV when it infects peanuts without GRAV. When both agents are in the same plant, it appears that the GRV ribonucleic acid (RNA) is encapsidated by protein subunits of GRAV and can then be transmitted by aphids.

A serological test has been developed to detect the GRAV. Using antiserum against potato leaf roll virus (a related luteovirus) in the enzyme-linked immunosorbent assay (ELISA) system, GRAV can be detected in infected plants. GRV can be detected by using gel-electrophoresis where the presence of a 900 base pair double stranded (ds) RNA indicates the presence of GRV.

Procedures to screen for resistance in peanuts to GR were developed for both field and greenhouse studies. These procedures are based on the evaluation of the pathogens and on their effect on the host. Resistance to GR in peanut does not appear to be dueto vector resistance; nor does it appear to be against GRAV. Aphids colonize both resistant and susceptible peanut lines, and GRAV can be detected in inoculated resistant lines that do not express rosette symptoms.

Recent studies indicate that when plants are infected with both GRV and GRAV the detrimental effect is greater than when the plants are infected with GRV alone. Virions have been purified from rosetted peanut plants by enzyme-assisted extraction, cloroform clarification, and sucrose density gradient ultracentrifugation. It is anticipated that some virions will contain GRAV-RNA and others GRV-RNA (experimental tests incomplete).

Late maturing lines resistant to GR were released in 1986 and increased in 1987. In 1988, 20 tons of seed resistant to GRV were available to growers. However, because of large numbers of isolated small farms, most growers are still using susceptible lines. The use of insecticides against the aphid vectors of GR are effective in preventing GR epidemics. An IPM recommendation of using systemic insecticides along with early planting and close spacing of peanut plants is effective against GR epidemics even when GR susceptible cultivars are employed.

A new disease 'little leaf', has been observed in Nigeria during the last four years. The two causal agents of GR and a 900 bp dsRNA have been associated with little leaf. Other viruses infecting peanut in Nigeria have been cowpea mild mottle virus (CMMV) and TSWV.

PStV has been characterized and placed in the potyvirus group. The virus has been shown to be transmissible both mechanically and by aphids. The aphid Myzus persicae is more efficient in transmitting PStV than Aphis craccivora. Both aphids transmitted PStV more efficiently than PMV. PStV was purified and antiserum produced. Serological tests to detect PStV in peanut and other hosts were developed. The probable origin of PStV in the U.S. was documented as passing through peanut seed obtained from China.

Data on seed transmission of PStV have been published. A non destructive test to detect PStV in peanut seeds has been developed. The susceptibility of other hosts such as soybeans and cowpeas has

been shown and lines having PStV resistance for each of these crops has been published. Resistance in commercial peanut lines to PStV has not been found but resistance to PStV in 'wild' peanut types has been identified. The epidemiology of PStV has not been fully determined although preliminary studies indicate that only short distance spread (50 m or less) is the norm.

Methods of detecting TSWV in peanut tissue have been developed and are routinely being used. A TSWV isolate from peanut has been purified and an antiserum produced. Preliminary data indicate that TSWV is not seed transmitted in peanut.

Training

Degree Training

Sukorndhaman, M. (Thailand) Ph.D. 1987 on Nucleic acid hybridization, serology and host reactions to studyclassification and detection of peanut mottle virus. Majority Peanut CRSP support.

Warwick,. Dulce (Brazil) Ph.D. 1987 on Biological properties of peanut stripe virus related to identification, diagnosis, diseases and epidemiology. Partial Peanut CRSP support.

Olorunju, P. (Nigeria) Ph.D. expected early 1990 on Groundnut rosette: inheritance of resistance and reaction of peanut genotypes to the causal agents. Majority Peanut CRSP support.

Pua, A. (Philippines) Ph.D. expected in 1991 from University of Philippines. Spent 16 months at University of Georgia taking classes and training in plant virology. Partial Peanut CRSP support.

Non Degree Training

Surname	Sex	Affiliation	Training	Location	Duration
Wayo	M	IAR	Serology	Nigeria	1 week
Sule	M	IAR	Serology	Nigeria	1 week
Ansa	M	IAR	Molecular Biology	Scotland	1 month
Ansa	M	IAR	Virus purification	Germany	1 month
Misari	M	IAR	Serology	UGA	1 week

At training workshops (Malang, Indonesia 1988 and ICRISAT 1989) on the identification of peanut viruses, eight lectures and two laboratory demonstrations were given to the trainees from 10

S. E. Asian countries.

Linkages:

For GR, formal linkage is with the Institute for Agricultural Research at Ahmadu Bello University; Dr. Steve Misari and Phindile Olorunju are the cooperators. Department of Crop Protection, Institute for Agricultural Research, Ahmadu Bello University, PMB 1044, Samaru-Zaria, Nigeria.

On completion of the Ph.D. in early 1990, Phindile Olorunju plans to accept and offer to join the faculty at IAR and become the principal cooperator from Nigeria.

Informal linkages have been formed with the people or institutes that are working with or have an interest in GR. The primary groups are: Dr. K. Bock, Chitedge Station, Malawi; Dr. T. Murant, Scottish Crops Research Institute, Scotland; Dr. R. Casper, Virus Institute, W. Germany; and Dr. D. V. R. Reddy, ICRISAT, India.

Joint meetings were held:

1983 at the Georgia Experiment Station, Georgia
1985 in Cambridge, England
1987 in Lilongwe, Malawi
The next meeting is scheduled from Montpellier, France in 1990.

For PStV, formal linkages are with;

Dr. Sopone Wongkaew
Faculty of Agriculture
Khon Kaen University
Khon Kaen, 4002
Thailand

Dr. Marina Natural
Institue of Plant Breeding
College of Agriculture
College of Laguna
Philippines

Additional linkages have been formed with ICRISAT, FAO, ACIAR and Peanut CRSP who have sponsored PStV Coordinators Meeting in Malang, Indonesia (1987) and at ICRISAT (1989). Participants have been from Australia, China, India, Indonesia, Japan, Malasia, The Philippines, Thailand and the United States.

Inter-Peanut CRSP linkages have been established with Peanut CRSP projects Tx/BCP/WA and GA/IM/BF in Burkina Faso. This facilitates research on GR by interacting with peanut breeders where selection of GR resistant lines is essential and with entomologists to study the biology of the aphid vectors.

Priority Constraints:

The thrust of this project is to reduce plant stress thus reducing yield losses by controlling virus diseases. Integrated

management packages will be developed which will lead to a more sustainable agricultural system.

Goal

Virus diseases, in epidemic proportion, are limiting factors in peanut production. The three most destructive viruses infecting peanut, on a worldwide basis, are PMV, GR, and TSWV. PStV is increasing in importance because of expanded distribution and increased incidence. Based on current information our goal is to reduce virus disease losses by GRV through resistant lines being developed by a breeding program; by the use of virus-free seed for PStV with continued searching for resistance; by obtaining data on the epidemiology of TSWV and seeking virus and/or vector resistance; and by a general program of virus identification, characterization, strain relationships and transmission of the viruses by vectors. Therefore, the major goal of this project is through research efforts to attain a better understanding of the causal agents and virus diseases so that some methods of control can be developed for the different viruses in the different countries.

Rationale:

In Nigeria, methods of GR virus detection have been developed, resistant lines identified and a few resistant lines increased for distribution to growers. However GR resistant lines better adapted to various areas of west Africa are needed especially those lines with early maturity and drought resistance. Support for a virus breeding program in west Africa is needed to provide effective control. Additionally the U. S. principal investigators will interact with other Peanut CRSP breeding (TX/BCP/WA) and entomology (GA/IM/BF) programs in West Africa to help identify resistant peanut genotypes for future use in developing appropriate peanut lines. In S.E. Asia the virus project was initiated in 1988. Preliminary surveys have identified PStV as a major virus disease of peanuts. In depth surveys to determine actual incidence and the presence of other viruses have not been completed. Weed host reservoirs of the major viruses have not been identified nor has the use of virus-free seed been evaluated.

Objectives:

Host Country - Nigeria

1. Breeding for resistance to GR with selection of lines adaptable to northern Nigeria and West Africa. This will include interacting with other Peanut CRSP programs and ICRISAT sahelian Center in West Africa for selection of GR resistant lines.

2. Establishment of demonstration plots containing GR

resistant and susceptible lines. (It is essential to show farmers that peanuts can be successfully grown without GR infection. Less nutritious alternate crops are being grown because growers fear total loss from GR epidemics)

Host Country - Thailand and the Philippines

The Peanut Stripe Virus Coordinators meeting was held 1-4 August 1989 at ICRISAT in India. In addition to representatives from countries where PStV occurs, outside consultants were Dr. Alan Brunt - United Kingdom, Dr. Dick Hamilton - Canada, Dr. D. D. Shukla and Dr. Adrian Gibbs - Australia. The group recommendations for S. E. Asia were finalized. Those recommendations being supported by this project are:

3. Conduct yield loss experiments to document the significance of PStV in S.E. Asia.

4. Conduct surveys to determine the incidence and geographical distribution of PStV and other viruses in S.E. Asia.

5. Identification of symptom variants of PStV should be made by mechanical inoculation of diagnostic hosts (in a standard list) and confirmed by serological tests using PStV specific antiserum.

6. Screening for resistance to virus and/or vector should be continued. Screening for non-seed transmission should be encouraged.

United States

7. Search for resistance to TSWV, PStV and PMV in Plant Introduction and 'wild' Arachis species in cooperation with TX/BCP/WA and the peanut curator at the Georgia Experiment Station.

8. Determine epidemiological factors of TSWV such as a internal spread of the virus or a continual outside virus source b. distance of virus dissemination c. primary source of virus for peanuts.

Plans Proposed:

Research

Host Country - Nigeria

1. Inheritance of resistance studies are being conducted in

a diallel test with eight peanut genotypes (28 crosses). The studies are designed to determine the nature of resistance to GR, the number of host genes involved in resistance, individual early-maturing F3 plants with resistance to GR, and F2 and F3 plants with acceptable agronomic characteristics. Selection of F2 and F3 plants will provide the basis for a 5-10yr. 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 identifing 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 and the Philippines:

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 m2 with 20 m spacing between each plot. Maize will be grown as a barrier crop between plots. Spacing within and between rows will be approx. 30 cm. Inoculate 100 randomly spaced plants (in each plot) at the 1st true leaf stage with PStV. Tag infected plants. Compare yield data from the mechanically infected plants and the same number of healthy plants 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 viruslike 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 peanuts.

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 progency will be mechanically and aphid 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 infector 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 (peanuts, datura, tomato or tobacco) will be placed in and near healthy peanuts and spread will be carefully monitored.

Training

Current budgets permit Thailand and Philippine 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 for one week of training at a

scientific laboratory. The budget for Nigeria only permits international travel in the 1990/91 year. Sufficient monies are not available for graduate student training in Nigeria or Philippines host country budgets.

The U.S. budget has monies for the training of a Ph.D. student and possibly could be used to train a student from one of the host countries where the need is greatest.

Benefits Expected:

The development and use of resistant GR cultivars for W. Africa can eliminate a major constraint to the production of peanuts in that area of the world. It would produce cash income to small farmers whose annual income is usually less than $500. It also would provide a more nutritional base to the people living in the semi-arid regions of Africa.

Immediate benefits for S. E. Asia will be interaction with other scientists and research methodology. Informal networking has been formed with ICRISAT, FAO, ACIAR and this Peanut CRSP project. Training workshops in plant virology have been held and another is planned for 1990/91. Host country representatives (faculty or technicians) are encouraged to participate. Integrated pest management packages can be expected which should help to reduce virus incidence. The incorporation of PStV and PMV resistance into commercial peanut lines will be a major step in reducing the current plant stress and yield losses.

TSWV incidence dramatically increased in S. Texas in the mid 1980's and in the eastern states of Alabama, Florida and Georgia in 1989. Because of severe yield reductions induced by TSWV, this disease now poses a serious threat to U. S. peanut production. If disease incidence continues to increase as it has in the past decade, all possible control measures must be examined. Identifying TSWV resistant lines may be essential to preserving a profitable industry in the U.S.

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. Cedric Kuhn, Department of Plant Pathology, UGA, Athens, GA 30602
	Technician:	Mr. James Chalkley, Georgia Experiment Station, Griffin, GA 30223

B. Nigerian Counterpart Inst: Institute for Agricultural Research (IAR) at Ahmadu Bello University, Samaru PMB1044, Nigeria

Principal Investigator: Mrs. Phindile Olorunju (Ph. D. expected June 1990)

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. Philippines Counterpart Inst: Institute of Plant Breeding, University of the Philippines at Los Banos, Los Banos, Philippines

Principal Investigator: Dr. Marina Natural

Collaborative Investigator: Ms. Araceli Pua

E. Informal Cooperation: ICRISAT, Patancheru P.O., A.P., 502324, India

Principal Investigator: Dr. D.V.R. Reddy

Time Table:Project GA/PV/N,TP

Objective____1990/91_____1991/92_____1992/93_____1993/94____1994/95

1. _____

2. _____

3. _____

4. _____

5. _____

6. _____

7. _____

8. _____

Notes to 1.5 option Budget

1. This budget permits the much needed funds in Nigeria to increase GR resistant and susceptible seed and to implement demonstration plots in different regions of W. Africa. It permits the hiring of a technician to handle this project. These demonstration plots are critical in educating W. African farmers of the value of using GR resistant seed.

2. The increased budget permits the training of professionals for S. E. Asia. It also permits sufficient funds for the cooperators to attend meetings to present information and to learn by interacting with other scientists. These funds may also permit a two week stay at another University to learn new techniques.

3. The increased budget permits the hiring of a Post Doctorate in the U.S. that will bring new skills to the project. It will double the output of the U.S. contribution and permit intensive work on getting virus resistant genes into commerical peanut cultivars.

4. This budget option helps to maintain activities at a level that adjusts for inflation, increased costs, etc.

PROJECT CODE: TX/MM/S

PROJECT TITLE: **Mycotoxin Management in Peanut by Prevention of Contamination and Monitoring**

Robert Pettit, Principal Investigator, TAMU

INTRODUCTION

Mycotoxin contamination of peanut poses a serious health hazard to consumers of peanut products throughout the world. The mycotoxin management project is designed to conduct experiments which can help discover improved procedures for reducing mycotoxin problems through prevention of contamination by development of new improved production practices and resistant varieties; monitoring of peanuts in trade channels for diversion of contaminated lots into either clean up or detoxification; the development of rapid, practical, and economical methods for the detection of mycotoxins in peanut and peanut-derived products; and to discover safe and effective detoxification protocols for use in crude peanut oil and peanut-derived products.

Host Country and U.S.

Previously, major efforts have concentrated on field screening peanut cultivars for possible resistance to invasion by the aspergilli; field plot studies to determine the influence of soil amendments on Aspergillus activity; studies to determine the importance of peg invasion; and characterization of potential biochemical defense mechanisms that could be selected for in breeding resistant varieties. Newly developed assay procedures for the detection of aflatoxin are quick, accurate, economical, and capable of detecting more than one mycotoxin using selective minicolumns. The discovery that hydrated sodium calcium aluminosilicates can function as sorbents of aflatoxin has opened up a whole new research area for testing the efficacy of clay-like materials in detoxification studies.

Accomplishments

Research - Senegal

1. Dr. Amadou Ba - Institut Senegalais de Recherches Agricoles, Kaolack, Senegal West Africa.

Field screening peanut cultivars in West Africa for resistance to *Aspergillus flavus* and *A. parasiticus* has revealed that cultivars SN 73-30 and SN 55-437 were less severely contaminated with aflatoxin compared to 73-33 and GH 119-20.

Laboratory studies on the electrical conductivity of soaking solutions from kernels of 47 breeding lines revealed that leachates

from breeding line 4992 had the lowest level of conductance and was less severely invaded by the Aspergilli.

Field applications of manure and gypsum to peanut soils containing high A. flavus and A. parasiticus levels revealed that manure applications failed to reduce the activity of these Aspergilli. They grew on the added organic matter in combination with a large number of.pasaprophytic fungi present within the soil. Gypsum applied 30-45 days after planting significantly reduced the recovery rate of A. flavus from peanut shells and kernels 15+ days after application.

2. Dr. Amadou Kane - Institute de Technologie Alimentaire, Dakar - Hann Senegal, West Africa.

Analysis of 205 peanut kernel samples from field experiments conducted by the staff of ISRA revealed that 19% of the samples contained aflatoxin.

Analysis of 83 animal tissue samples from sheep revealed that a majority of all samples were free of aflatoxin, except for the paunch.

Collection of crude peanut oil samples from peanut growing areas of Senegal, and their analysis for aflatoxin revealed that 75% of the samples from the Kaolack region contained aflatoxin, 81% from the Gossas region contained aflatoxin, while the oil samples from the Touba Toul region were free of aflatoxin.

Detoxification tests were performed on spiked and naturally contaminated aflatoxin-contaminated peanut oil using finely ground bentonite from the USA and attapulgite ATC from Prochimat (Dakar) Senegal. When added to the oil at a rate of 5-10%, bentonite bound the aflatoxin present providing maximum recovery of aflatoxin free oil. However, the fine clay particles were difficult to remove from the oil.

Studies to determine what chemical changes occur within the oil following addition of the bentonite and attapulgite revealed that no significant differences were found in the moisture content, impurities, free fatty acids, and peroxide number between the untreated and treated oils.

Cooking "mafee" (a senegalese food containing peanut paste), containing 360 ppb aflatoxin, in water for 1-2 hours revealed that up to 80% of the aflatoxin present was altered, only 20% of the original aflatoxin was detected following cooking. Addition of aqueous citric acid solution to the mafee failed to influence the extent to which the aflatoxin was altered.

Research - United States (Texas)

1. Dr. Robert E. Pettit - Department of Plant Pathology

and Microbiology, Texas A&M University, College Station, TX.

Provided encouragement, direction, and training of research staff in Senegal and provided leadership for graduate students Ahmdoul Bashir Sarr, Hassan Azaizeh, Julius Fajardo, and Russelyn Henson in their studies at Texas A&M concerning screening peanut genotypes for resistance to the aflatoxin producing fungi.

Screening peanut cultivars for resistance to invasion of the kernels by A. flavus and A. parasiticus and aflatoxin contamination has revealed that peanut cultivars Tx815667, Tx798736, and Tx811956 contained mean infestation levels lower than currently grown varieties and less aflatoxin following curing.

Electrophoretic studies of peanut protein patterns within live kernels, challenged by A. flavus or A. parasiticus revealed the presence of pathogensis-related proteins (PRs) 13-14 hrs after inoculation. Kernels from drought stressed plants lacked PRs except in the case of kernels from a selection of the cross Toalson/UF 73-4022 (Tx798736).

Artificially sealing the hila of peanut kernels slowed fungal penetration, however, could not (with time) prevent cotyledonary invasion. Cotyledonary invasion via open hila generally required less than 2 days while penetration through seed coats with sealed hila required 4-5 days, with cultivar differences.

Tests of phenolic compounds for their ability to inhibit A. parasiticus growth and aflatoxin production revealed that growth inhibition in liquid culture was greatest with tannic acid, catechol, and methyl catechol. Aflatoxin production was significantly inhibited by methyl catechol, naringenine, and umbelliferone. Hydrobenzoic acid and shikimic acid had limited influence on Aspergillus growth. Extracts of tannins from seed coats of the peanut cultivar Tx798736 caused the greatest inhibition of aflatoxin production.

Examination of peanut planting seeds from twenty-four villages in Senegal revealed that a high proportion of the seed are infested with A. flavus and A. niger. The variety SN 73-33 was the most heavily infested and GH 119-20 the least infested.

2. Dr. Timothy D. Phillips - Department of Veterinary Public Health, Texas A&M University, College Station, TX.

The successful installation and utilization of a modular high pressure liquid chromatograph at the Institut de Technologie Alimentaire (ITA) in Dakar, Senegal has been used to facilitate the detection, quantitation, and confirmation of mycotoxins in

peanuts and peanut products.

Advised the research staff in Senegal and supervised the graduate training of Ahmdoul Bashir Sarr at Texas A&M. Research developed fundamental and advanced concepts for detection and detoxification of mycotoxins.

Discovered that certain clays can be used for the field-practical removal of aflatoxins (and associated toxicity) from contaminated raw peanut oil in Senegal.

Discovered that in vitro biological systems (i.e., cultures of Hydra attenuata and postimplantation rat embryos) may be utilized to detect, confirm and rank mycotoxins according to developmental hazards. These systems may facilitate the rapid prioritization of mycotoxins for teratology testing, and the elucidation of molecular mechanisms of teratogenesis.

The discovery that the mechanism of formation of aflatoxin Q_1 (an important metabolite of aflatoxin B_1) is through the 9-hydroxylation of parent aflatoxin, catalyzed by liver microsomal cytochrome P-450p.

Developed and evaluated a new method for the rapid detection of mycotoxins (eg., SAM). Simple screening tests such as SAM for the detection of aflatoxins may facilitate prevention through effective monitoring programs that allow for the diversion of contaminated crops and animal feeds in West Africa.

The discovery of a dietary additive (NovaSil™) that significantly protects swine and poultry from aflatoxins. This substance (generically classified as a phyllosilicate) acts to neutralize aflatoxins via tight binding (chemisorption) in the gastrointestinal tract of animals, thus reducing bioavailability to target organs such as the liver.

3. Dr. Ralph D. Waniska - Department of Soil and Crop Sciences, Texas A&M University, College Station, TX.

Biochemical analysis of peanut testa and cotyledons from cultivars varying in degree of resistance to the Aspergilli were analyzed for free phenolic compounds and phenolic acids. Seed coats from cultivars which produce lighter colored seed coats had increased levels of phenols, however, these higher concentrations failed to correlate with resistance to A. flavus or reduced presence of aflatoxins. Extracts from peanut testa, and several phenolic acids inhibited A. flavus and A. parasiticus growth in vitro.

Extraction of phenolic acids from peanut shells and seed coats using HPLC revealed the presence of compounds tentatively identified as; protocatechuic acid, gentisic acid, methyl

catechol, p-hydroxybenzoic acid, vanillic acid, catechol, methyl catechol, epicatechin, syringic acid, umbellifermone, p-coumaric acid, protocatechuic acid, ferulic acid, and cinnamic acid. Several unidentified peaks were also present.

