# Integrated Pest Management
## Collaborative Research Support Program
## (IPM CRSP)

### Annual Workplan
### for Year Eleven
### (September 29, 2003 to September 28, 2004)

***Final Version – September, 2003***

**Management Entity**
**Office of International Research, Education and Development (OIRED)**
**Outreach Division – Office of the University Provost**
**Virginia Tech**
**1060 Litton Reaves Hall**
**Blacksburg, VA 24061-0334**

Contact Address for the Management Entity

**IPM CRSP**
**Office of International Research, Education and Development**
**1060 Litton Reaves Hall**
**Virginia Tech**
**Blacksburg, VA 24061-0334**

**Telephone (540) 231-3513**
**FAX (540) 231-3519**

**E-mail: ipm-dir@vt.edu**

## IPM CRSP US Institutions

Lincoln University
Montana State University
Ohio State University
University of Georgia
Penn State University
Purdue University
Virginia Tech
USDA Veg. Lab.
University of California - Davis
University of Maryland - Eastern Shore
North Carolina A&T University
Fort Valley State University

## Host Country Institutions

**Guatemala -** Agri-lab, ALTERTEC, ICTA, ICADA, UVG
**Jamaica -** CARDI, Ministry of Agriculture
**Mali -** IER
**Philippines -** NCPC/UPLB, PhilRice
**Uganda -** Makerere University, NARO
**Ecuador -** INIAP
**Eritrea** - DARHRD
**Albania** - PPI, FTRI, AUT
**Bangladesh** - BARC, BARI
**Honduras –** EAP, FHIA

## International Centers

**AVRDC -** Taiwan
**CIAT -** Colombia
**CIP -** Peru
**ICIPE** - Kenya
**IRRI -** Philippines
**IFPRI -** USA

## Private Sector

The Kroger Company
PICO
Caito Foods

## NGOs/PVOs

CLADES; GEXPRONT,Guatemala; CARE,Bangladesh

# Table of Contents

**....................................................................................................................................Page**

# YEAR 11 IPM CRSP ANNUAL WORKPLAN

## (September 29, 2003 – September 28, 2004)

This workplan describes the research and other activities to be undertaken during the eleventh year of the IPM CRSP, including their timing, scientists' time requirements, expected outputs and impacts, and expected budget allocations. Research objectives and hypotheses are noted and a description of each activity is provided. Workplans were developed by site committees and discussed and approved by the Technical Committee. Activities in the plan are directly related to the five major objectives in the proposal for the second five-year phase of the IPM CRSP. Special efforts were made in each site to solicit support from USAID missions. Each mission was visited, often multiple times, to discuss mission objectives and programs, IPM CRSP objectives and activities, and how to position the IPM CRSP to support mission objectives.

### Program Objectives from the IPM CRSP Proposal for Its Second Phase

Objective 1. Identify and describe the technical factors affecting pest management

Objective 2. Identify and describe the social, economic, political, and institutional factors affecting pest management

Objective 3. Work with participating groups to design, test, and evaluate appropriate participatory IPM strategies

Objective 4. Work with participating groups to promote training and information exchange on PIPM

Objective 5. Work with participating groups to foster policy and institutional changes

### The Year Eleven Plan in Perspective

Year Eleven represents a one-year extension of the second five-year phase of the IPM CRSP. The program completed year ten with seven prime sites (the Philippines, Guatemala, Jamaica, Mali, Uganda, Ecuador, and Bangladesh) fully operational, and the Albania site operating on carryover core funds provided by the USAID mission (funds run through EGAT). A reporting workshop was held in April in Indianapolis to share results of IPM CRSP research across the entire program. This was followed by a planning workshop. Prior to the workshops, approximately 40 investigators on the IPM CRSP participated in the 4th national IPM Symposium in Indianapolis, organizing two major sessions and presenting papers and posters in other sessions. The Technical Committee met three times during year ten. An IPM CRSP annual report, highlights report, and several newsletters were produced in addition to scientific publications.

The workplan that follows is organized by region and by country site. Brief progress reports for continuing activities are found within the workplan activities described for each site. Progress reports for completed activities are included in the annual report for year 10 and in a special document prepared by the IPM CRSP entitled "IPM CRSP Highlights".

Year eleven research activities reflect the expanded effort in biotechnology related to IPM that was begun in Year 9. Special attention is devoted to incorporating biotech solutions to pest management problems in several sites as part of IPM CRSP globalization efforts.

## Cross-Cutting Activities in Year Eleven

### 1. Workshops for Information Sharing Across Sites

A workshop will be planned and implemented that will include all U.S. scientists and at least two host country scientists from every site. A program of scientific papers will be assembled that will address central themes on the IPM CRSP. A poster session will be held for additional presentation of results. A technical committee meeting will be held immediately before and after the workshop. This workshop does not substitute for the regional workshops and meetings that will occur as well during year 11 to share information among larger groups of local and international scientists within the regions.