4. Dr. Raul G. Cuero - Agricultural Research, Prairie View A&M University, Prairie View, TX.

Discovery that chitosan applications to viable seeds at certain temperatures, water activities, and incubation periods influence induced defense responses of these seed to invasion by the mycotoxin producing fungi and also appear to influence the ability of these invading fungi to produce mycotoxins. Chitosan effectiveness is influenced by moisture levels and associated micoorganisms.

TRAINING

Technical short term training of international staff---3
Graduate student
Foreign - Ph.D. or M.S.----------3
United States - Ph.D. or M.S.----------2
Technical training of U.S. undergraduate students------3

LINKAGES

Peanut Variety Improvement TX/BCP/BMMS
Insect Management GA/IM/BF
Food Technology AL/FT/BF
Institut Senegalais de Recherches Agricoles (ISRA, Senegal)
Institut de Technologie Alimentaire (ITA, Senegal)
Societe de Commercialisaton des Oleagineux du Senegal (SONOCOS Senegal)
Institut de Recherches sur des Hules des Oleagineux (IRHO, France and Senegal)
Office de la Recherche Scientifique et Technique Outre-mer (ORSTOM, France and Senegal)
Socciete de Developpement et de Vulgarisation de l Agriculture (SODEVA, Senegal)
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, India and Niger)
Food and Agriculture Organization of the United Nations (FAO, Rome, Italy)

PRIORITY CONSTRAINTS:

Mycotoxin Hazards to Health

Mold damage and mycotoxin contamination of peanuts and peanut products poses a serious health hazard to animal and human health. Mycotoxin management involves prevention of contamination, monitoring mycotoxin levels in peanut products,

and diversion of contaminated products for cleanup and/or detoxification.

GOAL

The goals of the Peanut CRSP mycotoxin management research 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, and improved production, harvest, storage, and processing procedures will help reduce the costs of excessive processing to remove the mycotoxins. For those peanuts which still contain mycotoxins the goal is to develop improved inspection and diversion procedures, and cleanup and detoxification procedures which will reduce the levels of mycotoxins present within peanut and peanut products thus assist in meeting governmental safety standards.

RATIONALE

Progress has been made in selecting peanut genotypes and cultivars with increased levels of resistance to the Aspergilli and aflatoxin contamination. Improved detection procedures have been developed with are quick, accurate, economical, and can be used within the developing countries without refrigeration. Detoxification of peanut products has been accomplished through the utilization of sorbents such as the aluminosilicates (modified clay-like materials) which bind aflatoxin so tightly they are unavailable in animal metabolism. In order to prevent or reduce the levels of aflatoxin contamination of peanuts within the field and storage facilities continued efforts are needed to select aflatoxin resistant peanut genotypes for use in developing resistant varieties. Continued efforts are needed to develop procedures which detect more than one mycotoxin simultaneously. Expanded efforts are needed to experimentally determine the ability of different sorbents to bind aflatoxin and other mycotoxins within peanut products consumed by animals and man. These experiments must consider any harmful effects the sorbents may have on health.

OBJECTIVES

Host Country and U.S. (Long-term, see page 16)

1. To characterize the life cycle of A. flavus and A. parasiticus and determine factors which are capable of reducing the inoculum potential of these fungi within the soil.

2. Determine when peanut plant parts (e.g. pegs, pods and kernels) are invaded by aflatoxin producing fungi, and determine the extent to which such invasion correlates with

aflatoxin contamination.

3. To screen peanut cultivars and genotypes under field conditions for tolerance (resistance) to invasion by the aflatoxin producing fungi.

4. To characterize preformed and fungal induced defense mechanisms (molecular markers) within peanut plant tissues, and determine their effectiveness in restricting fungal invasion or mycotoxin production and value in breeding for resistance.

5. Develop interdisciplinary efforts to discover production, harvesting, and curing practices which can minimize mycotoxin contamination of peanut seed.

6. Develop rapid, economical, and safe mycotoxin detection systems for diversion of contaminated peanuts into processing for cleanup and/or detoxification.

7. Develop safe and efficacious methodologies for the detoxification of aflatoxin-contaminated crude peanut oil and peanut products used in animal feeds and human foods.

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

PLANS PROPOSED

Research - Senegal

1. Dr. Amadou Ba - ISRA - Kaolack, Senegal.

A. Field plots will be established to determine the influence of soil amendments and cropping practices on the incidence of aflatoxin producing fungi in the soil, and aflatoxin contamination of peanut kernels.

B. Peanut plant parts will be examined for the presence of the aflatoxin producing fungi in order to determine at what time during the growing season these fungi enter plant parts and the developing seed.

C. Field trials will be set up in replicated treatments to screen various peanut germplasm, breeding lines, and plant introductions for resistance to the aflatoxin-producing fungi.

D. Detoxification experiments will be established in collaboration with ITA in order to determine the ability of aluminosilicates to bind aflatoxin in peanut

products, and render them safe for consumption.

2. Dr. Amadou Kane - ITA - Dakar, Senegal.

A. Continue the collaborative studies with ISRA on screening peanut cultivars and breeding lines for resistance to aflatoxin contamination.

B. Microbiological studies will be initiated to determine the interrelationships of microorganisms commonly found associated with peanut kernels. Emphasis on the isolation, and testing of fungi or bacteria which inhibit A. flavus growth, or aflatoxin production.

C. Newly developed mycotoxin detection techniques will be tested in order to discover methodologies which: reduce the costs of mycotoxin analyses, and time required for each analysis; insure safety within the laboratory, and are sufficiently accurate to divert poisonous foods or feeds into detoxification procedures.

D. Detoxification studies will continue using various sorptive aluminosilicates (eg. attapulgite, bentonite, and other clay-like materials consumed by women in West Africa) to determine their effectiveness in binding aflatoxin, their practical value in reducing aflatoxin levels in peanut oil, and their usefulness as additives to animal feeds and human foods such as "mafee". Also the influence of local cooking practices will be studied to determine their ability to reduce aflatoxin levels in mafee. In each study the chemical quality of the detoxified products will be compared with non-treated, and industrially processed products.

E. Continued efforts will be made to monitor the levels of mycotoxins within the preferred roasted peanuts marketed and consumed by the urban and rural populations within Senegal. Peanut samples will be routinely collected from the markets in various regions of the country, each sample segregated into damaged, and sound kernels. Aflatoxin levels will be determined, and records maintained on the levels of aflatoxin present in each subsample.

Research - United States (Texas)

1. Dr. Robert E. Pettit - TAMU - Plant Pathology.

A. Efforts will be directed towards gaining an understanding of the ecology of A. flavus and A. parasiticus survival structures within peanut soils, and crop residues, as influenced by the type of plant residue, and various cultural and production practices.

B. Field plots will be established with several different

peanut genotypes to evaluate the susceptibility of different peanut plant parts to invasion by the aflatoxin producing fungi, and possible aflatoxin contamination.

C. Continued efforts will be directed towards a search for molecular components of peanut plant parts (eg. pathogenesis related proteins, phenolic acids, and isozymes) which correlate with the production of phytoalexins, and other defense mechanisms.

D. Microplot and greenhouse experiments will be established to determine the degree to which peg invasion influences the incidence of Aspergillus invasion into peanut kernels, and resultant aflatoxin contamination.

2. Dr. Timothy D. Phillips - TAMU - Veterinary Public Health.

A. Emphasis will be placed on the development of new applications of SAM technology for the detection of important mycotoxin in foods and feeds in Africa. Briefly, the effectiveness of newly developed configurations of SAM will be determined. Optimal SAM assays will be compared with other methods of mycotoxin analysis (e.g., immunoassay, minicolumns, and high pressure liquid chromatography) as a function of speed, sensitivity, specificity, and accuracy.

B. Continue studies on the detoxification of aflatoxins with emphasis on applications of NovaSil™ (a high affinity chemisorbent for aflatoxin) in peanut meal and animal feeds in Africa. Ammoniation of peanut meal, currently being utilized in West Africa, has several disadvantages (e.g. formation of potential toxic and mutagenic products of aflatoxin). In our studies, NovaSil will be tested for its ability to bind the major ammoniation products of aflatoxin, and to prevent their mutagenicity and toxicity. We will compare the safety and effectiveness of various combinations of ammonia and/or NovaSil in order to determine an optimal detoxification protocol for commercial application in Senegal.

C. Tests will be established to rank target chemicals (representative mycotoxins) according to their teratogenic potency using cultures of adult Hydra attenuata and regenerating hydra "artificial" embryos. Positive responses will be categorized as coaffective or intrinsic teratogens. Those intrinsic chemicals will be tested in cultures of extracorporeally maintained, postimplantation rat embryos. These findings will be compared with results from the hydra assay and animal feeding studies in order to: 1) determine the sensitivity and predictive ability of the hydra and rat embryo assays, 2) compare embryonal dosimetry in vitro and in vivo, and 3) prioritize mycotoxins in accordance with their developmental toxicities.

3. Dr. Ralph D. Waniska - TAMU - Soil and Crop Sciences.

A. The presence of phenolic barriers to invasion by pathogenic fungi will be investigated by analyzing phenolic compounds during the growth, and development of peanut pods of resistant, and susceptible cultivars. The shells, testae, and cotyledons will be separated at different developmental stages and analyzed for free and bound phenolic compounds (including tannins). These analyses should indicate which tissues and which developmental stages contain inhibitory levels of phenols.

B. The fungistatic activity of phenolic compounds analyzed above will be determined in vitro assays. The bioactivity of several extracts from peanut tissues during development will be determined. These activities will be correlated with the activities of individual phenolic compounds to confirm that appropriate inhibitors are being extracted and quantified.

C. Peanuts will be grown with different levels of A. flavus or A. parasiticus to determine if specific compounds are induced by the fungus. Phenols will be determined at various stages of development in peanut tissues that contained fungistatic activity. Treatment of peanut kernels and other tissues with chitosan (in collaboration with Dr. R. G. Cuero) will be analyzed to determine the effect on fungistatic activity and reduced aflatoxin production. The information acquired will be correlated with related protein and isozyme studies conducted in other laboratory studies (in collaboration with Dr. R. E. Pettit).

D. Various tissues from plants of specific peanut cultivars will be analyzed for inducability of phenols in response to A. flavus or A. parasiticus produced stress. Phenolic compounds will be analyzed in tissues that appear to provide a biochemical barrier to fungi. These experiments will utilize information from the earlier experiments to efficiently differentiate cultivar susceptibility. Cultivars and breeding lines with biochemical barriers will be utilized in resistant variety development.

4. Dr. Raul G. Cuero - Agricultural Research - Prairie View A&M University, Prairie View, Texas.

A. Peanut kernels from cultivars and breeding lines with potential resistance to invasion by A. flavus will be inoculated with varied inoculum concentrations. Test kernels will be subject to different water activity levels, relative humidities, temperatures, treated with chitosan and other microorganisms, and then incubated for different time intervals. Data will be analyzed to determine the range of conditions optimum for A. flavus and A. parasiticus growth and aflatoxin development with each test cultivar. Genotypes which resist fungal invasion and/or aflatoxin formation will be used in

other laboratory, greenhouse, and field plot experiments.

B. Peanut kernels maintained under environmental parameters within the laboratory, similar to those employed in "A", will be treated with various levels of chitosan concentrations to determine the ability of chitosan to trigger biochemical defense mechanisms within the kernels.

C. Greenhouse experiments will be conducted in pasteurized soil amended with Aspergillus flavus inoculum and other microorganisms (at different temperatures) to determine the ability of chitosan to induce potential defense mechanisms within peanut seed of different cultivars. Assays will also be conducted in vivo and in vitro on kernels attached to living plants grown in the greenhouse, field and in the laboratory, respectively.

D. Based on the outcome of the above experiments, additional field plot trials will be established to determine the potential of treating peanut seed with chitosan, to trigger defense mechanisms of the plant, to protect the developing plant, pods, and kernels from invasion by Aspergillus spp. Aflatoxin assays will be conducted on mature seed from each experiment.

TRAINING (1990-1995):

Technical short term training of international staff-------5
Graduate student training
Foreign - Ph.D. or M.S.----------3
United States - Ph.D. or M.S.----------4
Technical training of U.S. Undergraduate students----------5

Conferences - Regional Groundnut Meetings (ICRISAT - Sahelian Center, Niamey, Niger) in 1990 and 1993 (check dates)

International Workshop on Aflatoxin Contamination of Groundnut - Location to be determined

BENEFITS

In Senegal - Reducing the levels of aflatoxin in Senegalese grown peanuts 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 peanuts into processing for clean up and/or detoxification. Development of improved marketing procedures, those which provide an incentive for producing aflatoxin- free peanuts, will help encourage implementation of aflatoxin preventive measures and removal of mold-damaged kernels previous to processing. Newly developed aflatoxin sorption methodologies will allow local villagers 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 peanuts at the village level.

In United States - Research results will lessen the impact of the aflatoxin problem to the peanut industry in the U.S. Newly developed aflatoxin resistant peanut cultivars, adapted to the peanut growing regions of the United States, could greatly reduce the number of Segregation III peanuts marketed within the country. Marketing of peanut kernels 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 costs related to the diversion of contaminated peanut lots. Newly discovered sorption techniques to bind and inactivate aflatoxin, 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.

ORGANIZATION/PERSONNEL

A. Senegal

Institut Senegalasis de Recherches Agricoles

Dr. Mohamadouh Ly
Le Directeur General

Dr. Limamoulaye Cisse
Directeur
Department des
Productions Vegetales

Dr. Amadou Ba
Technologist

Mr. Jean Claude Mortreuil
Selectionneur

Institut de Technologie Alimentaire

Dr. Mouhamadou Diop
Le Directeur General

Dr. Ababacar N'Doye
Directeur Researches

Dr. Amdaou Kane
Chef du Laboratoire des Mycotoxines

B. Texas

1. Texas A&M University

Dr. J. Artie Browning
Department Head and
Research Administrator

Dr. Timothy D. Phillips
Co-Principal Investigator

Dr. Robert E. Pettit
Principal Investigator

Dr. Ralph D. Waniska
Co-Principal Investigator

Mrs. Ruth Ann Taber
Cooperator

Dr. Olin D. Smith
Cooperator

2. Prairie View A&M University

Dr. Raul G. Cuero
Co-Principal Investigator

TIME TABLE FORMAT

Objectives No	1990/91	1991/92	1992/93	1993/94	1994/95
1					
2					
3					
4					
5					
6					
7					
8					

JUSTIFICATION

Increased funding is required to maintain proposed research and operational activities. Proposed budgetary requests will offset inflationary increases which affect supply and service expenditures, provide for the cost of living increases for graduate students and support staff, and help cover the increased indirect costs approved within the University.

An urgent need exists within the Mycotoxin Management project to increase the funding for research activities within Senegal. Proposed increase is from approximately $35,000 to $75,000.

Funds are requested for training of an additional graduate student.

To improve communication and training of staff additional travel funds are requested. Increased travel funds will aid in scheduling annual planning sessions either in Texas or Senegal.

Sustainable Agriculture

Discovery of production practices which prevent aflatoxin contamination of peanuts during production and harvesting will help reduce production costs and help maintain product quality.

The development of peanut cultivars with increased resistance to aflatoxin contamination will help reduce production costs.

Discovery of detection procedures which are more efficient and less costly will ultimately reduce marketing costs.

Development of more efficient detoxification procedures will also reduce marketing costs and provide the consumer with foods and feeds which are free of toxins, thus safe for consumption.

New Thrusts

A description for a proposal approved for funding under new thrusts follows.

SHORT PROPOSAL

Timothy D. Phillips, PI
College of Veterinary Medicine, TAMU

PROJECT CODE: Peanut CRSP TX/MM/S

SUBJECT/TITLE: Aflatoxin Chemisorption: Prevention of Aflatoxicosis in Animals and Aflatoxin Residues in Food of Animal Origin with NovaSil™ and Similar Aluminosilicates

INTRODUCTION: Aflatoxins comprise a structurally similar group of naturally occurring, fungal-elaborated poisons that have been strongly implicated as chemical progenitors of disease in man and animals. Consequently, there is a growing awareness of the dangers of these incredibly potent substances as frequent contaminants of food and feed. A recent discovery in the Department of Veterinary Public Health has led to an exciting new approach to the detoxification of aflatoxins (i.e., the use of chemisorbents in the diet that tightly bind and immobilize aflatoxins in the gastrointestinal tract of animals, resulting in a major reduction in bioavailability and toxicity). NovaSil, or HSCAS (hydrated sodium calcium aluminosilicate) exhibited a high affinity for aflatoxin in vitro. Our preliminary studies (in vivo) demonstrated that NovaSil prevented the effects of aflatoxin in chickens and swine and significantly decreased the level of aflatoxin M_1 in the milk from lactating dairy cattle. Clearly, this new approach to the detoxification of aflatoxin and reclamation of contaminated grains and animal feed may foster the development of "safe and practical" procedures for the preventive management of these important chemicals. Funding is requested to expedite this effort through a collaborative research liaison between the College of Veterinary Medicine (Texas A&M University), the USDA/ARS (College Station, Texas), the Cooperative Agricultural Research Center (Prairie View A&M University) and the goat and sheep research programs in Burkino Faso, West Africa.

OBJECTIVES: Studies are herein proposed to elucidate the mechanism(s) responsible for this action and to thoroughly access the ability of NovaSil and similar high affinity chemisorbents to prevent aflatoxicosis and aflatoxin residues in experimental animals (e.g., dairy goats, dairy cattle, and poultry). The effectiveness of test materials will be determined as a function of aflatoxin binding, specificity, chemical stability, reactivity and safety. Specific objectives include: 1) Characterize the specific reaction sites and molecular mechanism(s) associated with aflatoxin chemisorption by NovaSil, 2) Assess the safety and efficacy of NovaSil and similar chemisorbents: feeding studies in sheep, goats and poultry; meat and milk residue studies in dairy goats and cattle, and environmental fate of the NovaSil/aflatoxin sorption complex, and 3) Evaluate the chemical stability of NovaSil in animal feeds.

RESEARCH PLANS: All in vitro studies (Objectives 1 and 3) will be carried out in the PI's laboratory (Texas A&M University) in accordance with established chemical and analytical methods for the testing of aflatoxin chemisorption. Animal safety and residue studies (Objective 2) will be initiated in Burkino Fasa, West Africa. Additional studies will be carried out at Prairie View A&M University and at the Veterinary Toxicology laboratories of the USDA/ARS (College Station, Texas). All research will be designed to follow appropriate guidelines for the care and use of experimental animal subjects and the safety of hazardous chemicals.

ADDED PERSONNEL:

Roger B. Harvey, DVM, MS (Co-Investigator); Veterinary Medical Officer, USDA/ARS, College Station, Texas; Expertise: Veterinary Toxicology (Mycotoxicoses in chickens, swine, goats and cattle).

Beverly A. Clement, PhD (Co-Investigator); Research Associate, Texas Agricultural Experiment Station; Expertise: Natural products synthesis and spectral elucidation of structure (GC/quadrupole MS, FT-NMR, FT-IR).

Ernest A. Smith, PhD (Co-Investigator); Research Scientist, Cooperative Agricultural Research, Prairie View A&M University; Expertise: In vitro biological assays to rapidly detect and predict the safety of mycotoxin-contaminated food and feed.

Ahmedoul Bashir Sarr, MS (Collaborator); Graduate Student, Veterinary Public Health, Texas A&M University; Expertise: Detection and Detoxification of aflatoxins.

SUBJECT CODE: TX/MM/S

BUDGET - SHORT PROPOSAL

Category	1990/91	1991/92	1992/93	1993/94	1994/95
Salaries	-0-	-0-	-0-	-0-	-0-
Fringe Benefits (24%)	-0-	-0-	-0-	-0-	-0-
Equipment	-0-	-0-	-0-	-0-	-0-
Supplies	12,200	12,200	12,200	12,200	12,200
Travel	8,400	8,400	8,400	8,400	8,400
Other Direct Costs	5,000	5,000	5,000	5,000	5,000
Sub Total	25,600	25,600	25,600	25,600	25,600
Indirect Costs - Local (43%)	11,008	11,008	11,008	11,008	11,008
Total U.S.	36,608	36,608	36,608	36,608	36,608
Burkina Faso Budget + 30% Indirect Costs	13,350	13,350	13,350	13,350	13,350
Total Burkina Faso	13,350	13,350	13,350	13,350	13,350
Total AID	49,958	49,958	49,958	49,958	49,958
Cost Shared Funds (25%)	12,490	12,490	12,490	12,490	12,490
GRAND TOTAL	62,448	62,448	62,448	62,448	62,448

Project Code: AAM/FT/S,BF

Project Title: An Interdisciplinary Approach to Optimum Food Utility in SAT (Semi-Arid Tropic) Africa

Bharat Singh, Principal Investigator, AAMU

INTRODUCTION

This project was established in 1982 to address the constraints of peanut utilization in SAT Africa. Initially, consumption and postharvest surveys were conducted in Sudan, one of the major peanut producing countries in the SAT region of Africa, to determine the current and potential dietary role of peanuts in Sudan and also to assess postharvest practices that impact the supply of peanuts including storage techniques. Results of the survey indicated that peanuts are widely used in Sudan in various forms. The most commonly utilized form of peanut was roasted peanuts followed by ground peanut paste. The data also indicated that there was need for research to (a) increase utilization of peanut into more refined/processed forms, (b) improve packaging to increase shelf-life of peanut products, (c) utilize peanut flour (after removal of oil) to increase value of cereal-based foods, and (d) improve the methods of storage and handling of peanuts and peanut products. Research was conducted both at Alabama A&M University and Food Research Centre (Sudan) to address the problem. Later, the project was established in Burkina Faso, where peanuts are widely used in various forms. It was also realized that the constraints of utilization of peanuts in SAT African countries were more or less similar. Additionally, the research during the first and second phase of the project will be applicable in Burkina Faso as well as other West African countries, such as Mali, Niger and Senegal. Considerations were also made for the fact that two other peanut projects (entomology and variety trial) exist at the same location and there could be a closer collaboration between projects.