### 2. Globalization

Several globalization activities will be undertaken during year 11. First, the IPM CRSP book is in progress. Drafts for all 14 chapters (except for two partially drafted chapters) have been completed. This book summarizes the participatory approach used on the IPM CRSP to globalize IPM programs and solutions. It also includes a chapter on IPM farmer field school activities that are being conducted both on and beyond the CRSP. Second, regionalization of IPM CRSP results will continue in each region through targeted research activities and IPM training of students who may not be from one of the prime sites. Third, scientific papers will be presented at international meetings and published. Fourth, close collaboration with international agricultural research centers such as AVRDC, CIP, IRRI, and IFPRI is helping the IPM CRSP spread its results into key IPM networks. Fifth, collaboration with international NGOs which are active in IPM outreach, such as CARE, is helping to spread research results. Finally, the expanded effort in biotech will address pest problems that are global in nature.

## Information Exchange and Networking

IPM CRSP newsletters will be produced and available in hard copy and on-line, facilitating contact within the IPM CRSP, among other CRSPs, and with outside IPM interests. The IPM CRSP website with trip reports, working papers, PowerPoint presentations, a photo gallery of activities at all sites, and other information on IPM CRSP activities will be maintained to make IPM CRSP results globally available to all with internet connections. The Africa IPM Link website, both in English and in French, will continue to focus on IPM-related issues in Africa. An IPM bibliographic search service is available through IPM CRSP collaborating scientists at Penn State.

**Biotechnology Statement**

Virginia Tech and other collaborating institutions each have their own Biotechnology Compliance Committees. They review any proposed biotechnology components of the program to ensure compliance with all relevant regulations dealing with biotechnology and genetically engineered biological products. We will also network with CGIAR initiatives to introduce pest-resistant varieties in our research sites. Year ten was a year in which the IPM CRSP took a major step forward in integrating biotechnology research into the IPM program and that work will continue in year eleven. Biotechnology research activities directed at insect problems in eggplant in Asia, a virus problem on peppers in the Caribbean and Latin America, late blight on potato in Latin America, and tomato viruses in Africa are just some of the activities planned in this area. Some of the biotech activities are funded through the site budgets and some are funded in special projects that were approved through a special call for proposals.

**Intellectual Property Rights**

An agreement on intellectual property rights will be worked out on a case-by-case basis with collaborating institutions at each site.

**Response to AID Requests for IPM Technical Assistance**

The IPM CRSP will respond to requests from USAID missions for IPM technical assistance (TA) in other countries as specified in the grant. These activities will be cost-shared by the requesting missions. Exact details of this cost sharing will be determined on a case-by-case basis in discussions among the ME, the mission, and USAID's Office of Agriculture. A dedicated fund has been set aside by the IPM CRSP for technical assistance. Unspent TA funds that were allocated to special projects in Year 10 and prior years, will be redirected to the general Year 11 TA fund to augment the available TA resources. Funds allocated to coffee wilt in Uganda and Gall Midge in Jamaica will continue to be spent for those purposes.

**External Evaluation**

The External Evaluation Panel is scheduled to meet once during the year.

**Technical Committee Meetings**

The technical committee will have at least three meetings during the year, at least one of which will be face to face.

**Board Meeting**

The board will meet in March, 2004.

**Degree Training**

In addition to short-term training, graduate students from the host countries or from the United States are assisting in the program and writing theses and dissertations. These students may be graduate students at academic institutions in the host countries or in the United States. A listing of the specific students, and their nationality, discipline, site, degree, and university is provided in Appendix table 1. The majority of these students are from the host countries.

## YEAR 11 WORKPLAN FOR THE SOUTHEAST ASIA SITE IN THE PHILIPPINES

Activities planned for Year 11 at the Asia Site in the Philippines are: 1) wrap-up of all continuing laboratory and field studies; 2) greater focus on technology transfer and socio-economic impact assessment studies; 3) biotechnology activities on a) development of *Bt* eggplant to manage the eggplant fruit and shoot borer and b) characterization of *Ralstonia solanacearum* strains; and 4) collaboration with USAID local mission projects where technical expertise of IPM CRSP scientists may be needed.

Most of the activities focus on technology transfer and on-farm technology demonstration and verification trials to showcase packages of IPM technologies developed over the past 10 years in efforts to hasten adoption of IPM CRSP technologies. Because onion culture varies with a particular variety and or location, different technology packages will be tested according to the location and variety used in that particular location. A training manual on "IPM in Rice-Vegetable Systems", and two field guides on "Pests and their Management in Onion" and "Pests and their Management in Eggplant" are in the final draft stages and will be published in Year 11.

Collaboration with USAID local mission in its projects involving agricultural crop production is another focus for year 11. One area is the GEM-2 (Growth and Equity in Mindanao) project in Mindanao involving vegetable production. A participatory appraisal will be conducted in GEM-2 based areas in Mindanao to determine where IPM CRSP pest management technologies can be used. The Bt eggplant (biotechnology) project will be done in collaboration with India, Bangladesh and the U.S. This is a novel approach that can be an alternative to insecticide use to manage one of Asia's most serious pests in eggplant, the fruit and shoot borer. The second biotechnology project will result in characterization of *Ralstonia solanacearum* strains collected in intensive surveys in eggplant production areas during Year 10. This work is particularly important because *R. solanacearum* race 3 biovar 2 is classified by the U.S. government as a "select agent" and it is important to verify that the race structure in the Philippines (primarily race 1) has not changed.

In anticipation of release of funds from PL 480, priority crops, pests and researchable areas in the proposed expansion areas (Ilocos, Pangasinan, Nueva Vizcaya) have been determined through a PA process conducted in Year 10. The 12 activities under PL 480 initially proposed for Year 10 will be started in year 11, should the PL 480 funds be released in Year 11 (see Year 10 workplan). These studies address additional technology generation and expansion to other parts of the country with rice-based cropping systems. Technologies developed at the Nueva Ecija sites will be also be disseminated to the expansion areas using PL 480 funds.

Collaboration of national and international scientists with highly complementary expertise in rice and vegetable IPM continue through year 11 at the IPM CRSP Philippine site. They come from U.S. universities (Virginia Tech, Ohio State, Pennsylvania State), Philippine research and educational institutions (PhilRice, University of the Philippines Los Banos, Central Luzon State University, Leyte State University), international institutions (Asian Vegetable Research and Development Center, International Rice Research Institute), non-government organizations (NOGROCOMA, site of the demo farm since 1996) and farmer-cooperators. Cooperation between the Philippine and Bangladesh sites on management of eggplant pests using genetic and cultural approaches will be continued. IPM CRSP-supported scientist training in graduate and non-graduate programs will also continue in year 11.

## FIELD EXPERIMENTS (On-Farm and PhilRice CES)

### I.1. Population Dynamics of Purple Nutsedge (*Cyperus rotundus* L.) in Different Weed Management Approaches in Rice-Onion Cropping Systems

**a. Scientists:** A.M. Baltazar – UPLB/PhilRice; J.M. Ramos, E.C. Martin, M.C. Casimero – PhilRice; A.M. Mortimer – IRRI; S.K. De Datta – Virginia Tech

**b. Overall objective:** To develop integrated weed management practices for control of *Cyperus rotundus* infesting rice-onion cropping systems. **Year 11 objective**: To determine tuber and shoot population dynamics of purple nutsedge (*Cyperus rotundus* L.) growing with rice and onion crops treated with preplant and postplant weed management practices.

**c. Hypotheses:** Reductions in tuber and shoot populations vary according to management practices; more significant reductions in stale-seedbed techniques than in farmers' practice or preplant applications without tillage.

**d. Description of research activity**: Onion cultivar Red Pinoy or Yellow Granex will be grown under different weed control treatments: preplant herbicide applications with and without tillage, stale seedbed technique, postplant herbicide applications. Farmers' practice and unweeded and weed-free control plots will be included. Purple nutsedge shoots will be tagged with different colors as they emerge and tuber populations will be counted before and after each crop in fixed quadrats. The same treatments will be evaluated during the rice cropping season to determine population dynamics of purple nutsedge in a rice-onion cropping system. Fresh weight of bulbs will be recorded at harvest. Cost-effectiveness of treatments will be analyzed.

**e. Justification:** As much as 90% of potential yields in onion are lost due to competition from weeds particularly purple nutsedge, the major weed problem in vegetables. Farmers spend about $300/ha or 20% of their production costs due to handweeding labor and herbicides. Understanding the population dynamics of this weed under different management practices will help in determining appropriate combinations of cultural and chemical interventions at the correct timing and frequency of applications that will involve less labor for handweeding as well as minimize herbicide use to reduce production costs due to weed control inputs.

**f. Relationship to other CRSP activities at the site:** Data obtained from this activity will be used in developing an integrated weed management package for purple nutsedge in onion and other vegetables.

**g. Progress to date**: First year studies are on-going as Ph. D. thesis research of Nazrul Islam, IPM CRSP scholar from Bangladesh site. A second year trial is needed to complete a two-year study involving a four-crop rotation cycle of the rice-onion cropping pattern.

**h. Projected output**: 1) Data on population dynamics of purple nutsedge in rice-onion cropping systems; 2) Reduced herbicide use and labor for handweeding.

**i.** **Projected impact**: 1) Lower production costs; 2) Lower yield losses due to weeds; 3) Increased net incomes of onion growers.