Accomplishments

(a) Research:

(1) A study on fortification of a sorghum-based food product, "kisra" has been completed. Results indicated that acceptable kisra of nutritionally superior quality could be prepared from sorghum flours with 30% defatted peanut flour. Addition of defatted peanut flour resulted in improvements of baking-ease, color and texture of the final product. In addition, defatted flour enhanced the nutritive value as evidenced by increased protein, lysine, methionine and other essential amino acids and improved the protein digestibility of the product. As a result of these enrichments the ratio of leucine/isoleucine and leucine/lysine in sorghum-peanut composite flours has been altered

favorably, hence diminishing the pellagragenic characteristic of food products derived from the straight sorghum flour.

(2) Studies on effects of water- and steam-blanching and packaging materials on shelf-life, sensory qualities and nutrient composition of peanuts have been completed. Blanching by water or steam and using glass jars as packaging materials improved the stability and extended the shelf-life of peanuts up to three (3) months as evidenced by lower peroxide value. Steam-blanching was more effective in prolonging the shelf-life of salted roasted peanuts than water-blanching. Sensory evaluation data indicated that the freshly roasted unblanched peanuts were more preferred than the blanched roasted peanuts for texture, flavor and color. However, sensory evaluations of the stored roasted peanuts showed that the flavor scores of unblanched roasted peanuts decreased with storage time while the flavor scores of the blanched roasted peanuts were stable throughout the storage period.

(3) A study has been completed on development of a method to prepare a spiced, yogurt-like product called "mish" from the peanut milk. Usually "mish" is prepared from whole milk. However, results of this study indicated that acceptable mish could be prepared from peanut milk. The consistency, flavor and texture of this product were found to be similar to the traditional mish prepared from the whole milk.

(4) A study involving additions of partially defatted peanut flour into the formulation of sugar snap cookies replacing 20% of the normal wheat flour has been completed. Within the study design, various preparations of faba bean flours were included in cookie formulations, and sensory evaluation of the several experimental materials were contrasted to full wheat flour preparations. It was clear that the flavor of peanut was discernable in the cookies formulated with the peanut material and was no more acceptable than several of the faba bean formulated cookies and discernably less acceptable than the full wheat formulated product.

(5) Roasted confectionery peanut processes deemed appropriate for SAT Africa region were explored: a) An alternate method employing ceramic beads as a particle-bed heat transfer medium (in contrast to traditional efforts with sand as the heat transfer medium) was shown to produce acceptable product quality characteristics to the same degree as dry roasted processing employing an air media within a cabinet (tray) convection roaster. b) Of two bead sizes tried for the ceramic heat transfer media, those roasted in the larger beads (>2.45 mm) were judged to be equally acceptable in terms of confectionery qualities by sensory perceptions as peanuts roasted in the smaller beads of approximately 1.53 to 2.45 mm diameters. c) Confinement of the ceramic media in a deep, cast-iron frying pan or alternately in a wok pan were contrasted with better results coming in the frying pan as evidenced by less charring of the product because of a presumably more uniform heat distribution in

the former with more surface contacting the heat source.

(6) Peanut paste stability was studied by comparing the factors of preparation and storage in 2(5-1) half-fractional factorial design. It became clear that stability as monitored by peroxide values of the stored peanut pastes was not greatly influenced by milling method whether with traditional stone grinding processes or by an effort with a manually operated plate mill or by additions or omissions of chelator in the form of EDTA. Instead, the most outstanding effect was temperature of storage followed by the effect of storage in the presence of fluorescent lighting interacting with temperature (a negative interaction) and the effect of storage in the presence of air interacting with temperature (a positive interaction).

(7) Scientists at the University of Ouagadougou have completed analyses of peanuts grown in the year 1987-1988. The data include determinations of protein, fat, vitamins and aflatoxins.

(8) "Kuli-kuli", an indigenous Nigerian peanut-based snacking food, was investigated under various regimes of oil pressing versus a commercially produced partially defatted flour. Formulation variations were considered involving alternate levels of flours with water and oil to produce an extrudable soft form to be deep-fat fried for varying durations. Finished product forms were evaluated for color and texture (both objectively and by a sensory panel) and acceptabilities were judged by the panel. The results suggest a complex set of factors affecting the final forms and potential to investigate alternate formulations with cereal components to make a more durable (more marketable) alternate product.

(b) Training:

(1) Six students (1 U.S., 1 of Guayana, 2 Nigerian and 2 Sudanese students have completed their M.S. theses under this project on various aspects of peanut food products.

(2) The host country collaborators have visited Alabama A&M University and other parts of the U. S. to gain experience in research, peanut processing and handling. Scientists from Alabama A&M have visited and participated in research in Sudan and Burkina Faso.

LINKAGES:

Direct linkages have been established with the University of Ouagadougou in Burkina Faso through an MOU. The Principal Investigator has visited Mali and will establish linkages during this phase of the research.

PRIORITY CONSTRAINTS:

Underutilization of peanuts: to overcome the problems of protein and calorie malnutrition due to lack of applied and appropriate technologies to offer a variety and quality of peanut products and forms including (a) refining and processing operations, (b) systems of storage and packaging, and (c) methods of assessing product integrity and safety especially due to contamination by mycotoxins.

GOALS

General Goal

To foster interdisciplinary (nutrition, food science, social and economic) institutional-based linkages between U.S. and LDC scientists serving major peanut producing and consuming populations of the Semi-Arid Tropic region 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 which is to develop collaborative research and development program between Alabama A&M University and the University of Ouagadougou for greater utilization of peanuts as direct food through promoting the role of peanuts as food items in diets, improvement of existing food products and development of new peanut food products.

RATIONALE

Research on production and utilization of peanuts in SAT Africa is of vital significance because (1) peanuts play an important role in human nutrition in the SAT region of Africa and (2) there is an urgent need to reduce food shortage and combat malnutrition in this region. A combined effort by agronomists and food scientists should lead to achievement of the goal of self-sufficiency in food in this region.

OBJECTIVES

Long Term Objectives - Host Country

To increase the availability of peanut-based food products in SAT region of Africa by development of new forms and improvement of existing forms.

Short Term Objectives - Host Country

1. Research for the improvement of existing peanut products and the development of new peanut products with suitable energy density

and nutrient concentrations, with assurance of safety of the products considering naturally occurring toxicants (particularly referring to mycotoxins in raw and finished products), and with preferred tastes at acceptable cost.

2. Research for improvement of the preferred cereal- or tuber-based food products using peanut material as supplements.

3. Evaluation of the processing quality of peanuts in collaboration with agronomists.

4. Research to identify postharvest handling and storage problems and develop improvements of the techniques that can be applied.

Long-term Objectives - U. S. Institution

To further enhance an 1890 Land-Grant University's experience and capabilities in international programs especially in improving food utility within underdeveloped countries.

Short-term Objectives - U. S. Institution

To develop expertise in investigations of peanut materials in combination with other suitable commodities in the preparation of food forms to improve the diets of persons who may have particular access to the peanut commodity and products.

PLANS PROPOSED

Note: Items marked with single asterisk (*) are based on added capabilities availed by Expanded Funding (150% of level); Item marked with the double asterisks (**) is a special project.

I. Research:

Based on the discussion with the host country collaborators and previous research, the following research areas have been planned for this phase of the program:

A. Research for Improvement or Modification of Peanut Processing (Objective 1):

1. Roasting Peanut Processes: Roasting in SAT Africa is frequently done in sand or sometimes in ash. Peanuts roasted in sand or ash are not uniformly roasted. In addition, these peanuts are contaminated with sand or ash residues which affect acceptability. To improve roasting process, ceramic beads were used as a particle-bed heat-transfer medium. Of two bead sizes used for the heat-transfer media, peanuts roasted in the larger size (>2.45 mm) were judged to be equally as acceptable in terms of confectionery qualities of the nuts as judged by sensory

perceptions as those roasted in the smaller beads (approx. 1.53-2.45 mm diameter).

(a) Further studies are needed to investigate a suitable roaster, preferably a hand-driven, drum type design to contain the peanuts with the beads. Research on design, material and fabrication of the roaster will be conducted at Alabama A&M University and the University of Ouagadougou.

(b) Also, the sensory evaluation assessments on the roasted peanuts will need to be determined in the host country.

(c)* Efforts will be made to involve entrepreneurs who might produce the system (roaster and the beads) using indigenous materials.

2. Shelflife Improvement: Earlier research at Alabama A&M University indicated that blanching with water or steam extends the shelflife of roasted peanuts. However, sensory evaluation data indicated that the freshly roasted unblanched peanuts are more preferred than the blanched peanuts for texture, flavor and color. Investigations are in progress to determine changes in soluble components of peanuts affected by blanching methods.

3. Peanut Paste: Peanut pastes are one of the most commonly utilized product forms in Burkina Faso and other Sahelian countries like Mali, Niger, and Senegal. The following research has been planned on peanut paste.

(a) Quality of peanut paste: A survey of the quality of peanut paste produced in three regions of Burkina Faso will be undertaken. Preliminary data indicate that large variations exist in the quality, chemical composition, microbial contamination and aflatoxin contents. The research will continue with samples collected from 3 peanut growing areas of Burkina Faso. These variations appear to be due to the following considerations: (i) milling method, (ii) roasting process, and (iii) packaging systems.

(b) Shelflife studies will be conducted in host country: Plate-milled peanut paste will be compared with the products processed by traditional methods in Burkina Faso. To understand the milling, a plate mill has been tested for production of the paste. Even though the product had a higher level of metal contamination, the stability of the product was not significantly altered. Studies to date indicate storage temperature and interactions with light and air are prime components related to lipid oxidation of peanut pastes.

(c)* Implementation of milling process: The plate milling process will be introduced in Burkina Faso and studied including (i) quality and (ii) economic impact and market potential.

(d) Rheological properties of peanut butter: A study is underway to determine the rheological properties of peanut butter as influenced by processing parameters and ingredients. This research has immediate application in the peanut butter industry in the U.S.A. However, data will be used to evaluate the peanut paste produced in host countries also.

4.* Honey-roasted Peanuts - Roasted peanuts in Burkina Faso and other Sahelian countries are frequently sugar coated. Recently, honey production in Burkina Faso has been encouraged. Research is needed to evaluate the qualities of honey-roasted peanuts including organoleptic, nutritional and microbiological attributes. Available technology from the U.S. on the methods of production of honey-roasted peanuts will be adapted for the conditions in Burkina Faso. The evaluation of honey, quality of peanuts and controls in processing parameters will be made at the University of Ouagadougou.

5. Development of dairy substitute - Mish: At Alabama A&M, a study has been completed on development of a method to prepare a spiced, yogurt-like product called 'mish'. Acceptability of mish in Burkina Faso and other Sahelian countries will be tested.

6.* Development of fried peanut snack - Kuli-Kuli: Kuli-kuli an indigenous Nigerian food product made from partially defatted peanut pastes, formed by hand into shapes and then deep-fat fried. Studies have been completed on formulations using commercially available peanut flour in the U.S. The product may have an appeal in the confectionery market in the U. S. as well as in the host country. Research will be focused on the optimization of processing parameters, packaging and shelf-life of the product at Alabama A&M and also under the conditions of market places in Burkina Faso.

B. Improvements of starch-rich indigenous foods with peanut materials (Objective 2):

1. Fortification of cereal-based foods: Earlier studies indicated that utilization of defatted peanut flour improves the nutrient values of cereal-based food products such as breads, cookies, kisra and gari. Investigations will continue to enhance peanut flour utilization and to improve foods consumed in Burkina Faso and other Sahelian countries, like Mali, Niger or Senegal through additional fortification schemes.

(a) "Toe'," a product prepared from sorghum, is commonly used in Sahelian countries. Studies will be made to determine an

optimum level of peanut flour fortification, the shelf-life of such composite flours, suitable packaging materials and nutritional values of these modified forms.

(b) "Sorbet" is a semisolid food normally produced from sorghum. Studies will be conducted to determine suitable amounts of fortification with peanut flours.

(c)* A "couscous"-like product, in Burkina Faso, can be made from 'fonio', a cereal with small seeds (smaller than sorghum seeds) and peanut paste or sauce. This cereal is also used to produce baby foods. Studies will be conducted to determine a suitable level of peanut incorporation into this and other couscous forms or into baby foods.

2.* Extruded Products: A study has been planned to investigate suitable mixes of sorghum-peanut and/or maize-peanut to produce acceptable extruded products for consumption in SAT region. A series of studies will be planned to evaluate the incorporation of peanuts into extrusion cooked sorghum and maize preparations. Forms of the products to be investigated will be pulverized multimix meals (appropriate for reconstitution as mushes), finger food kibbles (similar to common snack foods) and an attempt at making a partially defatted peanut-based structured vegetable protein form (suitable to replace or extend meat components in entrees and soups).

As a plan of study in the first year of the project combinations of sorghum and peanut with appropriate investigations of seed preprocessing will be formulated to produce snack forms that have favorable organoleptic and nutritional qualities as made. Pulverized, dried meal forms will also be produced. In the second year storage and handling stability will be investigated using forms found promising (above) considering ratios of peanut oil in formulations, tendency of material to toughen and stale with starch retrogradation, durability to mechanical actions, and interactions with packaging and storage environments. This will be followed by studies in the third year when partial defatting of peanut with modified extruder-expeller barrels will be pursued in developing structured vegetable protein prototypes and crude peanut oil byproducts. The fourth year will include refinements of extruder-expeller configuration and optimization of the processes will be pursued in conjunction with preliminary evaluations of earlier prototypes brought to SAT Africa for counterpart and client evaluation. Adaptations of earlier research with sorghum will be pursued with maize and or other cereals (e.g., fonio) into the fifth year with stability and acceptability studies to optimize the formulations and processes.

At any period that sufficiently durable and acceptable prototypes are produced, samples of the same will be sent to SAT Africa locations for evaluation. Assessments of economic

feasibility will be pursued by contacts with government and private sector organizations to understand what additional focus should be pursued. Efforts to transfer the technology will be pursued where promising results seem evident.

C. Quality of Peanuts (Objective 3):

1. Quality of peanuts for processing: In collaboration with scientists in the variety trial project, samples have been analyzed to determine variations in chemical composition and aflatoxin contamination of peanuts grown at three locations in Burkina Faso. A program of evaluation of peanuts grown in 1988-1989 and subsequent planning periods under the variety trial project in Burkina Faso and Texas has been developed. Plant scientists will be responsible for sampling. The samples will be analyzed by the food chemists to determine the quality for confection or for processing. The data will be produced on a timely basis so that determinations can be made for the subsequent selections for the trial and variety releases.

2.* A similar plan will be established to evaluate peanuts grown in Mali and Niger. The detail plan for quality evaluation of peanuts in Mali will follow the protocol established in the year 1988-1989 in Burkina Faso and Texas. The capabilities of the laboratory at the University of Ouagadougou will be enhanced to handle samples from the trial in Mali and Niger.

D. Improving Postharvest Handling and Storage (Objective 4):

1.* Postharvest handling and storage: Research and development in post-harvest handling and storage systems are desirable to assure quality peanut food products in peanut producing areas of SAT Africa. Investigations will be conducted with introduced improved postharvest handling methods. Research is in progress to collect information on changes in nutrient compositions and aflatoxin contamination during storage in homes. It is expected that a model storage facility will be established to reduce losses and to avoid contamination of aflatoxin during postharvest handling and storage. A variety of appropriate structures will be considered and evaluated. If possible, efforts will be made to establish common controlled atmosphere facilities for storage - probably on a cooperative basis or by small entrepreneurs.

2.* Quality of peanuts during storage: In collaboration with entomologists, a study has been planned to study the changes of quality of peanuts during storage. It will include a study on insects, on mold contamination following infestation and on changes in chemical compositions. Possible methods of control using traditional methods will be investigated.

II. Training:

A. Currently three graduate students from SAT regions are working on their M.S. theses.

B. Two M.S. degree students will be trained in rotation during the five year period beginning 1990.

C.* In the year 1991-1992, one graduate student from Burkina Faso will begin his Ph.D program.

D.* Dr. Alfred Traore is planning to spend three months in 1990-1991 in the U. S. to conduct research on processing methods, analytical procedures and packaging methods.

E.* In 1991-1992 and subsequent years host country participants will be spending 2 weeks to 3 months at Alabama A&M University.

F. Alabama A&M scientists will conduct at least 1 workshop per year involving food scientists on methods of analyses and processing of peanuts. The duration of the workshop will range from 1-2 weeks.

Collaborations:

(1) Alabama A&M scientists have had discussions with ICRISAT scientists in Niamey and Hydrabad and plan to collaborate on quality evaluation and product development research in the SAT region of Africa. A detailed plan of collaboration will be established.

(2) Other Peanut CRSP projects: Peanut CRSP projects in Burkina Faso are already collaborating in areas of phytopathology, entomology and food science. Such collaborations will continue during this phase of the program (Ref.: quality of peanuts).

(3)**Inter-CRSP collaboration: A process is underway to develop collaborative projects with the bean/cowpea project at the University of Georgia and sorghum/millet CRSP project at Texas A&M. An informal collaboration with sorghum/millet CRSP at Texas A&M and Peanut CRSP at Alabama A&M has existed since the earlier phase of the project. A study on production of kisra (a Sudanese food product) using a sorghum and peanut flour blend has been completed. During this phase of the program, collaborative studies will be extended to the Bean/cowpea project at the University of Georgia also. Rationale for such program is based on the following considerations:

(a) Sorghum, peanut, cowpea and other legumes are grown and utilized throughout the SAT region of Africa.

(b) Preliminary work has already been done on products made from combinations of sorghum, peanuts or other legumes. The method of processing and preparations are such that food scientists working in three CRSP projects can easily collaborate and contribute effectively without changing their original goals of work.

(c) Interests in such projects from the host country collaborators are high.

Investigations on these composite flour forms and their products (indigenous or new) will be conducted both in the U.S. and in the host country. The host country will take responsibility for acceptability testing, market and economic studies.

Benefits Expected

Benefits to Host Country: Increased food intake of protein and calories due to an increase in the use of peanuts as a basic food component. Improved peanut processing and foods will allow increased efficiency of women in food preparation; and/or allow alternative income generation via cottage industries. Professional personnel will achieve greater competence in delivery of food process and product development with safe and wholesome qualities while the research capabilities of the university will be well established.

Benefits to U. S.: Graduate students together with faculty will experience greater awareness of utility and processing options for the peanut commodity and products in conjunction with other appropriate food resources. The institution will advance its position and respect in the area of international program contributions especially in food utilization projects. Any improved peanut processes will benefit domestic peanut industry.

Organization/Personnel:

USA

Alabama A&M University

Dr. Bharat Singh, Principal Investigator, Department of Food Science, Normal, Food Scientist.
Dr. John C. Anderson, Cooperator, Department of Food Science, Normal, Food Scientist.
Dr. D. R. Rao, Cooperator, Department of Food Science, Normal, Nutritionist.

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.
Dr. Alain N. Sawadogo, Director, I.S.N., Cooperator.
Mr. Herve Campaore, Food Technologist, Cooperator.
Mr. Francois T. Ouedraogo, Food Technologist, Cooperator.
Dr. Philippe Sankara, Phytopathologist, Cooperator.

Justification for Optimal Budget:

1. Maintain current activities in research and training at operational levels due to increased indirect cost at Alabama A&M (50.6% vs 26.9% on the U.S. budget and 26.5% vs 19.1% on the H.C. budget), salary increases (faculty, technicians & graduate students),and increased cost of maintenance of equipment and supplies.

2. If the project is not funded at the expanded level, the following activities will be curtailed and thus reduce the effectiveness of the project:

a) Efforts for the introduction of suitable roasting process, with consumer acceptance and economic feasibility studies;
b) Research on honey-roasted peanuts;
c) Shelflife studies and packaging methods for peanut paste;
d) Comparative studies on light and dark-colored peanut pastes;
e) Feasibility studies on fortified sorbet (a sorghum-based drink) and a couscous-like product using fonio;
f) Development of dairy-like products for consumption. Preliminary studies have already been made on a concentrated yogurt-like product. However, if the base-line funding is maintained, acceptance, shelflife studies and market studies cannot be conducted;
g) Development of kuli-kuli-like products will be delayed;
h) Studies initiated on extruded products using sorghum-peanut mixtures or corn-peanut mixtures may not continue;
i) Quality evaluation of peanuts for processing and aflatoxin contamination have been planned for both Burkina Faso and Texas. It is planned to be extended to Mali. These studies are essential for releasing varieties and are possible only at the expanded level of funding;
j) Evaluation of quality of peanuts during postharvest handling and storage cannot be realized;
k) Inter-CRSP collaboration in Mali has been planned only with an expanded level of funding;
l) There is a need for training of at least one Ph.D.-level scientist in addition to the training of the M.S.

scientists planned; however the higher level of training will not be afforded without the expansion of the budget;

m) Only with the expanded level of funding can the linkage with Mali including development of an MOU be brought to operation.

AAM/FT/S,BF Time Table of Program Activities
(Refer to Objectives and Work Plan Outlines for Encoding)

```
Research  Plan # 1990-'91 1991-'92 1992-'93  1993-'94  1994-'95
Objective
     1    A:1a,b ---------------------
            1c                      *******************
            2       ------------------
            3a      ------------------
            3b            ----------------------------
            3c                                 ********************
            3d      ------------------
            4                            *********************
            5                  *******************
            6                       ****************************
     2    B:1a    ------------------------------------------
            1b                        -------------------------
            1c                      *******************   2
     ************************************************
     3    C:1  ---------------------------------------------
     2         ***************************************************
     4    D:1,2***************************************************

Training
Objectives
          A    --------------*--*--*--*--*--*--*--*--*--*--*--*
          B    ------------------------------------------------
          C    ***************************************************
          D    ***
          E              ***       ***       ***       ***
```

Lines with asterisks are efforts dependent upon expanded funding only.

New Thrusts

A proposal approved for funding under the "new thrusts" follows.