**j.** **Projected start**: October 2003

**k.** **Projected completion**: September 2004

**l.** **Projected person-months of scientists' time per year:** 3-4

**m.** **Budget**: PhilRice - $2,437; Virginia Tech - $ 1,277

## I.2. A Survey on the Seasonal Abundance of Onion Leaf miner *Liriomyza trifolii* (Burgess), Incidence of Parasitism and Effect of Trap Color on Attraction of Adults

**a.** **Scientists**: G.S. Arida, E.R. Tiongco, B.S. Punzal, A.V. Duca - PhilRice and E.G. Rajotte-Penn State Univ

**b.** **Overall objective:** To determine if naturally occurring biological control agents in combination with mass trapping of adult flies can be effective management strategies for *Liriomyza trifolii* in onion. **Year 11 objective**: 1) To assess the seasonal abundance of leaf miner and its parasitoids in onion; 2) Identify leaf miner parasitoids and predators; and 3) Determine the effect of trap color on the attraction of leaf miner adults.

**c.** **Hypothesis**: There are communities of natural enemies (parasitoids and predators) that attack leaf miner in the absence of insecticide applications. These naturally occurring biological control agents help regulate leaf miner populations in the field. Mass trapping of adults could be incorporated into an IPM program for this pest in vegetables.

**d.** **Description of research activity**:

<u>*Abundance of leaf miner and its parasitoid.*</u> Sampling will be done in farmer's fields in five towns in Nueva Ecija and three each from the provinces of Nueva Viscaya and Pangasinan. In each town, 2 fields will be sampled; each field will be visited 3 times during crop growth. Level of damage will be evaluated on 20 randomly selected plants at each sampling. Damaged leaves (50-100) will be collected at random from each field to assess level of parasitism. Leaf samples will be placed in containers mounted with an inverted funnel attached to vials to trap emerging flies or parasitoids. Collected parasitoids will be reared at the IPM CRSP laboratory and percent parasitism will be calculated..

<u>*Comparison of color of traps for attracting leafminer adults.*</u> Four colors of board traps will be compared for attraction to adult leaf miner: yellow, purple, blue and white (control). The traps will be set out in a 0.5 ha field at the NOGROCOMA, IPM-CRSP Demo Farm in Bongabon, Nueva Ecija. Each color will be replicated four times in a randomized complete block design (RCBD). Trap catches will be recorded weekly.

**e.** **Justification**: Very limited information is known on the natural enemies of onion leaf miner in the Philippines including its impact on the population dynamics of the pest. Maximizing natural control is an important principle in IPM.

Knowledge of the most attractive color is important in surveillance and monitoring system. These are useful in determining the best time of application of interventions if needed.

**f.** **Relationship to other CRSP activities at the site**: This study will augment other studies on insect pests of onion and on the development of IPM strategies for this pest.

**g.** **Progress to date**: The species of leaf miner attacking onion was recently identified as *Liriomyza trifolii* (Burgess). Dr. Sonja J. Scheffer (USDA-ARS, Beltsville, MD, 20705 USA) identified the specimens collected by IPM-CRSP staff from several onion growing provinces in Central Luzon, Philippines.

**h.** **Projected output**: Data on seasonal abundance of leaf miner and its parasitoids from different locations. Identification of parasitoids and other natural enemies in the Philippines.

**i.** **Projected impact**: Reduced insecticide use in onion against leaf miner.

**j.** **Projected start**: September 2003

**k.** **Project completion**: October 2004

**l.** **Projected person - month of scientists' time per year**: 4

**m.** **Budget**: PhilRice - $ 3,564; Penn State - $4,544

## I.3 Influence of Host Resistance and Grafting on the Incidence of Bacterial Wilt of Eggplant

**a.** **Scientists:** N.L. Opina – UPLB, R.T. Alberto, S.E. Santiago – PhilRice, R.M. Gapasin – LSU, and S.A. Miller – Ohio State

**b.** **Overall objective:** To determine the effectiveness of host resistance and grafting against bacterial wilt. **Year 11 objectives**: 1) To evaluate the effectiveness of grafting in reducing the incidence of bacterial wilt on eggplant during wet season; 2) To determine wilt severity of eggplant as influenced by root-knot nematode inoculum density; and 3) To evaluate the Co2 isoline which expresses Bt coded genes for its adaptability and reaction to bacterial wilt.

**c.** **Hypothesis**: Grafting using bacterial wilt and root-knot nematode resistant eggplant rootstocks will further decrease the incidence of bacterial wilt.

**d.** **Description of research activity**

*Effect of grafting*. Eggplant cultivars known to be resistant to both bacterial wilt and root-knot nematode, and a wild species of eggplant, *Solanum sisymbriifolium*, will be used as rootstock and compared with EG 203. The Bt eggplant Co2 isoline used in India will be tested for its reaction to bacterial wilt. Non-transformed plants will be grafted on bacterial wilt resistant rootstocks to determine its grafting compatibility and resistance to bacterial wilt.

Grafting will be done at PhilRice (CES) using technology from AVRDC and IPM CRSP Bangladesh site. One-month-old grafted and non-grafted eggplant seedlings will be transplanted in naturally infested fields where bacterial wilt incidence is high during the wet season. The plants will be planted in 4 x 5 m plots and treatments arranged in RCBD with four replications. Incidence of bacterial wilt will be monitored in each plot at weekly intervals. All inputs and crop yields will be recorded and potential economic benefits will be analyzed.

*Screening for resistance to root-knot nematode.* Seeds of different lines/varieties/ hybrids of egg plant will be obtained from different sources. The most virulent culture of *Ralstonia solanacerarum* will be obtained from N. Opina. The root-knot nematode will be mass produced or cultured in susceptible tomato. Thirty-day old eggplant seedlings will be grown in plastic pots filled with sterilized soil. After 45 days the plants will be inoculated with 1,000 eggs of the nematode and placed in the screenhouse. Data will be collected after another 45 days from time of inoculation. Gall and egg mass rating index will be recorded following the rating scale of: 1= 1-2 galls or egg masses; 2 = 3-10 galls or egg masses; 3= 11-30 galls or egg masses; 4= 31-100 galls or egg masses and 5= more than 100 galls or egg masses. Based on this index the resistance rating of the different lines/ varieties/ hybrids will be determined as follows: 0 – 0.9= Resistant; 2.0-2.9= Moderately Resistant; 3.0 –3.9= Moderately Susceptible and 4.0-5.0= Susceptible. Treatments will be replicated five times.

e. **Justification:** Bacterial wilt, caused by *Ralstonia solanacerarum* and root-knot nematode caused by *Meloidogyne incognita*, are destructive diseases affecting solanaceous crops in tropical, subtropical and even in temperate regions. The pathogen is soil-borne, has wide host range and can survive in the deeper layers of the soil. Eggplant cultivars believed to be wilt resistant succumb to bacterial wilt when planted in root-knot infested soil. The nematode predisposes the plants to bacterial infection. It is, therefore, important to screen eggplant varieties for resistance to root-knot nematode to be able to manage bacterial wilt disease.

f. **Relationship to other CRSP activities at the site**: The management of bacterial wilt in eggplant will complement management options being developed against eggplant leafhopper (*Amrasca biguttula*) and fruit and shoot borer (*Leucinodes orbonalis*). Its integration with insect pest management is essential to success of eggplant production in the country.

g. **Progress to date**: Initial results show decreased incidence of bacterial wilt in grafted plants compared to ungrafted plants.

h. **Projected output:** Reduced incidence of bacterial wilt; and identification of the most resistant lines/varieties/hybrids to root-knot nematode.

**i.** **Projected impact:** Lower production costs, higher yields, higher net profits of eggplant farmers.

**j.** **Projected start:** October 2003

**k.** **Project completion:** September 2004

**l.** **Projected person-months of scientists' time per year:** 4

**m.** **Budget:** PhilRice - $ 1,474; Ohio State - $1,449

### 1.4. Combined Resistance of Eggplant *Solanum melongena* L. to Leafhopper, *Amrasca biguttula* Ishida and Eggplant Borer, *Leucinodes orbonalis* Guenee

**a.** **Scientists:** M.T. Caasi-Lit, R.G. Maghirang, M.A.A. Capricho – UPLB; E.G. Rajotte – Penn State

**b.** **Overall objective:** To identify and develop genetic stocks of eggplant with combined resistance to *Amrasca biguttula* and *Leucinodes orbonalis*. **Year 11 objectives:** 1) Conduct village level integration activities to compare varieties resistant to leafhopper and fruit and shoot borer with farmers' varieties in Abar, Nueva Ecija and Bantog, Asingan, Pangasinan.

**c.** **Hypotheses:** 1) There are available sources of resistance of eggplant to leafhopper and eggplant borer that could be utilized to help regulate the populations of these pests below damaging levels; and 2) Use of resistant eggplant populations is an effective means of managing these two major insect pests.

**d.** **Description of research activity:** Three eggplant cultivars (A300, Abar, SRO) identified in the screening trials as resistant to leafhopper and fruit and shoot borer will be grown in farmers' fields and compared with performance of the variety grown by the farmer in terms of resistance to these two insect pests. This will be included as part of the village level integration activity in Pangasinan and Nueva Ecija. Counting for leafhopper and leafhopper damage will start at 45 days after transplanting at 15-day intervals until 105 DAT. Observations for shoot and fruit damage starts at 30 DAT at 7-day intervals until 105 DAT. Dissection of fruits for borer damage starts at first harvest (about 75 DAT until 105 DAT). Plants like okra, corn, squash and others will be grown around and between experimental plots.