<u>Project Code:</u> **AAMU/FT/CAR**

<u>Project Title</u>: **Collaborative Research and Training Program Between the University of the West Indies and Alabama A&M University**

Introduction

Scientists from Alabama A&M University and the University of the West Indies have completed studies on changes in fatty acid compositions of peanuts at various stages of maturity. Miss Margaret Hinds will be completing her Ph.D. from the University of the West Indies in June of 1990. A request has been made by the University of the West Indies to provide support to continue research on the post harvest and lipid components of peanuts. Such studies will be of significance not only to the Caribbean region but also be applicable to peanuts in SAT Africa. The study will include:

(1) Changes in lipid components including fatty acids, mono and diglycerides at various stages of maturity on peanuts grown at different locations.

(2) Field applications of the method of maturity indices in Eastern Caribbean region.

It is proposed that Peanut CRSP support Miss Hinds as a post-doctoral fellow for two years at Alabama A&M University. She will assist Peanut CRSP project at Alabama A&M University in SAT Africa as well as continue research relevant to Caribbean countries. This will also further develop Miss Hinds skills to assume the role of food scientist at the University of the West Indies, Trinidad.

BUDGET

	1990/91	1991/92	1992/93	1993/94	1994/95
Personnel	25,000	26,250	27,560	28,950	30,400
Materials/ Supplies	9,525	10,000	10,500	11,025	11,575
Travel	5,000	5,250	5,500	5,775	6,065
Total	39,525	41,500	43,560	44,750	48,040
Indirect Costs (26.5%)	10,475	11,000	11,550	12,125	12,730
Total USAID	50,000	52,500	55,110	57,875	60,770

PROJECT CODE: GA/FT/TP

PROJECT TITLE: Appropriate Technology for Storage/Utilization of Peanut

Larry Beuchat, Principal Investigator, UGA

INTRODUCTION:

To date, research efforts in this project have been directed toward investigating procedures for handling, sorting, packaging and storing peanuts in Thailand and the Philippines; emphasis has been to evaluate systems for reducing aflatoxin contamination and maintaining desirable sensory qualities. In addition, efforts have been expended to determine patterns of consumption of peanuts in Thailand and the Philippines. This has been accomplished through extensive surveys. A third major area of accomplishment has dealt with development of new and modified food products containing peanuts.

ACCOMPLISHMENTS

A. RESEARCH ACCOMPLISHMENTS

1. HOST COUNTRY: Thailand (Kasetsart University [KU])

a. Data from a survey of consumption patterns of peanuts in Thailand carried out by UGA and KU researchers revealed that the adult female is the household member who most significantly influences purchasing of peanuts. Consumption of peanuts varies by form, region and economic status.

b. Several products containing peanuts or peanut flour are in various stages of development and testing. One very promising product is Thai sausage supplemented with raw and roasted peanut flour. Sausage in which 25% of the ground pork was replaced by roasted peanut flour was preferred over the control formula.

c. A Kaset Peanut Bar containing fine and coarse ground roasted peanuts, ground dried cooked rice, coconut and sugar was developed which has highly acceptable flavor, aroma and color.

d. Preliminary results indicate that sommanut cake and infant foods can be supplemented with peanut flour without loss in sensory quality but with improved nutritive value.

e. Recommendations were made to farmers, shellers and marketers of peanuts concerning procedures for removing

aflatoxin contaminated nuts and maintaining aflatoxin-free nuts.

f. Peanuts (10 cultivars) obtained from the peanut variety improvement project at KU were analyzed for fatty acid content. The KUP-421 cultivar had highest protein (24-32%) and oil (39-59%) contents.

g. Oil-roasted peanuts are made from large or medium sized kernels. A shelf-life study was done for 6 months at 32°C and 25°C. The sensory quality was acceptable after 6 months. Roasted peanuts stored at 32°C produced higher peroxide contents than those stored at 25°C. Nevertheless, the taste panel did not detect rancidity in all samples.

h. Peanut spread was made by mixing peanut butter with tropical preserves, jam, fruit butter, or fruit paste. A spread containing a mixture of 20% fruit (banana, papaya and durian) powders and 80% peanut butter was highly acceptable. Sensory analysis showed that panelists preferred the banana-peanut butter spread.

i. A mixture of partially roasted peanut flour, rice meal, sesame meal, egg, sugar, full-fat dried milk, mashed papaya and natural orange flavor was processed into a supplementary food for infants. Results of sensory analyses show that the consumer panel rated all characteristics of infant food acceptable.

j. A chocolate flavored peanut beverage containing 3.5% peanut protein isolate, 3.5% fat, 8% sugar, 0.7% cocoa powder, 0.1% stabilizer and water was highly acceptable to to fifty-five untrained panel members. Formulation of a milk-shake type product based on peanut protein isolate may also be acceptable to Thais.

k. Sensory qualities of ground chicken extended with defatted peanut flours were determined. Cooking losses and shrinkage of extended ground chicken patties were less than those of control patties. Peanut flour increased water retention capacity. Pure chicken patties were less tender than extended patties.

l. A nutritious supplementary food for pre-school children was developed using partially defatted peanut flour, egg, milk powder, rice flour and papaya puree. The product is highly accepted by target consumers.

m. Fried peanut patties were collected in Bangkok and evaluated for physical, chemical, microbiological and sensory qualities. The results show that nearly all

samples were very poor in all respects of qualities.

n. Peanut tempeh was prepared from deskinned peanut. Sensory evaluation showed that flavored peanut tempeh was more acceptable than unflavored tempeh.

o. Ice-cream was prepared using peanut protein isolate to replace non-fat dry milk. Textural quality of peanut ice-cream was similar to the control. Consumer panels (50 panelists) preferred durian flavored peanut ice-cream over cocoa and jack fruit flavored products.

p. A mixture of peanut protein isolate, lactose and water fermented with a yogurt culture starter resulted in a product similar to milk yogurt except that it had a strong peanut odor. Strawberry flavored peanut yogurt drink was prepared from peanut yogurt and strawberry flavored syrup in order to reduce peanut odor.

q. A peanut industry in Thailand has adopted technology for processing oil roasted peanuts which was developed.

2. LINKAGE COUNTRY: The Philippines (University of the Philippines at Los Banos [UPLB])

a. A method for coprecipitating peanuts and soybeans to produce tofu was developed in the UPLB and UGA laboratories. A ratio of one part peanuts and two parts soybeans results in increased nutritional value of the protein over that in tofu prepared from only soybeans or peanuts.

b. The influence of steaming and roasting shelled peanuts on shelf-life at room temperature was evaluated. The sensory quality stability of roasted peanuts packaged using traditional practices was reduced considerably.

c. Defatted flour prepared from roasted peanuts has a significantly lower nitrogen solubility index compared to flour prepared from unroasted peanuts. Differences in this characteristic may enhance the use of roasted peanut flour in foods such as crackers, cereals and baby foods.

d. Various flavored curds can be successfully prepared from peanuts and peanut/soybean blends. The peanut residue produced in this process may have application as an ingredient in confections. A sauce formulation based on peanut was also evaluated for use as a meat and vegetable garnish.

e. A total of 84 samples of peanut products (representing

18 different products) were collected from the 13 regions of the Philippines. The source, region, province and manufacturer's name and address were recorded. A survey was also conducted to determine different uses of peanuts as food ingredients. Evaluation of each product included the product description and results of sensory evaluation. Improvement of several products will be based on information from the survey.

f. A total of 142 peanut samples (58 raw peanut kernels and 18 different peanut products consisting of 84 samples), collected from various regions in the Philippines were analyzed for aflatoxin content. Results of the analyses showed that 55.1% of the raw peanut seed samples and 27.3% of the products were positive for aflatoxin.

g. Mold isolates (159) from soil, water and air were screened at UPLB for their ability to inhibit A. parasiticus. A few strains of the A. niger group were capable of outgrowing A. parasiticus but the latter was able to recover in three days. Aspergillus fumigatus was another species capable of restricting the growth of A. parasiticus but it can be a more potent toxin-producer. A mold isolate possessing characteristics typical of Cladosporium fulvum completely suppressed the growth of A. parasiticus.

h. Chemical detoxification studies revealed the possibility of destroying aflatoxin in contaminated peanuts, though the appearance, color and texture are changed. UGA researchers affirmed that heating and blanching followed by separation of discolored nuts may have potential as a method for segregating aflatoxin-contaminated kernels.

i. Peanut milk containing a 1:8 (peanut:water) ratio was used in the production of yuba (peanut film). Glycerol at 1.0 and 2.5% levels was added and its effect on strength properties of films was determined. Increasing levels of glycerol caused an increase in breaking strength and a decrease in hardness of yuba. The amount of water used did not affect the chemical composition of films but tests for tensile strength revealed that the formulation with the least amount of water from both full-fat and partially defatted peanut milk produced the strongest films. Partially defatted films were generally stronger than full-fat films.

3. U. S. INSTITUTION: The University of Georgia (Department of Food Science and Technology, Griffin, GA [UGA])

a. The viability of peanuts stored for up to 11 months at 15°C is not affected by the CO_2 content of the atmosphere within sealed packages. Rates of adsorption and desorption of CO_2 from peanuts depend upon type of heat treatment and applications of coating materials.

b. Solar energy can be used very effectively to kill red flour beetles in peanuts, and may have application for disinfestation of a broad range of insects.

c. Consumer characteristics, food and nutrition related attitudes and perceptions of Thais living in the Atlanta, Georgia area toward peanuts and peanut products were determined using a questionnaire. Results suggest that a food product that can be classified under an everyday food category, such as milk or yogurt, or a spread such as jam or peanut butter, that is perceived as nutritious, convenient and provides good value, has the potential for being accepted by Thais.

d. A technique using immobilized papain to hydrolyze peanut protein was developed. Modification of protein by this treatment results in improvement in some physical and functional characteristics, thus enhancing potential use in food products.

e. A study was conducted to identify perceptions of Thai consumers toward peanuts and related products using a food/food use appropriateness matrix and to identify new peanut products that exhibit good potential for being accepted by Thais. Factor analysis resulted in two food groups (snack food and every day food) and three use groups (general use, special occasion and value/convenience). The snack food group was deemed appropriate for special occasions and children, while the every day food group was appropriate for general use and when concern existed about value and convenience. Three peanut-based products representing good potential for acceptance were identified as ice cream type, milk type and non-peanut butter spread type.

f. As part of an ongoing peanut utilization study in Thailand, a peanut-based spread product was developed and evaluated for sensory qualities by UGA researchers. Tofus coagulated with $CaSO_4$ and citric acid were used as base ingredients for the development of chocolate and tangerine flavored spreads, respectively. Optimization of amounts of ingredients (sugar, starch, colorants, and flavoring agents) in spread formulations was achieved using data collected from sensory evaluation tests.

g. Chinese-type noodles were prepared from what flour fortified with 7-21% defatted peanut and 4-12% cowpea flours were developed at UGA in conjunction with KU. Color and cutting force of supplemented noodles were affected negatively by cowpea and peanut flours, respectively. Sensory scores for 'firmness' and 'yellowness' of supplemented Chinese type noodles were decreased as the level of peanut-cowpea flours increased. Up to 15% peanut flour and 8% cowpea flour supplementation produced acceptable Chinese noodles while providing a high protein content (21%).

h. A non defatted peanut beverage (NDPB) and a partially defatted peanut beverage (PDPB) were developed. PDPB were rated significantly darker, more viscous and more chalky than NDPB. The NDPB samples homogenized at 3000 psi were rated lighter, and were characterized by greater particle size reduction than samples homogenized at 2000 psi. Sensory and objective measures were observed to be highly correlated.

i. Differences in sensory qualities of a peanut beverage processed for various times and temperatures were determined using analysis of variance techniques. Temperature had a significant effect on more sensory attributes than did time. Factor analysis was used to determine relationships among sensory qualities and gas chromotographic peaks of the headspace volatiles.

j. The general culture characteristics of Flavobacterium aurantiacum, a bacterium capable of removing aflatoxin from contaminated substrates, were defined. Growth in non-defatted peanut milk (NDPM) and partially defatted peanut milk (PDPM) was not inhibited by aflatoxin B_1 (1 mg/ml, AFB_1). The ability of F. aurantiacum to reduce the AFB_1 was determined by inoculating resting cells in contaminated phosphate buffer (PB), NDPM and PDPM. After 24 hr, the concentration of AFB_1 decreased about 40% in PB, 23% in NDPM, and 74% in PDPM.

k. Peanuts kernels and water extracts of peanuts were evaluated as substrates for lactic acid bacterial fermentation. Indications are that acceptable natto-like and yogurt-like products can be produced from peanuts.

l. The effects of acidification and glucose supplementation on fermentation of ammoniated peanut meal by Lactobacillus bulgaricus were studied. There appeared to be no significant differences in acid production between the treatments.

m. The effect of maturity and harvest time on mechanical properties of peanut kernels was studied. The hypothesis that peanut shell color can serve as a single index to group peanuts with similar mechanical properties was also tested. Results indicate that the mechanical properties of peanuts can be predicted from the maturity distribution of those peanuts.

n. A paste containing > 90% unroasted peanuts was developed. The ultimate use of this paste flavored with cheese, meat, fruit or chocolate would be in the form of a spread or filling for bread, crackers and confectionery items. The quality of pastes prepared from peanut kernels subjected to hot water treatment, steam and dry heat were compared. Hot water treatment produced a paste with lightest color and most bland flavor. Paste prepared from peanuts chopped to a particle size of 3.36 to 4.75 mm exhibited the most desirable sensory qualities. The flavor of pastes prepared from whole and chopped peanuts which had been subjected to heat treatment was compared with two commercial peanut butters and a paste made from raw untreated peanuts (control). The premium brand of peanut butter had the strongest roasted flavor while the pastes had significantly more beany flavor than the peanut butters but less than that in the raw control. A panel rated the paste as firmest, least adhesive, spread least on the tongue, least smooth, most grainy, and most difficult to swallow. Significant correlations were found between instrumental measures and sensory characteristics of spread, hardness and adhesiveness.

o. Six formulations of imitation cheese spread were prepared by mixing cheese flavoring, coloring, salt and buttermilk powder into a bland, light colored paste. Hedonic responses by 200 Filipino consumers to the formulations were obtained. Of the 6 formulations, two (4% flavoring/1% salt and 6% flavoring/0.5% salt) were preferred. Compared to commercial cheese spreads, the peanut-based samples had higher protein and oil contents and lower moisture indicating a more nutritious, potentially shelf stable product.

B. TRAINING:

In the area of training, four students from Thailand and the Philippines have been supported entirely or in part during the course of pursuing M.S. and Ph.D. degrees at UGA. Seven foreign national advanced-degree students from non-CRSP countries and four US students have conducted research in various areas outlined in the project. Six of these students were supported entirely by Research

Assistantships from resources other than the Peanut CRSP. Several students at KU and UPLB have received financial support and training from the Peanut CRSP.

Short-term trainees from KU and UPLB have come to UGA on several occasions. Visitations have ranged from one week to six months (one KU; one UPLB) and one year (one, UPLB).

LINKAGES:

During the original grant period, linkage with other CRSP projects was largely in the form of discussions and comparisons of research observations derived from U.S. and host country activities. During the current 3-year extension phase (FY 88-90), KU and UPLB researchers were allocated funds to carry out analytical and sensory quality evaluation of newly developed peanut cultivars emerging from the Peanut CRSP project (NCS/BCP/TP). This type of collaboration should be continued during the proposed 5-year extension (FY 91-95).

The UGA team will be cooperating with the Caribbean Peanut CRSP team (GA/PH/CAR) to evaluate the use of density segregation or the fluidized bed concept for segregation of aflatoxin-contaminated kernels from non-contaminated kernels.

Project researchers have participated and interacted with ICRISAT at three different workshops (one in Malang, Indonesia and two in Hyderabad, India) on peanuts as a human food. Future cooperative activities and consultation with ICRISAT, other international agricultural research centers and Peanut CRSP projects would serve to strengthen the global concept of the Peanut CRSP.

PRIORITY CONSTRAINTS TO BE ADDRESSED:

Peanuts are a good source of protein, fat, several vitamins and minerals for improving the nutritional value of foods in which they are incorporated. To date, emphasis on utilization of legumes as food ingredients has been directed toward soybeans. Limitations in utilization exist, however, due to undesirable "beany" flavor and flatulence problems associated with soybeans, even when subjected to various rigorous processing techniques. Peanuts, on the other hand, contain lower amounts of compounds responsible for beany flavors and are lower in oligosaccharrides which can cause flatulence.

Processes for utilizing peanuts in food products having high acceptability remain a major constraint in Thailand and the Philippines as well as in the U.S. In Thailand and the Philippines utilization has not been maximized due to cost, aflatoxin contamination and general lack of technologies for

incorporating them into the large number of food products extensively consumed in these and many other countries. Yet the potential for utilizing peanuts in foods which would be highly acceptable is substantial, as shown by extensive surveys done in Thailand and the Philippines during earlier phases of this project.

Utilization of peanuts in Thailand, the Philippines and the U.S. has largely been in the form of roasted peanuts, either consumed as such or in various confections, or in peanut butter in the U.S. Thus, a general lack of products containing peanuts, in whatever form, exists and must be considered as a major constraint to be addressed. Development of totally new and/or modified products such as spreads, soups, sauces, coffee/tea whitener, beverages, flans and fermented products containing substantial amounts of peanuts will be a major thrust in the proposed five-year research program. The rationale for developing these specific peanut products comes from documented evidence of the potential for acceptability of such products in Thailand and the Philippines based on surveys of socio-economic and demographic characteristics conducted during the original granting period. However, additional socio-economic and market demand studies need to be done, and increased efforts in these areas are integrated into the 5-year project.

Contamination of peanuts with aflatoxin also remains a major constraint to their utilization. In a survey conducted in 1987-88 by the UPLB Peanut CRSP team, aflatoxin was detected in 55.1% of raw peanuts and 27.3% of commercial peanut products. The presence of aflatoxin in Thai peanuts is also extensive. In the U.S., aflatoxin-contaminated peanuts are diverted to oilstock or fertilizer which results in reduced economic return to the farmer as well as the food industry. Unfortunately, highly contaminated peanuts sometimes find their way into animal feeds or are used in food products in Thailand and the Philippines as reflected by high levels of aflatoxin in, for example, peanut butter, at the retail level.

While aflatoxin-contaminated peanuts can be separated from sound peanuts using mechanical and human intervention, still there is no practical, affordable method to decontaminate rejected kernels which maintains sensory and nutritional qualities. The development of methods using relatively simple technologies to detoxify peanuts which, in turn, could be used as human food or animal feed urgently needs research attention.

Investment in development of human capital is viewed as absolutely essential to this project. The aspect of training and professional development of scientists at all cooperating institutions will receive major attention during the 5-year extension.

GOALS AND RATIONALE:

We propose to develop and adapt new technologies and processes to utilize peanuts and peanut products in traditional and new food products. The choice of such products will be based largely on socio-economic studies and consumer demand surveys, and also on intuition and insight to consumer behavior in Thailand, the Philippines and the U.S.

The need for devising simple, inexpensive procedures to remove and/or degrade aflatoxin in peanuts clearly exists. Such procedures would have application on a global scale.

The need for training of scientists and technologists to conduct meaningful peanut research and the transfer of technologies to the food industry becomes obvious and more critical as this project matures. Efforts in these areas are needed in Thailand, the Philippines and the U.S. Collaboration with individuals having expertise in marketing, socio-economics and psychobiology will be an integral part of the technology transfer phase of the project.

Development of the rationale for research needed is outlined in greater detail in Section VIII.

OBJECTIVES:

The proposed research is strongly mission-oriented. The objectives set forth are attainable during the five-year extension period and would be readily applicable in the U.S., Thailand, the Philippines and many other countries worldwide. Specific objectives are as follows:

A. <u>HOST INSTITUTION (KASETSART UNIVERSITY [KU])</u>

1. Conduct socio-economic and market demand studies on new and existing peanut products.

2. Develop peanut tempeh products acceptable to the Thai consumer.

3. Improve qualities of ground roasted peanuts, produce on an industrial scale and test for consumer acceptability.

4. Develop peanut product for tube feeding on industrial scale and test for consumer acceptability.

5. Produce peanut-extended chicken patties on industrial scale and test for consumer acceptability.

6. Produce fried peanut patties on industrial scale and test for consumer acceptability.

7. Develop nutritious snack foods using peanut flour.

8. Prepare textured vegetable protein fromlow fat peanut flour and evaluate as ingredient in traditional and vegetarian Thai food items.

9. Develop animal feed from good quality undersized peanuts.

B. LINKAGE INSTITUTION (UPLB)

1. Conduct socio-economic and market demand studies on new and existing peanut products.

2.a.i. Determine the influence of peanut cultivar and processing parameters on product quality.

2.a.ii. Monitor aflatoxin levels in commercial peanut and peanut products.

2.a.iii. Determine the effect of processing on aflatoxin content of peanut products.

3.a.i. Develop and evaluate snack foods, soups and sauces from peanuts which will be acceptable to Filipinos.

3.a.ii. Develop and evaluate beverages, flan, spreads and fermented products from peanut milk.

3.a.iii. Design, fabricate and test appropriate food processing equipment for making peanut milk products.

4.a.i. Study various chemical control procedures for degrading aflatoxins in peanuts.

4.a.ii. Study control of aflatoxin formation through microbial antagonism; elucidate mechanism of antagonism.

5.a.i. Introduce developed peanut products as prospective investment areas in small scale industry.

5.a.ii. Make available to small scale producers new technologies in peanut storage, handling and utilization.

C. U. S. INSTITUTION (UNIVERSITY OF GEORGIA)

1.a.i. Determine feasibility of replacement of protein

sources in coffee/tea whitener with peanut extract; study the effect of drying on physico-chemical properties and sensory characteristics of coffee/tea whitener prepared from peanut extract.

1.a.ii. Investigate methods for utilizing peanut flour.

1.a.iii. Investigate lactic acid bacteria for producing fermented milk products and fungi for producing fermented semi-solid peanut products; evaluate sensory and chemical characteristics of products containing fermented peanut milk.

2. Develop methodology for pilot scale processing of peanut paste and formulation of an imitation cheese spread from the paste; assess shelf life stability and determine feasibility of commercial processing of the peanut paste in the Philippines.

3.a.i. Optimization of bisulfite and sunlight (ultraviolet light) treatments to degrade aflatoxin in peanuts.