**e.** **Justification:** While leafhopper was observed to cause significant yield loss at early vegetative stage of eggplant growth, shoot/fruit borer is now the number one insect pest of eggplant at early to fruiting stages. The larva damages the plant at the early vegetative stage by boring into the shoots. This causes tips or shoots to wilt and dry up. Damage increases at the flowering to fruiting stage when larvae start to bore into the flower buds and newly formed fruits. This causes significantly heavy losses or even total crop yield loss. Screening leafhopper resistant varieties for resistance to the eggplant borer is the first attempt to identify genetic stocks and develop eggplant populations with combined resistance to these two major insect pests. The use of resistant varieties or combination of farmer's and commercial resistant varieties would also help minimize yield loss and are environmentally friendly. Specifically, the use of resistant varieties is safe to non-target pests, enhances establishment of parasites and predators and, thus, is a safer alternative to pest management than heavy pesticide use.

f. **Relationship to other CRSP activities at the site:** Use of resistant varieties can complement other control measures in eggplant against these pests such as use of biological control agents (*Trathala*, *Chelonus*, *Cotesia* against eggplant borer and *Campylomma livida* against the leafhopper) and use of cultural management practices (fruit removal and sanitation).

g. **Progress to date:** Host plant resistance studies in eggplant against the eggplant leafhopper started at the Institute of Plant Breeding, UPLB in 1987 and improved IPB lines, IPB-GSI and IPB GS2, were included in the leafhopper resistance screening and hybridization work. Several land races collected from the different regions of the country include Abar, C, and SRO2. EG203 from AVRDC is a promising material suggested by Dr. Talekar. Screening eggplant for resistance to the eggplant borer started in 1997. Several accessions from NPGRL were screened in the field and 15 entries showed moderate resistance against the borer. Screening protocols for the eggplant borer are being developed or improved. With funding from IPM CRSP, a number of farmers' and commercial varieties of eggplant were screened and showed promising response against these two major insect pests. Several entries were selected with resistance to both insect pests including EG203, Abar, C, IPBGS1, SRO2 etc. These open-pollinated varieties can be recommended to the farmers for backyard and commercial production. Further work is being done on the development of eggplant populations with combined resistance to leafhopper and shoot/fruit borer.

h. **Projected output:** 1) Identification of sources of resistance or genetic stocks of eggplant with resistance to leafhopper and to the eggplant borer; 2) Field techniques and procedures to screen eggplant genotypes for resistance to the pests and basic information on host plant resistance; 3) Techniques to incorporate borer resistance to commercially grown eggplant varieties.

i. **Projected impact:** 1) Reduced or no pesticide use as HPR-based pest management strategy capitalizes on sound, safe and environmentally friendly approaches; 2) Genetic diversity in eggplant for insect pest resistance.

j. **Projected start:** October 2003

k. **Projected completion:** September 2004

l. **Projected person-months of scientists' time per year:** 3

m. **Budget:** PhilRice/UPLB - $ 550

### I.5. Management of the Eggplant Fruit and Shoot Borer *Leucinodes orbonalis* (Guenee): Evaluation of Farmers' Indigenous Practices

a. **Scientists**: G.S. Arida, A.V. Duca, B.S. Punzal-PhilRice and E.G. Rajotte-Penn State University

**b.** **Overall objective:** To develop safe and economical management strategies against the eggplant fruit and shoot borer. **Year 11 objective:** To complete evaluation of farmers' indigenous pests management practices against the eggplant fruit and shoot borer.

**c.** **Hypothesis**: Pest control practices of some farmers to manage the eggplant fruit shoot and fruit borer are effective and comparable to, if not better than, the prevalent method of 60 to 80 insecticide sprays per season.

**d.** **Description of research activity**: This study will be conducted at the PhilRice Central Experiment Station (CES). There will be five treatments, three of which are practices of some farmers (use of insect repellant, dusting the plant with burned rice hull, and weekly spray of insecticide), another is based on results of IPM CRSP studies (weekly removal of damaged fruits and shoots), and control (unsprayed).

Treatments will be arranged in a randomized complete block design replicated 4 times. The treatments are: 1) Planting marigold (*Tagetes* sp.) with eggplant; 2) Weekly application of burned rice hull by dusting; 3) Weekly removal of damaged fruits and shoots (based on previous CRSP results); 4) Weekly spray of insecticides; and 5) Control. Damaged fruits and shoots will be monitored weekly beginning at 2 weeks after transplanting. Yield of each plot will be recorded.

**Note:** Three sex pheromone baited traps will be installed in the field to monitor adult population density. Sex pheromones of *L. orbonalis* recently arrived from Europe. The relationship between sex pheromone trap catches and damaged shoots and fruits will be analyzed.