3.a.ii. Optimize ammoniation/fermentation procedures for degrading aflatoxin in peanuts.

3.a.iii. Investigate the use of foams and peroxide blanching to separate aflatoxin-contaminated peanut kernels from non-contaminated kernels.

3.a.iv. Determine quality attributes of detoxified peanut meals.

3.a.v. Run pilot plant and field trials to evaluate detoxification and separation techniques.

RESEARCH PLANS PROPOSED:

The major research thrusts of this proposal are two-fold. The first is to develop and evaluate sensory and nutritional qualities of foods and food ingredients consisting in part or entirely of peanuts. Technologies for preparing such products will include (separately or in combination), blanching, heating, freezing, extraction, coagulation, emulsification, extrusion, drying, milling and fermentation. Optimization and characterization of these processes will be achieved by subjecting products to trained sensory panels as well as untrained consumer panels and by instrumental, nutritional, chemical and microbiological analyses. Transfer of technologies from the laboratory to the pilot plant and finally

to commercial scale production of products will be our ultimate goal. Marketing specialists, socio-economists and psychobiologists will be involved with this phase of the project.

The second major research thrust is to develop methods to reduce or remove aflatoxins from peanut kernels using biological, physical and/or chemical technologies which will not render the kernels unpalatable or otherwise unsafe for human or animal consumption. Procedures to be investigated include application of chemical, biological and physical treatments of contaminated peanuts as well as the use of microbial antagonists of aflatoxin-producing fungi directly to peanuts to prevent aflatoxin production.

An overriding essential element of the project will be the development and enhancement of research capabilities of faculty, students and technicians at all collaborating institutions. Substantial attention will be given to the training component of the project.

Proposed research to be carried out at the Department of Product Development, Kasetsart University; the Institute of Food Science and Technology, the University of the Philippines at Los Banos; and the Department of Food Science and Technology, University of Georgia is as follows:

A. HOST INSTITUTION: KASETSART UNIVERSITY, BANGKOK, THAILAND

Two main thrusts will characterize the proposed KU research program. The first is to develop and evaluate peanut-supplemented foods, including both traditional and new products. Appropriate methods and techniques for administering a systematic product development process will include generation of product ideas, screening of the product ideas, business evaluation of product ideas, development of formulation and process, and testing of the

process, product quality, shelf-life, consumer acceptability and market acceptability.

The second major thrust involves transfer of technology for processing peanut products to the industry. Success in transferring technologies will depend on the product development system in the course of the project. Socio-economic and market demand studies will be an integral part of the technology transfer process.

Objectives are as follows:

1. CONDUCT SOCIO-ECONOMIC AND MARKET DEMAND STUDIES ON NEW

AND EXISTING PEANUT PRODUCTS

Technologies to improve traditional peanut products and to develop new products are in various stages of completion at this juncture in the project. Although considerable time and effort have been devoted to conducting surveys designed to determine utilization and consumption patterns of peanuts and peanut products, still specific improved and new peanut products need to be evaluated with regard to their socio-economic impact and consumer acceptability in the marketplace.

Methods for conducting such analyses would vary somewhat depending upon the location and specific product being tested; however, properly designed and executed market demand and socio-economic studies must be done by scientists with demonstrated expertise in these areas. Collaboration with these individuals is essential to the success and extent of technology transfer achieved in the proposed research program.

2. DEVELOPMENT OF PEANUT TEMPEH ACCEPTABLE TO THE THAI CONSUMER

Fermented foods are a significant part of the diet in some parts of the world, especially Southeast Asia and parts of Africa. These foods commonly contain legumes, oilseeds and/or grains, and make important contributions to the diet in the form of protein and some vitamins. Tempeh is a popular Indonesian food made from cooked dehulled soybeans by fermenting them with *Rhizopus oligosporus*.

Fermented peanut press cake (peanut presscake tempeh) has characteristics similar to soybean tempeh. Both products can be widely used interchangeably in various recipes. There is a need to develop tempeh-like products from peanut or peanut press cake. The products will be used as snacks or as ingredients in traditional foods to improve their palatability and nutritional quality.

a. OBJECTIVES

i. Develop peanut tempeh acceptable to the Thai consumer.

ii. Determine consumer acceptance of products containing peanut tempeh as an ingredient.

b. METHODOLOGY

Whole peanuts and peanut presscake will be fermented with Rhizopus oligosporus. The effects of type of peanut on physical, chemical and sensory qualities will be determined. An optimal process for fermentation will be developed. Fermented products will be then incorporated into snacks and subjected to consumer evaluation. Fermented products will also be used as ingredients in Thai foods in suitable forms (fresh or dehydrated). Quality characteristics of these Thai foods will also be determined.

3. IMPROVEMENT AND DEVELOPMENT OF GROUND ROASTED PEANUT AND TEST FOR CONSUMER ACCEPTABILITY

Ground roasted peanut grits is a traditional product made from small peanuts. It is used as an ingredient with sauces eaten with fried tofu, roasted squid, fried fish pattie and saté. A very popular dish is Tom Yum soup which contains equal amounts of ground roasted peanut, ground hot chili pepper and sugar.

Generally ground roasted peanut is made from low quality peanuts. The Department of Medical Science (Ministry of Public Health) reported that 95% of ground roasted peanut in Thai markets contained more than 20 ppb aflatoxin. Manufacturers use misshaped and dirty peanuts to prepare this product since identity of these peanuts is not evident in the finished product. Inspection of this product is not enforced because it is not sold in certified packages. Sometimes restaurants will serve it in regular server. Because of these problems, ground roasted peanuts have been given top research priority among products which might be contaminated with aflatoxin in Thailand. Problems associated with rancidity, nonuniform grit size, color and high microbial populations also characterize this product. There is a need to improve the qualities of ground roasted peanut products in order to decrease risk of public health and increase the utilization of peanut products.

a. OBJECTIVES

i. Determine safety and sensory qualities of ground roasted peanut in Thailand.

ii. Determine the most suitable grade of peanut for making ground roasted product as well as the best process for manufacture.

iii. Determine consumer acceptance and market potential of the product.

b. METHODOLOGY

Ground roasted peanut samples will be collected from markets at locations around country. Sensory qualities and aflatoxin content will be determined Specifications for ground roasted peanuts will be established and guidelines for production of the product will be prepared.

The effect of size of peanut kernels on qualities and cost of ground roasted products will be determined. Optimization of time and temperature of processing for obtaining good quality product will also study. The most acceptable size of grits will be determined. This study will also involve development of pilot processing equipment. The storage and packaging requirements of the product will be determined. The product will also be subjected to sensory evaluation as well as consumer evaluation to determine acceptability and marketability.

4. DEVELOPMENT OF A TUBE FEEDING PRODUCT AND TEST FOR CONSUMER ACCEPTABILITY

Patients suffering from upper gastrointestinal tract disorders often must be fed through by-pass systems directly to the stomach or small intestine using liquid diets. In Thailand, two types of such diets consist of commercial formulae and a blenderized feeding formula which is prepared in hospitals as needed. Commercial formulae are imported and very expensive. The preparation of blenderized formulae in hospitals is a time consuming process.

Peanut protein isolate holds potential as a protein source in the feeding formula to be developed because of its functional and nutritional properties. A formula has been developed in preliminary studies at KU using peanut isolate as a protein source. Physical, chemical, microbiological and sensory qualities were similar to blenderized formulae. In addition, good shelf-life at room temperature was observed.

a. OBJECTIVES

i. Develop a tube feeding product for patients requiring same.

ii. Determine consumer acceptability of the product.

b. METHODOLOGY

The proposed research will be done in three phases:

i. The first phase will involve process development and shelf-life studies on tube feeding products using peanut isolate as protein source. Quality characteristics of the products will be evaluated during this phase. Adjustment of formula and process will be done and packaging will be selected according to preservation needs and material cost.

ii. A prototype product will be processed in a commercial setting in Bangkok, Thailand. Materials

and technologies will be supplied through the project while industry will provide equipment for processing.

iii. Consumer tests will be conducted in various hospitals in Thailand. Nurses will be the target evaluaters of the product. They will be asked to comment on acceptability, degree of convenience to use, and purchase intention.

5. PILOT SCALE PRODUCTION OF EXTENDED CHICKEN PATTIES

Recent developments in utilizations of peanuts in meat products have dealt primarily with the performance of peanut products as meat extenders. Peanut flour, grits, protein concentrates, protein isolates and various textured protein products have been studied. Their behavior in frankfurters, bologna, meat loaves, meatballs, meat patties, Salisbury steak, luncheon meats and other similar items is of great interest.

Chicken patties extended with peanut flours were developed at KU in 1987-88. These products were test for physical and sensory qualities and were found to be acceptable to laboratory panels. The use of peanut flour in chicken patties offers potential for cost reduction as well as improved overall qualities of products. Consumer acceptance of the products will determine the success of the development scheme.

a. OBJECTIVES

i. Optimize a process for making chicken patties extended with peanut flour in terms of cost and sensory quality.

ii. Extend production of patties up to an industrial scale.

iii. Determine consumer acceptance of the product.

b. METHODOLOGY

Prototype extended chicken patties will be developed. Qualities and cost of the product will be determined. The fast food industry in Thailand will cooperate in this project. Industry will provide all necessary equipment and facilities for production of the patties while materials and technologies will come from the project. A consumer study will be conducted using the general population in Bangkok and nearby towns to determine acceptability and purchase intention. Data will be analyzed, and technology will be transferred to the fast food industry.

6. PRODUCTION OF FRIED PEANUT PATTIES ON AN INDUSTRIAL SCALE AND TESTS FOR CONSUMER ACCEPTABILITY

Sensory qualities of peanut patties were evaluated previously during the project. Results indicated that more than 80% of the samples collected in various places in Bangkok contained more than legal limit (20 ppb) of aflatoxin. Other characteristics such as color, size, texture, flavor and amount of peanuts in the samples varied depending on producer. Based on these studies, appropriate technologies for quality improvement and process development will be done on a larger scale and products will be tested for consumer acceptability. The transferring of such technology will assist many small scale industries and enhance the safety of products for Thai consumers.

a. OBJECTIVES

i. Produce fried peanut patties at industrial scale and evaluate the qualities of such products.

ii. Determine storage requirements and test consumer acceptance.

b. METHODOLOGY

Small scale industries will be contacted to request their cooperation in production of fried peanut patties. Industries would be requested to supply all necessary equipment and facilities for processing; the project will provide materials. Qualities of the products will be evaluated. Products will be produced for storage tests and consumer surveys. Workshops will be conducted to demonstrate the procedures for making patties. This will be done in cooperation with the Department of Industrial Extension, Ministry of Industry.

7. DEVELOPMENT OF SNACK FOODS CONTAINING PEANUT FLOUR

The Thais have had snacks as a part of the daily diet since ancient times. Scientists have classified traditional Thai snack foods and described how development of traditional snacks can be organized in Thailand. Since snack foods are an important part of the diet in Thailand, it was suggested that any development of new snack foods should carefully consider the nutritional value as well as eating quality of the snacks.

Extrusion provides a mechanism for transforming food materials into products having properties considerably different from the starting material. It may involve simply shaping the material into a new form by forcing it through a die or producing more complex alterations by the combining processes of shaping, texturizing, and cooking. Chiplike

products have been prepared from peanut meal with or without binders. These types of products were similar to corn or potato chips but contained a substantially higher level of protein. Acceptable high-protein corn curl snacks can be produced with 15 to 20% defatted peanut flour without significantly affecting bulk density or flavor. The development of snack foods from peanuts in Thailand will result in providing highly nutritious foods at low price to children from low income families.

a. OBJECTIVES

i. Develop high-protein snack products using peanut flour as major source of protein by using a systematic product development process.

ii. Determine consumer acceptability of the snack foods.

b. METHODOLOGY

Extruded and non-extruded snack foods will be formulated using linear programming to maximize nutrient content and minimize cost. Peanut flour will be used as a major protein source. A systematic product development process will be used. Quality characteristics including physical, chemical, nutritional and sensory will be evaluated at every step of development. Storage and packaging requirements will also be studied. Prototype products will be subjected to consumer tests to determine the acceptability and marketability.

8. DEVELOPMENT OF TEXTURED VEGETABLE PROTEIN FROM LOW FAT PEANUT FLOUR AND EVALUATION ITS USE IN VEGETARIAN FOOD ITEMS

Increasing numbers of Thais are becoming vegetarians because of religious preference and a desire to reduce cholesterol intake. Protein from soybeans contributes a very important part to the vegetarian diet in Thailand. Beef and chicken flavored Kaset protein are very popular.

Bologna-type meat analogs have been formulated from mixtures of comminuted meat and drum-dried peanut flakes. Meat analogs also can be prepared from peanut fibers and proteins by a wet spinning process that simulate the fibrous texture of meat fiber.

Development of meat analogs from peanut protein will result not only in making more meat analogs available but will also serve as the avenue to improve the nutritional status of the vegetarians in Thailand and other countries.

a. OBJECTIVES

i. Optimize the process for obtaining textured protein from peanut flour to be used in vegetarian foods.

ii. Determine sensory quality, consumer acceptability and market potential of vegetarian foods containing texturized peanut proteins.

b. METHODOLOGY

The effect of peanut flour:water ratio, type of equipment (village type texturizer and extruder), process time and temperature on qualities of texturized peanut protein will be determined. Utilization of the product in vegetarian foods will be investigated and foods will subjected to sensory evaluation. Acceptance by vegetarians in Bangkok will be determiend.

9. DEVELOPMENT OF ANIMAL FEED FROM GOOD QUALITY UNDERSIZED PEANUT

In Thailand and other Asian countries, oilseeds are mixed with corn, sorghum, vitamin supplements and minerals for use as animal feeds. According to our study in 1986, 10% of the undersized (under 15/64"x3/4") peanuts are aflatoxin-free. Undersized peanuts are not suitable for humans but may be used for oil extraction and animal feed. Development of new animal feeds using detoxified undersized peanuts will add value to this peanut segment.

a. OBJECTIVES

i. Formulate animal feed using peanut as a major source of protein and calories.

ii. Determine quality characteristics of the products.

b. METHODOLOGY

This project will be done in cooperation with the Department of Animal Science at KU. Animal feed will be developed using a linear programming model to maximize nutritional value and minimize cost. Products will be analyzed for physical, chemical and nutritional qualities. Packaging and storage requirements will also be investigated. A prototype product will be subjected to animal feeding trials. Determination of nutritional value will be conducted by the Department of Animal Science. Market potential will also be determined if performance of the feed is acceptable.

B. LINKAGE INSTITUTION: UNIVERSITY OF THE PHILIPPINES AT LOS BANOS

The major thrust of this research is to develop peanut-supplemented products and technologies to produce

them, and to transfer these technologies to the end user, whether on a family, village or commercial level. Appropriate socio-economic and market demand studies will augment this phase of the project. Processing, handling and storage must be such that products are essentially free of aflatoxin when they reach the consumer.

Assessment of the processing quality of peanut cultivars and appraisal of the quality of peanut products will also be undertaken. Compositional studies on developed peanut cultivars and peanut products will be conducted and the influence of peanut cultivars and processing parameters on product quality will be determined.

1. CONDUCT SOCIO-ECONOMIC AND MARKETING DEMAND STUDIES ON NEW AND EXISTING PEANUT PRODUCTS

   See A.1. above.

2. ASSESSMENT OF THE PROCESSING QUALITY AND PRODUCT QUALITY OF PEANUT CULTIVARS

   Peanut is a major legume crop in the Philippines. It is widely cultivated for food use and for manufacture of cooking oil, shortening, soap, cosmetics and other industrial products. Due to the varied uses of peanut, many studies have been conducted to maximize its potential. In the Philippines, 6% of 129 research studies on legume crops deal with peanut varietal improvement and processing. However, an assessment of the effect of peanut cultivar on quality of processed peanuts is not among these studies. Thus the development of peanut-supplemented products containing these cultivars is somewhat limited by this lack of information.

   Aflatoxin contamination is another factor that limits the production of quality products. About 27.3% of Philippine peanut products is contaminated with aflatoxin. Being a carcinogen, it is necessary to monitor the level of aflatoxin in foods and eventually devise methods for its removal.

   a. OBJECTIVES

      i. Determine the influence of peanut cultivars and processing parameters on product quality.

      ii. Monitor aflatoxin content in commercial peanuts and peanut products.

      iii. Determine the effect of processing conditions

on aflatoxin content of peanut products.

b. METHODOLOGY

Peanut cultivars will be subjected to various physical, chemical and sensory analysis. Chemical analyses will include the determination of moisture, fat, protein, sugar, fatty acid and lipid contents.

Aflatoxin content in peanut products will be monitored. The effect of processing on aflatoxin content will be studied.

3. DEVELOPMENT OF PEANUT PRODUCTS

Peanuts are considered as a popular raw material in food product development. It is rich in protein and fat, and thus an excellent source of energy. In terms of energy value, 0.5 kg of peanut is equivalent to 0.90 kg of beef, 0.70 kg of Cheddar cheese, 4.3 L of milk or 36 medium-sized eggs. Peanuts are also a good source of vitamins and minerals. Upon processing, the nutritive value of peanuts remains relatively unchanged but aroma, flavor and texture greatly improve. In the Philippines, the utilization of peanuts is limited largely to its direct consumption as snack food, mostly as roasted kernels or as peanut butter. Development of other peanut-based products such as soups, sauces and beverages needs to be done.

a. OBJECTIVES

i. Develop and evaluate snack foods, soups and sauces using peanuts as a major ingredient.

ii. Develop and evaluate beverages, flan, spreads and fermented products from peanut milk (aqueous extracts).

iii. Design, fabricate and test appropriate food processing equipment for fermented peanut milk products.

b. METHODOLOGY

A flavored peanut butter will be developed. New formulations of litson sauce, kare-kare sauce and saté sauce using peanut as fillers will be studied. The peanut spread formulations developed at UGA will be subjected to Filipino consumer evaluation.

Developed products will be subjected to sensory

evaluation to determine the consumer's preference.

4. AFLATOXIN CONTROL IN CONTAMINATED PEANUTS

Peanut is a good substrate for the growth of many molds, including *Aspergillus flavus* and *A. parasiticus*, and consequently the production of aflatoxin. A suitable method should be developed to detoxify peanuts which would enable their utilization as human food.

a. OBJECTIVES

i. Study various chemical treatments to reduce aflatoxin content of peanut.

ii. Control aflatoxin formation in peanuts through microbial antagonism.

b. METHODOLOGY

The most suitable detoxifying agent will be optimized. The optimized method will be adopted for field application. Aflatoxin content in peanuts will be determined. Aflatoxin determination using the HPLC will also be conducted.

5. INTRODUCTION OF PEANUT PRODUCTS

This work will be done in conjunction with results from market demand and socio-economic studies.

a. OBJECTIVES

i. Introduce developed peanut products as prospective investment areas in small scale industries.

ii. Make available to small scale producers new technologies in peanut storage, handling and utilization.

b. METHODOLOGY

The technology transfer process must be carried out to achieve full benefit of research efforts put forth to date and during the proposed research program. Methods for effective and efficient transfer will depend upon information obtained from market demand and socio-economic studies. Direct contact of collaborators with food industry will be necessary. Pilot studies with full cooperation of industry will be essential to the success of

technology transfer.

C. U. S. INSTITUTION: UNIVERSITY OF GEORGIA

1. ALTERNATE USES OF PEANUTS

One method by which peanut utilization can be increased is to find alternative uses for peanuts as a substitute for animal based ingredients. The substitution of dried peanut extract for caseinate in products such as coffee/tea whitener would increase utilization of peanuts.

Technologies for processing light colored peanut flour containing .2% oil have been developed and manufactured commercially. Unfortunately, utilization of the flour in food products is limited. Continued production cannot be sustained by the low demand for the product. Studies are needed to more thoroughly characterize peanut flours relative to its potential as a food ingredient.

Modification of peanuts and peanut constituents (water extracts, presscake) through the use of fermentative bacteria and molds holds great promise as a mechanism for developing new products which could be used as ingredients in currently accepted food formulations.

a. OBJECTIVES

i. Determine the feasibility of replacement of protein sources in coffee/tea whitener with dried peanut extract.

1. Determine the optimum level of peanut extract and vegetable fat in coffee/tea whitener formulations.

2. Study the effect of drying processes on the quality of coffee/tea whitener prepared from peanut extract.

3. Evaluate the performance of peanut-based coffee/tea whitener formulations with commercially available products.

4. Determine physicochemical and sensory characteristics of a coffee/tea whitener, coffee/tea whitener in suspension.

ii. Determine potential for utilization of peanut flour in food products.

iii. Investigate the use of lactic acid bacteria and molds traditionally used to ferment oilseeds to produce acceptable food ingredients.

b. METHODOLOGY

i. Formulations of a coffee/tea whitener containing various amounts of dried peanut extract and vegetable fat will be prepared and quality attributes will be determined.

Formulations will be prepared using drum, spray and freeze drying methods. Parameters to be studied include color, particle size, pH and sensory quality of whitener and whitener in coffee/tea suspension.

ii. The potential of peanut flour for use in food products will be examined by creating a model system consisting of formulations containing various amounts of peanut flour and other ingredients, including cowpea, sorghum and cassava flours. The potential of these formulations in baking and stove-top cooking will be evaluated.

iii. Water extracts of peanuts will be further evaluated as substrates for fermented products. *Lactobacillus* and *Streptococcus* species will be examined. Solid peanut substrates will be fermented with *Rhizopus oligosporus* and *Neurospora intermedia*. Changes in chemical composition and sensory qualities will be monitored.

2. TRANSFER OF PEANUT PASTE TECHNOLOGIES

Considerable effort has been spent during the current 3-year extension of the project to develop and optimize a process for preparing a paste product to be used as an imitation cheese spread and as a food ingredient. Studies have been conducted to determine the potential of the spread as an imitation cheese product.