**e.** **Justification**: *L. orbonalis* is the most serious insect pest of eggplant in Asia including the Philippines. Farmers usually spray several times a week in order to manage this pest, seldom with success. Surveys showed that farmers in the Philippines sprayed 58 times on the average while it was 80 times in Bangladesh. This insecticide misuse resulted in high cost of production and pesticide hazards to farmers, consumers and the environment. It is therefore necessary to find an alternative method in managing this pest. Our present evaluation of a net barrier against this pest showed it may not be economical, not acceptable to most farmers and the pest can still infest the crop inside the cage.

In some areas in the Philippines some farmers reported that repellant crop like *Tagetes* sp. protected their eggplant against insect pests and obtained good yields. In another area, farmers reported using ash from burned rice hull to repel the pests attacking eggplant. They applied the burned rice hull as dust on eggplant leaves. If these management practices of some farmers are proven effective, these will be economical, safe and acceptable to all eggplant farmers.

**f.** **Relationship to other CRSP activities at the site**: This is a complementary project on the management of the eggplant fruit and shoot borer.

**g.** **Progress to date**: Previous studies in IPM-CRSP Philippine site showed that weekly removal of damaged shoots and fruit is a good alternative to high frequency of insecticide sprays against the borer.

**h.** **Projected output**: An alternative management strategy against the eggplant fruit and shoot borer.

**i.** **Projected impact**: Reduction in costs and hazards caused by insecticide applications.

**j.** **Projected start**: October 2003

**k.** **Projected completion**: September 2004

**l.** **Projected person-months of scientists' time per year**: 4

**m.** **Budget:** PhilRice - $ 3,344; Penn State - $ 2,726

### I.6. Management of Anthracnose (*Colletotrichum gloeosporioides*), a Disease of Increasing Importance in Onion

**a.** **Scientists:** R.T. Alberto – CLSU; M.S.V. Duca – PhilRice, S.A. Miller – Ohio State

**b.** **Overall objective:** To develop integrated management strategies against anthracnose disease of onion. **Year 11 objectives:** 1) Compare cultural and chemical control and their combination for management of anthracnose in onion; 2) Determine effective timing, rates and frequency of application of commercially available fungicides against anthracnose disease of onion; 3) Determine the therapeutic effects of the test fungicide (Mancozeb) against anthracnose of onion.

**c.** **Hypothesis:** Currently available fungicides, when combined with other management strategies, will be effective against anthracnose.

**d.** **Description of research activity:** The study will be conducted at PhilRice Central Experiment Station. Forty-five day old seedlings of onion cv. Takiis will be transplanted into raised beds with eight rows per bed in six 20 $m^2$ plots arranged in RCBD with five replications. Plants will be inoculated with 14 day-old spore suspension of *C. gloeosporioides* (spore density of 2.5 x $10^6$ with 10 drops of Tween 80/liter of suspension) at 1 week after transplanting. The inoculated plants will be covered with plastic mats overnight and removed the following morning for 3 consecutive days to induce infection. Mist or overhead irrigation will be used to simulate rainfall and to maintain 100% relative humidity. The treatments are: 1) Untreated control, standard plant spacing (10 x 15 cm) & standard nitrogen (120 kg/ha); 2) Mancozeb, 7 days interval (2 weeks after transplanting at recommended rate), standard plant spacing & nitrogen; 3) Low nitrogen (60 kg/ha), standard plant spacing, no Mancozeb; 4) Wide plant spacing (18 x 20 cm), standard nitrogen, no Mancozeb and positioning of rows in the direction of the wind; 5) Low nitrogen, 7 days interval of Mancozeb, wide spacing; 6) Low nitrogen, 14 day Mancozeb, wide spacing; 7) Standard nitrogen, 7 day Mancozeb, wide spacing; 8) Standard nitrogen, 14 days interval of Mancozeb, wide spacing and 9) Low nitrogen, no Mancozeb, wide spacing. Plants in all plots will be managed according to recommended cultural and management practices. Plants will be evaluated for disease incidence (%), disease severity (%) and crop stand at weekly intervals. Based on the disease proportion, AUDPC will be computed. Onion bulbs will be harvested from 1$m^2$ area at the center of each plot. Bulbs will be classified into small, medium and large and then weighed.

**e.** **Justification:** Anthracnose is currently the most destructive disease of onion in the Philippines and the use of fungicides is the only effective means of control so far. In the absence of resistant varieties, cultural and other disease management strategies, farmers have no choice but to use chemical methods. There is a need to know optimum rates, timing and frequency of application to address the negative impact of using chemical fungicides, to develop a strategy of using fungicides in combination with other management methods to lessen its negative impacts to the environment and health, and to avoid development of resistance of the pathogen to fungicides. With these, development of an integrated approach in managing the disease is highly justified.