The adaption of research technologies for formulation, pilot scale processing and subsequent storage will be examined. The feasibility of commercial

processing, marketing and utilization of the product will be investigated.

a. OBJECTIVES

i. To develop methodology for pilot scale processing of peanut paste and a formulation of an imitation cheese spread from the paste.

ii. To assess shelf life characteristics of the spread.

iii. To determine the feasibility of commercial processing and marketing of spread.

b. METHODOLOGY

i. Pilot scale methods for processing spread will be developed from optimized procedures for laboratory-scale processing. Shelf stability of the spread will be monitored over a 6-month period.

ii. Commercial processing, marketing and subsequent utilization by consumers will be assessed.

3. REMOVAL OF AFLATOXIN

Many techniques have been suggested for the removal of aflatoxins from peanuts. However, only a few techniques have potential for use in developing countries. One of the best known techniques to destroy aflatoxins in peanut products is ammoniation. Although ammoniation is most effective when done at high temperature and pressure, detoxification can also be successfully be accomplished by simply mixing contaminated meal together with liquid ammonia in a closed container.

Another technique which shows promise for detoxifying peanuts is treatment with sodium bisulfite. A procedure for destroying aflatoxin B_1 in corn has been described. More recently, work by the Peanut CRSP team at UPLB demonstrated that sodium bisulfite could also be used for detoxifying peanuts.

A third general way for degrading aflatoxins in peanuts is through the use of ultraviolent (UV) irradiation. However, the efficacy of using UV irradiation is not clear. No destruction of aflatoxin when peanut meal was exposed to UV light. In contrast,

up to 30% decrease in aflatoxin has been observed when contaminated corn was exposed to tropical sunlight. However, in neither case was the amount of UV light or sunlight quantified.

A technique for separating aflatoxin-contaminated peanuts from aflatoxin-free peanuts could be based on the use of foam dispersions. However, this technique has not been investigated.

a. OBJECTIVES

i. Investigate methods for detoxification of peanuts and peanut products that can be used in small scale situations in Thailand and Philippines.

ii. Optimize previously tested physical and chemical methods for reducing aflatoxins in peanuts.

iii. Determine physical and statistical characteristics of peanuts likely to be correlated with aflatoxin contamination.

iv. Determine the effects these methods might have on functional and nutritional qualities of kernels.

v. Run pilot plant and field trials to evaluate detoxification and separation techniques.

b. METHODOLOGY

Methods chosen for optimization are those which have shown potential for decreasing aflatoxin concentrations in peanuts and other commodities, and require little or no complicated or expensive equipment.

The proposed research will be done as follows:

i. Factors influencing the efficacy of aflatoxin detoxification by treating with sodium bisulfite will be investigated. Factors to be tested include form of peanuts (whole or meal) and time and concentration of sodium bisulfite required for optimum detoxification. Aflatoxins will be quantified using high performance liquid chromatography and detected by fluorescence.

ii. The effects of peanut particle size, sunlight intensity and amount of UV irradiation on detoxification will be determined. Both sunlight and UV irradiation will be quantified using appropriate instrumentation.

iii. Conditions for ammoniation and subsequent fermentation will be optimized relative to effectiveness in degrading aflatoxin. The general method of ammoniation used involves sealing contaminated peanuts and aqueous ammonia in an air-tight container. Specific factors to be investigated will be concentration of ammonia, temperature, exposure time and size of peanuts. In addition, fermentation will be carried out as previously described.

iv. The effects of detoxification treatments on functionality and nutritional attributes will be determined. Detoxified kernels will be evaluated for color and texture using a colorimeter and Instron texture device, respectively. In addition, proximate analysis and amino acid analysis will be done.

v. A stable foam column composed of water and either polyvinylpyrollidone (PVP), albumen or polyethyleneglycol will be tested for their abilities to separate classes of peanuts. The separated groups will be tested to determine if a correlation exists between density, surface texture and aflatoxin content. If correlations exist, a laboratory model will be constructed to provide a continuously renewed foam column which would illustrate the basis for a machine prototype.

The basis of the proposed experiment is the Stoke's equation:

$$V = \frac{2ga^2(d_1-d_2)}{9n}$$

where V = velocity, cm/sec
g = gravitational constant, 980 cm/sec^2
d_1 = density of kernel, g/cm^3
d_2 = density of foam, g/cm^3
n = viscosity in poise, g/cm-sec
a = radius of kernel

Thus, with a constant head and a fairly uniform size of kernel, the time of fall would increase as the density decreases. The difference in time could be used as a basis for separation of classes. Also, the density or viscosity of the foam can be changed, affording a further control of the variables. Peroxide blanching would be used to distinguish color differences on the surface of peanut kernels and thus, theoretically, distinguish mold-infected kernels from sound kernels.

TRAINING PLANS PROPOSED:

A major thrust in the proposed project will be directed toward training students, technicians and faculty in the area of peanut science and technology. Disciplines within this area include chemistry, engineering, sensory evaluation, nutrition, microbiology, socio-economics and marketing.

Students from Thailand, the Philippines and the U. S. will be identified to pursue M.S. and Ph.D. degrees at the University of Georgia. Short-term (up to 6 months) visitations by Thai and Filipino technicians and faculty to the University of Georgia will be arranged. Attendance of Thai, Filipino and U. S. scientists at international scientific workshops, symposia and other professional meetings encompassing peanut science and technology will be encouraged.

EXPECTED BENEFITS:

The U.S. as well as Thailand, the Philippines and other countries will benefit greatly by knowledge gained from the proposed research. Specific benefits are as follows:

A. Increased production of peanuts as a result of increase in demand.

B. Increased capacity of industries to produce peanut products through technology transfer.

C. Increased utilization of peanuts in value-added products.

D. Increased availability of peanut products having enhanced nutritional value, thus contributing to improved quality of life.

E. Increased choices in the food supply, e.g., increased vegetarian products other than those based on soybean.

F. Decreased risk to public health due to consumption of

aflatoxin-contaminated peanuts and peanut products.

G. Increased availability of animal feed in the form of detoxified peanuts.

H. Increased data base on peanuts and peanut products developed in Thailand, the Philippines and the U.S.

I. Significant impact on level of training and professional development of scientists.

J. Global impact on the store of knowledge available on peanut utilization for application in developing and developed countries.

ORGANIZATION/PERSONNEL:

A. HOST COUNTRY LEAD INSTITUTION: Kasetsart University, Bangkok, Thailand

Principal Investigator: Penkwan Chompreeda
Co-Investigators: Vichai Haruthaithanasan and Chintana Oupadissakoon
Cooperators: S. Khotaveewattana, P. Thamratwasik, U. Kanto (Animal Nutritionist) and P. Yamali (Marketing Specialist)

B. LINKAGE INSTITUTION: University of The Philippines at Los Banos, College, Laguna, Philippines

Principal Investigator: Virgilio V. Garcia
Co-Investigators: Ricardo R. del Rosario and Reynaldo C. Mabesa

C. U. S. LEAD INSTITUTION: University of Georgia, Griffin, Georgia

Principal Investigator: Larry R. Beuchat
Co-Investigators: Robert E. Brackett, Tommy Nakayama and Anna V.A. Resurreccion
Cooperator: Charles R. Santerre

TIME TABLE:

Institution and Objective	Years During Which Activity Will Occur
Kasetsart Univ. (Host Institution):	
Number	
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
Univ. of the Philippines at Los Banos (Linkage Institution):	
1.	
2.a.i.	
2.a.ii.	
2.a.iii.	
3.a.i.	
3.a.ii.	
3.a.iii.	
4.a.i.	
4.a.ii.	
5.a.i.	
5.a.ii.	
Univ. of Georgia (Lead Institution):	
1.a.i.	
1.a.ii	
1.a.iii.	
2.a.	
3.a.i.	
3.a.ii.	
3.a.iii.	
3.a.iv.	
3.a.v.	

JUSTIFICATION OPTIMAL BUDGET

PROJECT CODE: GA/FT/TP

The expanded budget will facilitate the strengthening of the training, socio-economic and technology transfer components. Additional components identified in the expanded budget include research devoted to investigating the mechanism of aflatoxin degradation by Flavobacterium aurantiacum and chemical and sensory analysis of new peanut cultivars developed by scientists in the NCS/BCP/TP project.

1. Strengthening the Training Component: Training is a key element of the expanded budget. In addition to increased support of graduate degree training at UGA, students at KU and UPLB will be encouraged to pursue degrees at UPLB and KU, respectively. The number of short-term trainees and visitations by KU and UPLB faculty and technicians at UGA will be increased.

2. Strengthening the Socio-Economic and Technology Transfer Components: The rationale for developing the specific peanut products outlined in the project comes from documented evidence of the potential for acceptability of such products in Thailand and the Philippines based on surveys of socio-economic and demographic characteristics conducted during the original granting period. However, additional socio-economic and market demand studies need to be done, and increased efforts in these areas would be expended if the expanded budget is authorized. The transfer of technologies of the industry, on whatever scale, becomes obvious and more critical as the project matures. Increased involvement of individuals with expertise in socio-economics, marketing and psychobiology is critical to the effectiveness and timeliness of this transfer process.

3. Investigation of the Mechanism of Aflatoxin Degradation: We have already demonstrated that a bacterium (Flavobacterium aurantiacum) is capable of removing aflatoxin from a peanut substrate. However, we do not know whether aflatoxin is degraded or merely bound in such a form that it is not easily extracted using routine analytical techniques. If it is degraded, is the process enzyme mediated? What are the degradation products and are they toxic? All of these questions and more must be answered before judgments can be made concerning the practical use of this bacterium to reduce the aflatoxin content of contaminated peanuts. The expanded budget will enable us to pursue this research area.

4. Chemical and Sensory Quality Analysis of New Cultivars: The need for evaluation of new peanut cultivars developed by the NCS/BCP/TP project continues. Analysis of total protein and oil content, fatty acid profiles and sensory quality after roasting is an important link in the total systems approach to breeding/growing/harvesting/storage/processing/marketing of peanuts in developing as well as developed countries. The expanded budget will enable this activity which was

Project Code: GA/PH/C

Project Title: Postharvest Handling Systems for the Small Peanut Producer

Manjeet Chinnan, Principal Investigator, UGA

INTRODUCTION

Accomplishments

Research

This project is the newest of all the Peanut CRSP projects, which began in July of 1987. The emphasis is on investigating and identifying suitable methods for maintaining postharvest quality and reducing post production cost through improved postharvest handling operations including harvesting, drying, threshing, shelling, storing, cleaning and packaging. The current project replaced an earlier project in the Caribbean, which had the goal of introducing new and viable cultivars for increased production and objectives of that project (GA/BCP/CAR) were met to a great extent. The existing project is progressing well in meeting its goals. All the aspects of postharvest operations are being researched and tested on various locations in five countries (Antigua, Belize, Jamaica, St. Vincent and Trinidad) of the Eastern Caribbean region. More specific achievements are listed below.

Site Visits - Information Gathering: Site visits were made to Antigua in May 1987, Jamaica, St. Vincent and Trinidad in December 1987, and Belize in February 1988 to collect information on existing production and postharvest approaches.

Plans to upgrade machine shop facilities in Jamaica: Plans were developed to upgrade the facilities at the Lawrence Field Station in Jamaica. If these facilities are upgraded other CARDI countries would also benefit, as farm equipment modification and prototype devices could be fabricated here.

Threshers: Two threshers, old Ce Co Co model, were refurbished at Georgia and one each was shipped to Jamaica and Belize. On-farm tests were designed for their suitability on each location. Field evaluations were conducted and appropriate modifications were done in the country of testing. Initial tests were found to be very successful from the technical considerations and also farmers' acceptability. However, further tests are planned to obtain more data. Tests with threshing aids such as a metal comb, designed under an earlier CARDI project was tested in Antigua, but was not found to be very acceptable. The alternative of small scale motorized threshers of 3-5 hp, stationary type, is a possibility for use in Antigua and St. Vincent; this possibility will be explored in near future.

Sheller: A hand operated peanut sheller was fabricated in Georgia based on an earlier design concept of CARDI sheller. This was further modified to make the device pedal-operated, as well as make the provision of adapting to different size peanuts by having replaceable screens. This device is being tested in Belize and will be later tested in Jamaica.

Drying: One existing drier was modified for better air flow, and inexpensive and improved heating arrangements at a farmer's cooperative in Belize; preliminary testing was done last year, further testing is ongoing at present. The blower and the engine were selected, matched and assembled at Georgia before shipment to Belize. Tests were designed and conducted for evaluating drying practices in Jamaica, Antigua and St. Vincent.

Storage: Storage facilities at Belize and Jamaica were surveyed and experiments were designed for on farm tests of the effectiveness of existing storage practices. Modifications for improved ventilation and reducing the quality loss due to insect damage and mold growth were initiated and implemented. Tests are in progress to evaluate improved storage methods. Tests procedures to study production of aflatoxin in peanuts during storage were planned with the assistance of GA/FT/TP investigators.

Training

Mr. Urvan Wilson, M.S. student at University of West Indies, Trinidad. Jan. 1989 - present. Research: Evaluation of some selected postharvest handling equipment for peanuts with special emphasis on digging and lifting.

Mr. Vivek Gnanasekharan, M.S. student at University of Georgia. Peanut CRSP support since Nov. 1988. Research: Physical properties of peanuts as related to development of improved separation technologies.

Ms. Deepa Pendalwar, M.S. student at University of Georgia. Graduated June 1989. Partial support from Peanut CRSP (10 weeks). Research: Design of flexible film packaging systems.

Mr. J. E. Grant. I from CARDI-Jamaica. Spent two weeks at Georgia in May 1988. Research: Design of shelling and threshing equipment.

Mr. Tal Oz-Ari, Research Engineer from UGA spent two weeks each in Belize and Jamaica in training and assisting cooperators for conducting threshing, shelling and storage studies.

Visiting Scientists Mr. I. K. Garg and Dr. Y. Heikal spent three months and four months, respectively, at Georgia conducting research on Peanut CRSP related activities. Garg, a research engineer from India, was sponsored by FAO (no CRSP funds were spent). Heikal, a

food engineer from Egypt, was a Fulbright Scholar (25% Peanut CRSP support).

LINKAGES

Khon Kaen University, Thailand
Asian Institute of Technology, Thailand
Kasetsart University, Thailand
International Rice Research Institute, The Philippines
University of Philippines at Los Banos
Punjab Agricultural University, India
Central Institute of Agricultural Engineering, India
National Institute of Agricultural Engineering, UK

PRIORITY CONSTRAINTS

It is an established 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 the cost associated with the production, harvesting and post harvest operations.

Need for improved postharvest handling operations exist not only in the Caribbean region but also in Southeast Asian countries, such as Thailand and the Philippines, and other peanut growing regions of the developing nations. Another major emphasis will be towards a greater effort of training and development of scientists and staff in the area of postharvest handling. This aspect will be given a greater attention because investment in development of human capital is considered as an essential component of the peanut CRSP activities.

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, socio-economics and existing infrastructure for marketing and consumer acceptance factors.

RATIONALE

Three terms, systems approach, integrated system, and global model are used in this proposal; these terms are defined below before proceeding any further:

Systems approach. It considers individual components and activities

as interrelated parts of the system. Change in one of the component can affect the performance of the whole system. Investigation of inputs and outputs to various components of the system and understanding the interrelating factors is called the basis of systems approach.

Integrated system. In this proposal it refers to all the postharvest handling steps combined, whether manual, completely machine handled, or machine assisted.

Global model. An overall model which provides alternatives in designing or selecting an integrated system suitable for a particular situation based on the infrastructure, natural resources, socio-economic and climatic factors of the situation.

To date most of the research and development associated with designing new machinery or improving existing equipment, and methods of drying and storage in the postharvest handling scheme have focused around one postharvest handling step at a time. This approach has been true not only for the activities underway in the Caribbean under the auspices of the current Peanut

CRSP project, but also at other institutes in different parts of the world. There is a need for following and implementing a systems approach which will lead to development of a global model for peanut postharvest handling system. The global model, which is not site or region specific, can then be used in designing one or several scenarios of integrated systems for a given peanut producing location. The global model has to be evaluated under several test situations. Farm units in different regions of the Caribbean will be used as laboratory; in addition, some work will also be carried out in one or two locations outside the Caribbean region (preferably in Thailand and/or Philippines), this additional work will depend on the availability of funds.

OBJECTIVES

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.

PLANS PROPOSED

Research

The research activities are listed by objectives rather than by the country. However, the role played by the U. S. and host country scientists and personnel in relation to each each activity is identified. The time table attached at the proper place in this proposal does identify the activities by objectives in each of the countries.

1. Identify the segments of the postharvest handling system, and various constraints, and develop a qualitative relationship(s) among the segments. Some information is already available as a result of current or past CRSP project activities in the Caribbean. However, information will be gathered and compiled in a systematic manner for the peanut growing regions of Jamaica and one more country in the Caribbean. Most likely the second Caribbean country will be Belize, but St. Vincent is a possibility. Based on the format and success of collecting appropriate information in the Caribbean, data will be collected in one country in South East Asia, most likely Thailand, during the later part of the 5-yr proposal. Cooperation of a faculty member from the

Department of Agricultural Economics, person to be identified, at Georgia Station will be sought along with CARDI personnel. The knowledge of quantitative relationships obtained in the initial phases of 5-yr plan will be of utmost importance in meeting the overall goal of this proposal.

2. Evaluate the economic value of each postharvest handling operation or segment identified. Information related to this objective will be compiled along with that for the above objective. Economist(s) from Georgia and CARDI and other CARDI personnel will assist in this matter. This information will be particularly needed in developing quantitative relationships for possible integrated systems suited for postharvest handling of peanuts. This step will dwell on objective #1 in moving towards accomplishing the proposal goal. Economic value of each postharvest handling operation will also be obtained and evaluated for certain selected peanut growing regions in South East Asia in the same manner as in the Caribbean. Availability of the data for a South East Asian location will be useful in validating the

global model for a location outside the Caribbean region.

3. Identify existing technologies for adaptation or modification. Contacts will be made by a U. S. institution investigator through visitations and/or other appropriate means to some selected institutes (such as Khon Kaen University, Thailand; Asian Institute of Technology - A. I. T., Thailand; International Rice Research Institute - I. R. R. I., The Phillipines; Punjab Agricultural University, India; Central Institute of Agricultural Engineering, India; National Institute of Agricultural Engineering - N. I. A. E., England; etc.) for the purpose of obtaining pertinent information on postharvest handling equipment developed at those institutes for peanuts or other commodities which may have applications in the Caribbean regions as well as regions other than those where the equipment was developed. Efforts will be made to obtain engineering drawings from the institutes involved in designing and developing the equipment. Visitations to all the institutes mentioned will not be made during the same trip. Attempts will be made to combine foreign travel with other Peanut CRSP activities, such as the ICRISAT meeting in 1991. Also, visitation to all the institutes listed may not be necessary, the need for which will be evaluated based on the level of funding.

4. Evaluate the technologies identified for functionality and economic value. The existing technologies identified as part of objective #1 and #3 will be evaluated for functionality and economic value when used as part of different integrated systems. Emphasis will be given to determine their (technologies) applicability in different Caribbean regions; and also determine who, where and how those technologies could be made available for actual use. Linkages will be developed, through CARDI, with the Caribbean Industrial Research Institute (CARIRI) in Trinidad for cost analysis and fabrication of equipment.

5. Evaluate the anticipated change in quality loss. Studies will be designed to quantify the changes in quality of peanuts as a result of introducing alternative technologies in the postharvest system. A systems approach followed by the Postharvest Team at the Georgia Station in studying the fruit and vegetable handling system will be employed. Dr. Stan Prussia, who is a member of the 4-member Postharvest Team, will be a possible collaborator in designing the studies for this objective and also coordinating the related activities.

6. Determine the physical properties of peanuts and associated materials. Physical and textural properties of in-shell peanuts, peanut shells and peanut kernels as applicable in developing and designing systems for cleaning,

sorting, and other postharvest handling operations for improved quality of peanuts will be determined. Special emphasis will be given to characterizing aflatoxin contaminated and aflatoxin

non-contaminated peanuts for developing concepts or devices to be used in obtaining aflatoxin free peanuts; cooperation of investigators from a sister Peanut CRSP project (GA/FT/TP) will be sought to meet some aspects of this objective.

7. Identify the input and output parameters of all the components of the global model, and build the model. Model building will be done by the scientists at Georgia. Key role will be played by a person having expertise in model building. Dr. Chi Thai is one such person identified for this role. Coordination will be provided by the U. S. PI who has considerable experience in modeling food processing operations and food processing systems; and close cooperation of U. S. Agriculture Economist and Host country collaborators will also be sought.

8. Develop alternative scenarios of integrated systems. Several alternatives of possible integrated systems will be designed based on the theoretical model to be built as a result of the activities associated with objective #7. Following the design step, these integrated systems will be evaluated based on the information generated as part of the objectives 1 to 6. Out of various alternatives considered the systems showing the greatest promise of success (one for each location or region) will be subjected to field test.

9. Test the global model in field for functionality and acceptability. Testing of integrated system(s), designed as result of activities in the above objective, will be carried out in Jamaica on an extensive scale and to a lesser degree at other locations in Belize or one other location in the Caribbean. Field testing of the model will be an important part of this overall study. This objective will be carried out with the close cooperation of host country collaborators. Field testing and evaluation of the global modeling approach will be extended to the South East Asian region depending upon the availability of funds for this research.

Training

One graduate student assistantship will be funded form Peanut CRSP project at Georgia throughout the 5-yr duration of the project. Expect to graduate one M.S. and one Ph.D. student.

Graduate student support for at least one student per year will be provided for host country institution, whether in the Caribbean or South East Asia.

Periodically, short term training visits will be planned for host country personnel at Georgia or other institution(s) as appropriate. Training workshops will be organized and conducted for host country personnel in host country. U. S. scientists will provide training and assistance in conducting tests in host country as necessary.

BENEFITS EXPECTED

In Host Country

A global model of an integrated system of postharvest handling operations will be available. Such a model will have the features of being applicable to a small or large farm, highly mechanized or not-so-highly mechanized farming system, dry or humid farming pattern, individual or cooperative farming environment (e.g. Belize has highly successful cooperatives whereas it is not so in Jamaica), and not be site specific. A successfully implemented postharvest handling system should increase the availability of low cost, high quality, safe and nutritious peanuts and peanut based food products for the rural and the urban consumer through the introduction of improved handling and storage techniques. Another most important benefit to the host country will be the investment made in the development of human capital through training provided to the host country personnel during the course of meeting the objectives of this Peanut CRSP project.

In U.S.

The knowledge gained in the area of physical properties of peanuts will be greatly useful in developing more efficient and improved postharvest handling equipment for the U.S. industry. Particularly useful will be the knowledge in area of properties of aflatoxin contaminated and non-contaminated peanut kernels, which could be employed in obtaining aflatoxin free peanuts for the domestic industry or for export purposes. The global modeling approach should be applicable to peanut post-production systems in the U. S.; and should provide basis for similar systems of other crops.

ORGANIZATION/PERSONNEL

U.S. LEAD INSTITUTION: University of Georgia (UGA)

Personnel:

Principal Investigator:	Manjeet S. Chinnan, Department of Food Science and Technology, UGA, Georgia Sta., Griffin, GA
Collaborators:	Department of Agricultural Engineering, UGA, Georgia Sta., Griffin, GA Chi Thai Stanley Prussia
	Department of Agricultural Economics, UGA, Georgia Sta., Griffin, GA

Cooperators:	Department of Agronomy, UGA, Coastal Sta., Tifton, GA Craig Kvien
	Department of Plant Pathology, UGA, Coastal Sta., Tifton, GA Dave Wilson
Research Staff: (at Georgia Sta.)	Tal Oz-Ari, Research Engineer Joe Garner, Coordinator, Postharvest Lab. Durward Smith, Manager, Engineering Shop
HOST COUNTRY INSTITUTION:	Caribbean Agricultural Research Institute (CARDI), St. Augustine, Trinidad

Personnel:

Brian Cooper, Principal Coordinator for all CARDI locations (Antigua)

Joscelyn Grant, Principal Investigator (Jamaica)

Maurice Taylor, Research Assistant (Jamaica)

B. Sinha, Principal Investigator (Belize)

Murali Rao, Cooperator (St. Vincent)

Gordon Muller, Cooperator (Trinidad)

Clement Sankat, Cooperator (University of West Indies, Trinidad)

TIMETABLE

U. S. Institution

Objective No.	Years during which activity will occur				
	1990/91	1991/92	1992/93	1993/94	1994/95
1	———	———			
2	———	———			
3	———	———			
4	———	———			
5		———	———	———	———
6	———	———	———	———	———
7	———	———	———	———	———
8			———	———	———
9			———	———	———

Jamaica

Objective No.	Years during which activity will occur				
	1990/91	1991/92	1992/93	1993/94	1994/95
1	———	———			
2	———	———			
3					
4	———	———			
5		———	———	———	
6					
7	———	———	———	———	
8					
9		———	———	———	

Belize (or some other CARDI country)

Objective No.	Years during which activity will occur 1990/91	1991/92	1992/93	1993/94	1994/95
1	———	———			
2	———	———			
3					
4	———	———			
5		———	———	———	
6					
7	———	———	———	———	
8					
9		———	———	———	

A South East Asian Country (Thailand)

Objective No.	Years during which activity will occur 1990/91	1991/92	1992/93	1993/94	1994/95
1			———	———	
2			———	———	
3					
4			———	———	———
5				———	———
6					
7				———	
8					
9				———	———

JUSTIFICATION FOR OPTIMAL BUDGET

Expand project activities in South East Asia beginning 1990 instead of 1993.

Maintain activities in the Caribbean at operational levels in view of 5% increased adjustment in spending due to inflation.

Train additional two host country graduate students and two U. S. institution graduate students.

Hold training workshops in South East Asia in 1994 and 1995 at two separate locations.

Every year travel for one U. S. scientist to S.E. Asia and for one host country scientist to the U. S. or other institute of relevance.

Resource Management.

The Peanut CRSP has adopted the model used by ICRISAT for Resource Management Research, which includes agronomy (soil fertility, cultural practices such as seed rate or row spacing, agroclimatology, farming systems, entomology and pathology), agricultural engineering, and socioeconomics. The Peanut CRSP will also integrate aflatoxin and food technology efforts into the agronomic system.

New or improved technologies that have promise for general transfer to beneficiaries should first be evaluated for fit into Resource Management Systems. The research in West Africa will be primarily in agronomy and socioeconomics.

The Resource Management thrust is in its early stages of development and is presently perceived as follows.

Agronomy: Technology that has an agronomic or biological nature will be evaluated in the resource management system context. The thrust is presently perceived with three components.

- Intra-Peanut CRSP research activities including breeding and food technology; breeding and mycotoxin, insect management and virus, and breeding and insect management.

- Cooperative efforts with other in-country, regional, or international programs; and

- Inter-CRSP activities involving multidisciplinary research (i.e. crops, soils, and animals); and interdisciplinary research, (i.e. food technology).

A component in the optimum level budget will earmark funds for this purpose. Additionally, some activities will be funded through normal research funds in various Peanut CRSP projects. The leadership structure for this thrust has not been decided. Description of activities presently being planned are in the Global Plan and Extension Proposal Document.

Socioeconomics: New technology must not only be acceptable agronomically or biologically, but must also be sound socioeconomically. The structure of this program is still being planned, but it may be led by a working group of social scientists, economists, and food scientists from the present participating U.S. universities with host country collaboration. Four components of the program are now perceived:

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- The social implications of new technologies would be evaluated, such as changing labor requirements and influence on women's role when adopting a technology.

- The economic benefits of new technologies would be studied, such as the increased income derived from a higher yielding cultivar or the decrease in inputs required by adoption of a new pest management practice.

- The food technology projects have protocol in the projects for surveys to be conducted to determine the need and acceptability of new or improved food products, and to determine the socioeconomic acceptability of a newly introduced product.

- Problems exist in market development and government policies that affect peanut which will be studied.

A component in the optimum level budget will earmark funds for this thrust. Aso, some activities will be funded through normal research funds in various Peanut CRSP projects. Description of activities presently being planned or considered follow.

Communications and Outreach

An expanded thrust in Communications and Outreach will be a feature of the optimum budget programs of the Peanut CRSP in response to the constraint of information on production and utilization not being available to the beneficiaries. The Peanut CRSP has matured to the point of having produced many new or improved technologies that should be valuable to the beneficiaries. We will continue to encourage publication of results in recognized outlets while increasing capability to communicate results to policy makers and extension workers. Support of participation in workshops, networks, and pilot programs to stimulate technology transfer will continue. Cooperation with ICRISAT in the publication of International Arachis Newsletter will continue. With increased funds, the Peanut CRSP will:

- Expand capability by addition of a Communications Specialist to produce publicatins, brochures, leaflets, videos, and slides that will communicate Peanut CRSP results to a variety of audiences, including decision makers in funding agencies, state and national legislative bodies, extension workers, and the research beneficiaries in the U.S. and host-countries.

- Increase the number of workshops to communicate research results and plan future needs in-country, regionally, and internationally.

- Strengthen network relationships with international cooperators. Develop a working relationship with the French CORAF program in Africa.

- Support on farm and cottage industry Pilot Programs to demonstrate and encourage adoption of new technologies that are of value to the beneficiaries.

A description of initial activities proposed for each region is presented in the Global Plan and Extension Proposal.

Peanut CRSP Management

Peanut CRSP Management is a cooperative effort involving the Management Entity, Board of Directors, Technical Committee, External Evaluation Panel, USAID, and BIFAD. Management responsibilities also extend to U.S. and host country institutions and principal investigators through Memoranda of Understanding and Plans-of-Work.

The purpose of Peanut CRSP Management is to develop programs, manage funding, evaluate progress, plan for dissemination of results, make necessary program and finding adjustments, and make necessary reports to USAID. Our goal is to accomplish management with minimum cost and involvement of researcher's time, with maximum focus on programs, funding of programs, and conduct research.

The general duties and responsibilities of Peanut CRSP Management groups will continue as defined and practiced.

Management Entity Staff shall consist of a Director, Administrative Secretary, and an Accounting Assistant.

A. The Program Director is a full-time position for overall leadership of the CRSP, and should be an established, experienced, administratively competent plant scientist with a Ph.D. degree.

B. The Administrative Secretary is a full time position for an experienced person with secretarial competence and ability to assist in organization and execution of the various CRSP functions.

C. The Accounting Assistant is a full-time position located at the College of Agriculture Business Office for a person to assist in Management of CRSP funds.

Maximum operational flexibility should be given to the participating universities by the Management Entity. The initial role of the Management Entity will be to assist the universities in initiating research programs, and afterwards have a supportive role.

The Management Entity will be responsible to AID for technical and administrative matters for the Peanut CRSP.

A. Negotiate, execute, and maintain grant agreements with AID, participating U.S. universities, and host country (LDC) institutions.

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B. Receive from AID all grant funds and assume fiscal accountability for those funds, to include: Annual fund allocations to subgrantees, suitable procedures for fiscal reports, and preparation of an annual budget plan in collaboration with the Technical Committee and Board of Directors approval. Provide for central administration of funds for meetings of the Board of Directors, Technical Committee, External Evaluation Panel, reports, and other documents. The Management Entity will provide travel funds for the Board of Directors and External Evaluation Panel. The Technical Committee travel should come from the domestic travel portion of individual projects.

C. Recommend and negotiate with AID program extensions or modifications based on the advice and recommendations of the External Evaluation Panel, Administrative Review Team, and the Technical Committee and with approval of the Board of Directors.

D. Make necessary reports to AID, BIFAD, and JCARD on progress and accomplishments of the Peanut CRSP.

Board of Directors. Each participating U.S. university shall appoint one administrative representative to the Board of Directors, and an alternate representative if desired. Board members should be able to make institutional commitments for the CRSP. These members cannot also be members of the Technical Committee. A representative from ICRISAT will be on the Board. The Board will:

A. Provide liaison between institutional administrators and the Management Entity.

B. Establish policy for the CRSP.

C. Review and approve annual budgets, expenditure patterns, and the plan for allocation of funds to the component projects.

D. Approve program changes such as addition or deletion of projects or changes in project objectives.

E. Receive, and utilize in its decisions, reports from the Technical Committee and External Review Panel, and review progress and accomplishments of the CRSP.

F. Elect a Chairman for the Board by procedures and terms as outlined by the Board.

G. Schedule any appropriate or necessary meetings with host country administrators, Technical Committee, External Review Panel, and host country, or U.S university principal investigators.

H. Concur in the selection of the Peanut CRSP Director.

Technical Committee. One principal or co-principal investigator from each participating U.S. university shall be a member of the Technical Committee, and the CRSP Director shall be an ex-officio member. A chairman and terms of appointment will be determined by procedures established by the committee. The committee will assist in:

A. Review work plans and budgets for the projects.

B. Evaluate projects annually for progress in attaining objectives of programs.

C. Establishment of mechanisms for coordination of programs in host countries and the U.S.

D. Make recommendations to the Board of Directors for all program activities of the CRSP.

E. Foster meetings of all PI's at APRES and report on progress of CRSP.

External Evaluation Panel. This Panel shall consist of three to five eminent scientists recommended by the CRSP Management Entity to AID/BIFAD for specified terms of appointment. Periodically as appropriate the Panel shall:

A. Make selected annual review of projects and programs of the CRSP and provide written of evaluation.

B. Make designated extensive reviews for program extension and recommend the addition, elimination, or modification of component projects and overall objectives, to include retention, elimination, or addition of new overseas sites.

The Peanut CRSP plans to enhance its management activities during the course of the five year plan in several ways as recommended by the External Evaluation Panel and the Administrative Management Review Team.

- Rotate meeting sites of Board of Directors.
- Delineate procedures and policies for Board and Technical Committee.

- Define more explicitly annual work plans and budgets with adequate peer review.
- Consider a plan to add host country representation to Technical Committee, and consider makeup of U.S. membership to cover more disciplines.
- Maximize EEP involvement in annual evaluations of progress and projection of work plans. Employ "extra disciplinary" consultants for EEP as necessary.
- Encourage inputs from host country coordinators for consideration in management decisions.
- Outline training plan and goals for the entire CRSP.
- Encourage increased in-country funding of peanut research.
- Continue to emphasize in-country, regional, and international coordination of research.
- Continue to enhance interaction with ICRISAT and other international cooperators.
- Work for more inter-CRSP activities.
- Interact with USAID mission programs and seek "buyin" opportunities.
- Maintain linkage with the U.S. peanut industry.
- Encourage in-country transfer of Peanut CRSP - derived technology.
- Encourage host country collaborators to publish results of research more frequently.
- Maximize host country expenditures of research funds.

Detailed Budgets

This section presents the detailed budgets for the Nine Projects, the Resource Management component, the Communications and Outreach component, and the Management Entity. A summary justification of the funds is presented in Section 6.5. in the Global Plan and Extension Proposal 1990-1995. The preceding project and component description listed earlier in this document expand on the justification. Restrictions on the CRSP research at current and current plus 5% inflation levels is discussed in Section 6.5. of the Global Plan and Extension Proposal for 1990-1995.

Three levels of funding are shown:

1. Optimal - The optimal budget includes funds that are critical for continued operation of the project at levels to support progress toward relief of the constraints. Included in the totals presented are U.S. and host country funds, and funds for the "new thrust" proposals listed with budgets at the end of each project in this document. A 5% annual inflation factor was used in projecting the 5-year funding needs.

2. Current plus 5% inflation - The "inflation" budget was based on current levels of funding with a 5% annual inflation factor starting in 1990 to project the 5-year funding needs.

3. Current - The current level budget is a straightline projection of the current budget level of $1,700,000 per year.

Table 1. PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
OPTIMAL BUDGET						
1. Salaries, Wages, Fringe Benefits	981,547	1,030,624	1,082,154	1,136,262	1,193,075	5,423,662
2. Graduate Students, Training	421,539	442,616	464,745	487,983	512,381	2,329,264
3. Equipment	34,886	36,630	38,462	40,385	42,405	192,768
4. Travel	197,821	207,712	218,098	229,000	240,452	1,093,083
5. Materials & Supplies	554,194	581,904	611,000	641,547	673,621	3,062,266
6. Other Direct Costs	555,719	583,506	612,684	643,327	675,488	3,070,724
7. Indirect Costs	612,247	642,857	675,000	708,746	744,183	3,383,033
Total	$3,357,953	3,525,849	3,702,143	3,887,250	4,081,605	**$18,554,800**
CURRENT 5% INFLATION BUDGET LEVEL						
1. Salaries, Wages, Fringe Benefits	634,467	664,222	701,487	739,377	770,869	3,510,422
2. Graduate Students, Training	269,773	285,487	300,716	324,120	334,881	1,514,977
3. Equipment	26,486	26,217	16,315	16,431	16,553	102,002
4. Travel	130,387	121,761	136,431	138,960	144,456	671,995
5. Materials & Supplies	317,331	334,357	355,400	378,950	400,812	1,786,850
6. Other Direct Costs	19,769	33,093	25,258	24,864	30,574	133,558
7. Indirect Costs	386,787	409,113	432,355	443,658	471,533	2,143,446
Total	$1,785,000	1,874,250	1,967,962	2,066,360	2,169,678	**9,863,250**
CURRENT BUDGET LEVEL						
1. Salaries, Wages, Fringe Benefits	612,396	619,039	629,947	641,911	652,179	3,156,363
2. Graduate Students, Training	258,170	269,263	273,336	281,300	276,467	1,358,536
3. Equipment	24,386	20,014	7,000	7,000	7,000	65,400
4. Travel	119,451	107,544	114,192	108,351	101,781	551,319
5. Materials & Supplies	297,647	289,534	284,720	280,867	276,103	1,428,871
6. Other Direct Costs	20,011	23,965	16,765	15,187	14,934	90,862
7. Indirect Costs	367,939	369,750	374,040	365,384	371,536	1,848,649
Total	$1,700,000	1,700,000	1,700,000	1,700,000	1,700,000	**8,500,000**

Table 2. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

OPTIMAL BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			TX/BCP/S,N,BF			
1. Salaries, Wages Fringe Benefits	184,320	193,536	203,212	213,372	224,040	1,018,480
2. Graduate Students Training	83,100	87,255	91,617	96,197	101,006	459,175
3. Equipment	0	0	0	0	0	0
4. Travel	23,900	25,095	26,349	27,666	29,049	132,059
5. Materials & Supplies	81,190	85,249	89,511	93,986	98,685	448,621
6. Other Direct Costs	15,725	16,512	17,341	18,210	19,122	86,910
7. Indirect Costs	135,538	142,314	149,429	156,900	164,745	748,926
8. Total	523,773	549,961	577,459	606,331	636,647	2,894,171
9. Univ. Cost Share	130,982	137,436	144,307	151,522	159,098	723,345
10. TOTAL	654,755	687,397	721,766	757,853	795,745	$3,617,516
			NCS/BCP/TP			
1. Salaries, Wages Fringe Benefits	214,871	225,615	236,895	248,740	261,177	1,187,298
2. Graduate Students Training	105,300	110,565	116,093	121,898	127,993	581,849
3. Equipment	0	0	0	0	0	0
4. Travel	30,315	31,831	33,422	35,093	36,848	167,509
5. Materials & Supplies	113,970	119,669	125,652	131,935	138,531	629,757
6. Other Direct Costs	5,994	6,294	6,608	6,939	7,286	33,121
7. Indirect Costs	63,182	66,341	69,658	73,141	76,798	349,120
8. Total	533,632	560,315	588,328	617,746	648,633	2,948,654
9. Univ. Cost Share	114,856	120,599	126,629	132,960	139,608	634,652
10. TOTAL	648,488	680,914	714,957	750,706	788,241	$3,583,306

Table 3. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

OPTIMAL BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			GA/IM/BF			
1. Salaries, Wages Fringe Benefits	55,998	58,798	61,738	64,825	68,066	309,425
2. Graduate Students Training	0	0	0	0	0	0
3. Equipment	11,000	11,550	12,128	12,734	13,371	60,783
4. Travel	16,000	16,800	17,640	18,522	19,448	88,410
5. Materials & Supplies	36,065	37,868	39,762	41,750	43,837	199,282
6. Other Direct Costs	13,047	13,699	14,384	15,104	15,859	72,093
7. Indirect Costs	33,240	34,902	36,647	38,479	40,403	183,671
8. Total	165,350	173,617	182,299	191,414	200,984	913,664
9. Univ. Cost Share	55,226	57,987	60,887	63,931	67,128	305,159
10. TOTAL	220,576	231,604	243,186	255,345	268,112	$1,218,823
			NCS/IM/TP			
1. Salaries, Wages Fringe Benefits	46,500	48,825	51,266	53,830	56,521	256,942
2. Graduate Students Training	38,500	40,425	42,446	44,569	46,797	212,737
3. Equipment	0	0	0	0	0	0
4. Travel	18,000	18,900	19,845	20,837	21,879	99,461
5. Materials & Supplies	33,140	34,797	36,537	38,364	40,282	183,120
6. Other Direct Costs	5,500	5,775	6,064	6,367	6,685	30,391
7. Indirect Costs	21,200	22,260	23,373	24,542	25,768	117,143
8. Total	162,840	170,982	179,531	188,509	197,932	899,794
9. Univ. Cost Share	34,849	36,591	38,421	40,342	42,359	192,562
10. TOTAL	197,689	207,573	217,952	228,851	240,291	$1,092,356

Table 4. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

OPTIMAL BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			GA/PV/N			
1. Salaries, Wages Fringe Benefits	52,468	55,091	57,846	60,738	63,775	289,918
2. Graduate Students Training	27,562	28,940	30,387	31,906	33,502	152,297
3. Equipment	0	0	0	0	0	0
4. Travel	7,500	7,875	8,269	8,682	9,116	41,442
5. Materials & Supplies	26,970	28,319	29,734	31,221	32,782	149,026
6. Other Direct Costs	0	0	0	0	0	0
7. Indirect Costs	23,500	24,675	25,909	27,204	28,564	129,852
8. Total	138,000	144,900	152,145	159,751	167,739	762,535
9. Univ. Cost Share	60,900	63,945	67,142	70,499	74,023	336,509
10. TOTAL	198,900	208,845	219,287	230,250	241,762	$1,099,044
			TX/MM/S			
1. Salaries, Wages Fringe Benefits	61,765	64,853	68,096	71,501	75,076	341,291
2. Graduate Students Training	55,113	57,869	60,762	63,800	66,990	304,534
3. Equipment	0	0	0	0	0	0
4. Travel	14,870	15,614	16,394	17,214	18,075	82,167
5. Materials & Supplies	45,000	47,250	49,613	52,093	54,698	248,654
6. Other Direct Costs	10,047	10,549	11,077	11,631	12,212	55,516
7. Indirect Costs	80,963	85,011	89,262	93,725	98,411	447,372
8. Total	267,758	281,146	295,204	309,964	325,462	1,479,534
9. Univ. Cost Share	64,399	67,619	71,000	74,550	78,277	355,845
10. TOTAL	332,157	348,765	366,204	384,514	403,739	$1,835,379

Table 5. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

OPTIMAL BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			AAM/FT/BF			
1. Salaries, Wages Fringe Benefits	84,606	88,836	93,278	97,942	102,839	467,501
2. Graduate Students Training	43,290	45,455	47,727	50,114	52,619	239,205
3. Equipment	4,000	4,200	4,410	4,631	4,862	22,103
4. Travel	16,049	16,851	17,694	18,579	19,508	88,681
5. Materials & Supplies	33,165	34,823	36,564	38,393	40,312	183,257
6. Other Direct Costs	4,000	4,200	4,410	4,631	4,862	22,103
7. Indirect Costs	59,890	62,883	66,028	69,329	72,795	330,925
8. Total	245,000	257,248	270,111	283,619	297,797	1,353,775
9. Univ. Cost Share	59,756	62,744	65,881	69,175	72,634	330,190
10. TOTAL	304,756	319,992	335,992	352,794	370,431	$1,683,965
			GA/FT/TP			
1. Salaries, Wages Fringe Benefits	63,043	66,195	69,505	72,980	76,629	348,352
2. Graduate Students Training	39,868	41,861	43,954	46,152	48,460	220,295
3. Equipment	17,386	18,255	19,168	20,126	21,133	96,068
4. Travel	11,500	12,075	12,679	13,313	13,978	63,545
5. Materials & Supplies	37,930	39,827	41,818	43,909	46,104	209,588
6. Other Direct Costs	156	164	172	181	190	863
7. Indirect Costs	38,617	40,548	42,575	44,704	46,939	213,383
8. Total	208,500	218,925	229,871	241,365	253,433	1,152,094
9. Univ. Cost Share	39,206	41,166	43,225	45,386	47,655	216,638
10. TOTAL	247,706	260,091	273,096	286,751	301,088	$1,368,732

Table 6. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

OPTIMAL BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			GA/PH/CAR			
1. Salaries, Wages Fringe Benefits	53,976	56,675	59,509	62,484	65,608	298,252
2. Graduate Students Training	28,806	30,246	31,759	33,347	35,014	159,172
3. Equipment	2,500	2,625	2,756	2,894	3,039	13,814
4. Travel	9,687	10,171	10,680	11,214	11,775	53,527
5. Materials & Supplies	25,764	27,052	28,405	29,825	31,316	142,362
6. Other Direct Costs	750	788	827	868	911	4,144
7. Indirect Costs	35,517	37,293	39,157	41,115	43,171	196,253
8. Total	157,000	164,850	173,093	181,747	190,834	867,524
9. Univ. Cost Share	35,517	37,293	39,157	41,115	43,171	196,253
10. TOTAL	192,517	202,143	212,250	222,862	234,005	$1,063,777

Table 7. PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS

CURRENT + 5% INFLATION BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
TX/BCP/S,N,BF						
1. Salaries, Wages Fringe Benefits	123,976	133,276	139,960	146,979	154,316	698,507
2. Graduate Students Training	25,541	19,876	20,850	26,072	23,385	115,724
3. Equipment	0	0	0	0	0	0
4. Travel	15,500	13,640	15,200	14,900	15,100	74,340
5. Materials & Supplies	43,472	50,931	53,448	56,020	59,673	263,544
6. Other Direct Costs	6,458	7,604	7,135	3,445	8,762	33,404
7. Indirect Costs	78,145	82,419	86,540	90,873	95,017	432,994
8. Total	293,092	307,746	323,133	338,289	356,253	1,618,513
9. Univ. Cost Share	68,833	72,170	75,778	79,569	83,414	379,764
10. TOTAL	$361,925	379,916	398,911	417,858	439,667	$1,998,277
NCS/BCP/TP						
1. Salaries, Wages Fringe Benefits	124,130	129,469	137,396	144,307	152,747	688,049
2. Graduate Students Training	55,200	56,200	58,400	59,400	61,600	290,800
3. Equipment	0	0	0	0	0	0
4. Travel	14,000	10,000	11,000	11,000	12,000	58,000
5. Materials & Supplies	68,663	73,455	78,427	83,555	88,875	392,975
6. Other Direct Costs	1,937	7,978	5,712	7,199	5,495	28,321
7. Indirect Costs	34,060	35,788	37,600	39,499	41,491	188,438
8. Total	297,990	312,890	328,535	344,960	362,208	1,646,583
9. Univ. Cost Share	55,165	57,923	60,820	63,860	67,053	304,821
10. TOTAL	353,155	370,813	389,355	408,820	429,261	$1,951,404

Table 8. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

CURRENT + 5% INFLATION BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
GA/IM/BF						
1. Salaries, Wages Fringe Benefits	42,092	43,950	45,889	47,916	50,033	229,880
2. Graduate Students Training	0	0	0	0	0	0
3. Equipment	5,000	6,000	8,000	6,000	6,000	31,000
4. Travel	9,000	9,000	9,000	9,000	9,000	45,000
5. Materials & Supplies	11,562	12,208	12,169	15,282	16,952	68,173
6. Other Direct Costs	3,672	3,844	3,822	4,668	5,111	21,117
7. Indirect Costs	19,919	20,805	21,717	22,761	23,812	109,014
8. Total	91,245	95,807	100,597	105,627	110,908	504,184
9. Univ. Cost Share	22,226	24,158	24,158	25,286	26,384	122,~~322~~ 212
10. TOTAL	113,581	119,965	124,755	130,913	137,292	$626,~~506~~ 496
NCS/IM/TP						
1. Salaries, Wages Fringe Benefits	26,300	27,500	29,000	30,750	32,000	145,550
2. Graduate Students Training	24,400	25,700	26,700	27,300	28,300	132,400
3. Equipment	0	0	0	0	0	0
4. Travel	12,000	12,500	13,588	14,500	15,300	67,888
5. Materials & Supplies	23,858	25,175	26,100	27,056	28,042	130,231
6. Other Direct Costs	0	0	0	500	1,500	2,000
7. Indirect Costs	11,617	12,208	12,849	13,542	14,188	64,404
8. Total	98,175	103,083	108,237	113,648	119,330	542,473
9. Univ. Cost Share	19,096	20,067	21,121	22,260	23,323	105,867
10. TOTAL	117,271	123,150	129,358	135,908	142,653	$648,340

Table 9. PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS

CURRENT + 5% INFLATION BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			GA/PV/N			
1. Salaries, Wages Fringe Benefits	22,375	23,334	24,745	25,620	26,724	122,798
2. Graduate Students Training	25,400	26,200	27,500	29,000	29,500	137,600
3. Equipment	0	0	0	0	0	0
4. Travel	9,400	9,800	10,800	11,400	13,000	54,400
5. Materials & Supplies	23,125	25,046	25,545	26,970	28,376	129,062
6. Other Direct Costs	0	0	0	0	0	0
7. Indirect Costs	16,300	17,100	17,950	18,850	19,800	90,000
8. Total	96,600	101,480	106,540	111,840	117,400	533,860
9. Univ. Cost Share	60,900	60,900	60,900	60,900	60,900	304,500
10. TOTAL	157,500	162,380	167,440	172,740	178,300	$838,360
			TX/MM/S			
1. Salaries, Wages Fringe Benefits	43,773	45,962	48,260	50,673	53,207	241,875
2. Graduate Students Training	43,676	45,859	48,152	50,560	53,086	241,333
3. Equipment	0	0	0	0	0	0
4. Travel	4,100	4,100	4,200	4,200	4,300	20,900
5. Materials & Supplies	13,238	13,830	14,442	15,074	15,527	72,111
6. Other Direct Costs	3,502	3,954	4,389	4,852	5,506	22,203
7. Indirect Costs	44,171	46,378	48,698	51,133	53,690	244,070
8. Total	152,460	160,083	168,141	176,492	185,316	842,492
9. Univ. Cost Share	38,440	40,362	42,364	44,463	46,725	212,354
10. TOTAl	190,900	200,445	210,505	220,955	232,041	$1,054,846

Table 10. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

CURRENT + 5% INFLATION BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			AAM/FT/BF			
1. Salaries, Wages Fringe Benefits	36,579	38,805	40,387	42,225	43,363	201,359
2. Graduate Students Training	31,490	31,490	30,390	31,490	31,490	156,350
3. Equipment	2,000	5,000	6,000	8,000	8,000	29,000
4. Travel	10,000	10,000	10,000	10,000	10,000	50,000
5. Materials & Supplies	15,155	14,890	18,617	19,149	23,755	91,566
6. Other Direct Costs	4,000	4,000	4,000	4,000	4,000	20,000
7. Indirect Costs	36,945	38,460	40,052	41,724	43,479	200,660
8. Total	136,169	142,645	149,446	156,588	164,087	748,935
9. Univ. Cost Share	30,140	31,646	33,229	34,890	36,635	166,540
10. TOTAL	166,309	174,291	182,675	191,478	200,722	$915,475
			GA/FT/TP			
1. Salaries, Wages Fringe Benefits	24,845	24,514	26,359	28,978	26,151	130,847
2. Graduate Students Training	39,868	49,743	62,046	72,286	78,107	302,050
3. Equipment	17,386	13,012	0	0	0	30,398
4. Travel	11,500	10,000	12,000	12,000	11,200	56,700
5. Materials & Supplies	26,930	24,870	25,479	26,361	24,228	127,868
6. Other Direct Costs	200	200	200	200	200	1,000
7. Indirect Costs	25,221	30,909	34,826	29,131	37,518	157,605
8. Total	145,950	153,248	160,910	168,956	177,404	806,468
9. Univ. Cost Share	26,851	28,958	28,442	30,781	32,415	147,447
10. TOTAL	172,801	182,206	189,352	199,737	209,819	$953,915

Table 11. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

CURRENT + 5% INFLATION BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			GA/PH/CAR			
1. Salaries, Wages Fringe Benefits	45,340	45,103	49,567	54,009	56,012	250,031
2. Graduate Students Training	24,198	30,419	26,678	28,012	29,413	138,720
3. Equipment	2,100	2,205	2,315	2,431	2,553	11,604
4. Travel	8,137	4,134	10,128	9,420	9,890	41,709
5. Materials & Supplies	21,639	20,571	23,880	27,283	29,576	122,949
6. Other Direct Costs	0	5,513	0	0	0	5,513
7. Indirect Costs	29,836	29,868	32,136	30,784	32,091	154,715
8. Total	131,250	137,813	144,704	151,939	159,535	725,241
9. Univ. Cost Share	26,127	27,433	29,114	29,838	31,091	143,603
10. TOTAL	157,377	165,246	173,818	181,777	190,626	$868,844

Table 12. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

CURRENT BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
TX/BCP/S						
1. Salaries, Wages, Fringe Benefits	123,057	123,958	123,808	123,827	123,827	618,477
2. Graduate Students Training	21,784	19,172	19,172	19,122	19,122	98,372
3. Equipment	0	0	0	0	0	0
4. Travel	11,801	11,801	11,801	11,801	11,801	59,005
5. Materials & Supplies	41,704	42,605	42,455	42,474	42,474	211,712
6. Other Direct Costs	6,150	6,150	6,150	6,150	6,150	30,750
7. Indirect Costs	74,354	75,164	75,464	75,476	75,476	375,934
8. Total	278,850	278,850	278,850	278,850	278,850	1,394,250
9. Univ. Cost Share	65,460	65,460	65,460	65,460	65,460	327,300
10. TOTAL	$344,310	344,310	344,310	344,310	344,310	$1,721,550
NCS/BCP/TP						
1. Salaries, Wages, Fringe Benefits	120,968	123,514	123,514	125,092	125,645	618,733
2. Graduate Students Training	55,200	55,200	56,400	56,400	57,600	280,800
3. Equipment	0	0	0	0	0	0
4. Travel	10,000	7,000	9,000	7,000	6,000	39,000
5. Materials & Supplies	62,000	62,500	61,500	62,500	62,000	310,500
6. Other Direct Costs	3,171	3,125	925	347	94	7,662
7. Indirect Costs	32,461	32,461	32,461	32,461	32,461	162,305
8. Total	283,800	283,800	283,800	283,800	283,800	$1,419,000
9. Univ. Cost Share	55,165	55,165	55,165	55,165	55,165	275,825
10. TOTAL	$338,965	338,965	338,965	338,965	338,965	$1,694,825

Table 13. PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS

CURRENT BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
GA/IM/BF						
1. Salaries, Wages Fringe Benefits	40,313	40,313	40,313	40,313	40,313	201,565
2. Graduate Students Training	0	0	0	0	0	0
3. Equipment	5,000	5,000	5,000	5,000	5,000	25,000
4. Travel	9,000	9,000	9,000	9,000	9,000	45,000
5. Materials & Supplies	10,225	10,225	10,225	10,225	10,225	51,125
6. Other Direct Costs	3,308	3,308	3,308	3,308	3,308	16,540
7. Indirect Costs	19,054	19,054	19,054	19,054	19,054	95,270
8. Total	86,900	86,900	86,900	86,900	86,900	434,500
9. Univ. Cost Share	21,176	21,176	21,176	21,176	21,176	105,880
10. TOTAL	$108,076	108,076	108,076	108,076	108,076	$540,380
NCS/IM/TP						
1. Salaries, Wages Fringe Benefits	24,750	24,750	24,750	24,750	25,250	124,250
2. Graduate Students Training	24,300	24,300	25,300	25,300	25,800	125,000
3. Equipment	0	0	0	0	0	0
4. Travel	11,500	11,500	11,000	11,000	11,000	56,000
5. Materials & Supplies	21,775	21,775	21,275	21,275	20,275	106,375
6. Other Direct Costs	0	0	0	0	0	0
7. Indirect Costs	11,175	11,175	11,175	11,175	11,175	55,875
8. Total	93,500	93,500	93,500	93,500	93,500	467,500
9. Univ. Cost Share	18,333	18,333	18,333	18,333	18,333	91,665
10. TOTAL	$111,833	111,833	111,833	111,833	111,833	$559,165

Table 14. PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS

CURRENT BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
GA/PV/N						
1. Salaries, Wages Fringe Benefits	20,800	20,650	20,950	20,700	21,150	104,250
2. Graduate Students Training	25,000	25,000	26,500	28,000	29,000	134,100
3. Equipment	0	0	0	0	0	0
4. Travel	8,900	9,400	9,800	10,800	11,800	50,700
5. Materials & Supplies	22,000	21,050	19,450	17,200	14,750	94,450
6. Other Direct Costs	0	0	0	0	0	0
7. Indirect Costs	15,300	15,300	15,300	15,300	15,300	76,500
8. Total	92,000	92,000	92,000	92,000	92,000	460,000
9. Univ. Cost Share	60,690	60,690	60,690	60,690	60,690	303,450
10. TOTAL	$152,690	152,690	152,690	152,690	152,690	$763,450
TX/MM/S						
1. Salaries, Wages Fringe Benefits	41,689	41,689	41,689	41,689	41,689	208,445
2. Graduate Students Training	41,593	41,593	41,593	41,593	41,593	207,965
3. Equipment	0	0	0	0	0	0
4. Travel	4,000	4,000	4,000	4,000	4,000	20,000
5. Materials & Supplies	12,665	12,665	12,665	12,665	12,665	63,325
6. Other Direct Costs	3,182	3,182	3,182	3,182	3,182	15,910
7. Indirect Costs	42,071	42,071	42,071	42,071	42,071	210,355
8. Total	145,200	145,200	145,200	145,200	145,200	726,000
9. Univ. Cost Share	36,300	36,300	36,300	36,300	36,300	181,500
10. TOTAL	$181,500	181,500	181,500	181,500	181,500	$907,500

Table 15. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

CURRENT BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			AAM/FT/BF			
1. Salaries, Wages Fringe Benefits	35,643	36,887	37,437	38,192	40,837	188,996
2. Graduate Students Training	31,490	31,490	30,390	31,490	26,200	151,060
3. Equipment	0	0	0	0	0	0
4. Travel	10,000	10,000	10,000	10,000	10,000	50,000
5. Materials & Supplies	13,366	13,122	13,672	12,817	15,462	68,439
6. Other Direct Costs	4,000	3,000	3,000	2,000	2,000	14,000
7. Indirect Costs	35,501	35,501	35,501	35,501	35,501	177,505
8. Total	130,000	130,000	130,000	130,000	130,000	650,000
9. Univ. Cost Share	28,648	28,648	28,648	28,648	28,648	143,240
10. TOTAL	$158,648	158,648	158,648	158,648	158,648	$793,240
			GA/FT/TP			
1. Salaries, Wages Fringe Benefits	23,845	22,204	22,359	23,788	21,913	114,109
2. Graduate Students Training	35,758	44,317	50,936	56,350	54,107	241,468
3. Equipment	17,386	13,014	0	0	0	30,400
4. Travel	11,500	8,000	12,000	12,000	11,200	54,700
5. Materials & Supplies	26,930	25,560	24,479	25,461	24,228	126,658
6. Other Direct Costs	200	200	200	200	200	1,000
7. Indirect Costs	23,381	25,705	29,026	21,201	27,352	126,665
8. Total	139,000	139,000	139,000	139,000	139,000	695,000
9. Univ. Cost Share	24,530	24,867	22,460	22,780	22,260	116,897
10. TOTAL	$163,530	163,867	161,460	161,780	161,260	811,897

Table 16. **PROPOSED PEANUT CRSP BUDGET SUMMARY BY CATEGORY FOR 5-YEARS**

CURRENT BUDGET LEVEL

Category	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			GA/PH/CAR			
1. Salaries, Wages Fringe Benefits	43,181	40,908	42,818	43,636	43,635	214,178
2. Graduate Students Training	23,045	27,591	23,045	23,045	23,045	119,771
3. Equipment	2,000	2,000	2,000	2,000	2,000	10,000
4. Travel	7,750	3,750	8,750	7,750	7,750	35,750
5. Materials & Supplies	20,610	18,660	20,627	21,652	21,652	103,201
6. Other Direct Costs	0	5,000	0	0	0	5,000
7. Indirect Costs	28,414	27,091	27,760	26,917	26,918	137,100
8. Total	125,000	125,000	125,000	125,000	125,000	625,000
9. Univ. Cost Share	24,838	24,838	24,838	24,838	24,838	124,190
10. TOTAL	$149,838	149,838	149,838	149,838	149,838	$749,190

Table 17.

PROPOSED PEANUT CRSP BUDGET SUMMARY FOR
5-YEARS FOR RESOURCE MANAGEMENT
OPTIMAL BUDGET, 1990-95

Region	1990/91	1991/92	1992/93	1993/94	1994/95	Total
			Agronomy			
West Africa (To be planned)	100,000	105,000	110,250	115,763	121,550	552,563
InterCRSP/ Food Tech	40,000	42,000	44,100	46,305	48,620	221,025
Southeast Asia (To be planned)	100,000	105,000	110,250	115,763	121,550	552,563
InterCRSP Planning, 2 regions	15,000	15,750	16,638	17,364	18,233	82,985
Total	$255,000	267,750	281,238	295,195	309,953	1,409,136
			Socioeconomics			
West Africa	100,000	105,000	110,250	115,763	121,550	552,563
Southeast Asia	100,000	105,000	110,250	115,763	121,550	552,563
InterCRSP Planning, 2 regions	15,000	15,750	16,638	17,364	18,233	82,985
Total	215,000	225,750	237,138	248,890	261,333	1,188,111

Table 18. **COMMUNICATIONS AND OUTREACH BUDGET**

	1990/91	1991/92	1992/93	1993/94	1994/95
			OPTIMAL BUDGET		
Communications Assistant	25,000	26,250	27,563	28,940	30,388
Editorial Cons.	5,000	5,250	5,513	5,788	6,078
Workshops	25,000	26,250	27,563	28,940	30,388
Int. Arachis Newsletter	6,000	6,300	6,615	6,946	7,293
Miscellaneous	24,000	25,200	26,460	27,783	29,172
Total Direct Costs	85,000	89,250	93,714	98,397	103,319
IDC (36%)	30,600	32,130	33,737	35,422	37,194
TOTAL	115,600	121,380	127,451	133,819	140,513
			CURRENT PLUS 5% INFLATION ANNUALLY		
Editorial Cons.	2,067	4,239	5,000	5,000	5,000
Workshops	15,000	15,000	16,519	17,913	20,427
Int. Arachis Newsletter	6,000	6,000	6,000	7,000	7,000
Miscellaneous	20,372	20,372	20,372	20,372	20,372
Total Direct Costs	43,439	45,611	47,891	50,285	52,799
IDC (36%)	15,639	16,420	17,241	18,103	19,008
Total	59,078	62,031	65,132	68,388	71,807
			CURRENT		
Editorial Cons.	---	---	---	---	---
Workshops	15,000	15,000	15,000	15,000	15,000
Int. Arachis Newsletter	6,000	6,000	6,000	6,000	6,000
Misc. (Publications, annual rept, brochures, promotional materials)	20,372	20,372	20,372	20,372	20,372
Total Direct Costs	41,372	41,372	41,372	41,372	41,372
IDC (36%)	14,893	14,893	14,893	14,893	14,893
Total	56,265	56,265	56,265	56,265	56,265

Table 19. **MANAGEMENT ENTITY BUDGET**

	1990/91	1991/92	1992/93	1993/94	1994/95
OPTIMAL BUDGET					
Salaries (3) & Fringe Benefits	139,000	145,950	153,246	160,910	168,956
Communications	5,000	5,250	5,513	5,788	6,078
Operating Sup.	10,000	10,500	11,025	11,576	12,154
Travel (ME Int.)	25,000	26,250	27,563	28,940	30,388
Meeting Costs (ME Dom., BD,TC)	25,000	26,250	27,563	28,940	30,388
EEP Costs	20,000	21,000	22,050	23,152	24,309
Technical Asst.	10,000	10,500	11,025	11,576	12,154
Contingency, Audits	16,000	16,800	17,640	18,522	19,448
Total Direct	250,000	262,500	275,625	289,404	303,875
IDC (36%)	90,000	94,500	99,225	104,185	109,395
Caribbean Hold-back	30,500	32,025	33,425	35,311	37,075
Total	$370,500	$389,025	$408,275	$428,900	$450,345
CURRENT PLUS 5% INFLATION ANNUALLY					
Salaries (3)	145,057	152,309	159,924	167,920	176,316
Communications	4,200	4,410	4,630	4,861	5,104
Operating Sup.	6,300	6,615	6,945	7,292	7,656
Travel (ME Int.)	15,750	16,537	17,363	18,231	19,142
Meeting Cost (ME Dom., BD,TC)	21,000	22,050	23,152	24,309	25,524
EEP Costs	15,750	16,745	17,827	19,762	20,249
Total Direct Costs	208,057	218,666	229,841	242,375	252,892
IDC (36%)	74,934	78,758	82,746	87,258	91,439
Total	282,991	297,424	312,587	329,633	345,430
CURRENT					
Salaries (3)	138,150	145,057	152,309	159,924	167,920
Communications	4,000	4,000	4,000	3,000	3,000
Operating Sup.	6,000	6,000	5,000	4,000	3,000
Travel (ME Int.)	15,000	15,000	12,748	10,000	10,000
Meeting Cost (ME Dom.,BD,TC)	20,000	18,093	16,093	15,000	9,230
EEP Costs	15,000	10,000	8,000	6,226	5,000
Total Direct Costs	198,150	198,150	198,150	198,150	198,150
IDC (36%)	71,335	71,335	71,335	71,335	71,335
Total	$269,485	$269,485	$269,485	$269,485	$269,485