**f.** **Relationship to other CRSP activities at the site:** Results of this experiment will complement the activity on the effect of nitrogen on bulb rot incidence in onion during storage.

**g.** **Progress to date:** First year studies are ongoing. Results will be available at the end of the cropping season.

**h.** **Projected output:** Development of integrated approaches to manage anthracnose disease in onion.

**i.** **Projected impact:** Reduced fungicide use, reduced hazards of pesticide application, less farm input and higher yields.

**j.** **Projected start:** October 2003

**k.** **Projected completion:** September 2004

**l.** **Projected person-months of scientists' time per year:** 2

**m.** **Budget:** PhilRice - $2,805; Ohio State - $ 2,741

### I.7. Sex Pheromones in Pest Management: Surveillance, Monitoring and Mass Trapping of Male Moths

**a.** **Scientists**: G.S. Arida, B.S. Punzal, A.V. Duca - PhilRice and E.G. Rajotte – Penn State U

**b.** **Overall objective**: To develop monitoring and surveillance tools for effective timing of interventions against *Spodoptera litura, S. exigua, Helicoverpa armigera* and *Leucinodes orbonalis* in eggplant and other vegetables. **Year 11 objective**: To determine the relationships between sex pheromone trap catches and pest densities and damage in vegetables (tomato, bitter gourd, eggplant pole beans, etc).

**c.** **Hypothesis**: Sex pheromone trap catches could predict early season arrival of *S. litura, S. exigua, H. armigera and L. orbonalis* in several vegetables. Peaks in sex pheromone trap catches could be used as an indicator for effective timing of interventions against the above mentioned insect pests thus reducing insecticide applications.

**d. Description of research activity**

*S. litura, S. exigua, H. armigera in tomato, pechay and pole sitao and L. orbonalis in eggplant.* This study will be conducted in several farmers' fields and at the PhilRice Central Experimetal Station (CES). Three-sex pheromone traps for each of the target insects will be installed 1-2 weeks before planting. Traps will be monitored for catches three times a week. Each field will be divided into four main plots, each representing a replicate. Number of larvae of the insect and its damage will be monitored on 10 randomly selected plants/plot/ week.

**e. Justification:** Monitoring and surveillance systems are essential components of an effective Integrated Pest Management (IPM) program. No alternative controls are available at the moment for vegetable farmers so they usually apply insecticides as prophylactic treatments resulting in high incidence of insecticide misuse. Sex pheromone baited traps could be used as an effective monitoring tool to effectively apply insecticide as our studies in onion against *S. litura* and *S. exigua* have shown.

**f. Relationship to other CRSP activities at the site:** This is an important component in the management of *S. litura, S. exigua. H. armigera* and *L. orbonalis* in onion, eggplant and other vegetables.

**g. Progress to date**: Results of IPM CRSP studies in onion on the management of *S. litura* and S. *exigua* showed that there was a direct relationship between trap catches and *S. litura* eggs, larvae and its subsequent damage.

Further tests showed that when sex pheromone baited traps were utilized as tools for effective timing of application, these resulted in a 70-90% reduction in the frequency of spray without sacrificing yield. Trying the same strategy in other vegetables should will yield similar results.

Results of preliminary studies on *L. orbonalis* in eggplant showed that the synthetic pheromone material was attractive to male moths. The relationship between sex pheromone trap catches and damaged fruits and shoots in farmers field during this preliminary study was not clear and could be due to different ages of eggplant grown in adjacent fields.

**h. Projected output**: Trends in sex pheromone trap catches could be used for efficient timing of pesticide applications against *S. litura, S. exigua, H. armigera* and *L. orbonalis* in other vegetables.

**i. Projected impact**: Reduced frequency of insecticide application in several vegetables grown in low elevation areas.

**j. Projected start**: October 2003

**k. Projected completion**: September 2004.

**l. Projected person-months of scientists' time per year: 4**

**m. Budget:** PhilRice - $ 1,474; Penn State - $2,302

## I.8. Biological Control of *Meloidogyne graminicola* and Other Soil Borne Pathogens in Rice -Vegetable Systems Using Specific Biological Control Agents Under Field Conditions

**a. Scientists:** E.B. Gergon – PhilRice; R.M. Gapasin - LSU; M. Brown – UPLB; S.A. Miller – Ohio State

**b. Overall objectives:** 1) Evaluate selected biocontrol agents for activity against root knot and pink root disease of onion; 2) Determine effects of biocontrol agents on the growth and yield of onion under field conditions. **Year 11 objective:** Evaluate VAM, *Bacillus* sp. and organic materials for control of pink root disease and root-knot nematode infesting onion.

**c. Hypotheses**: 1) Biocontrol agents are effective in reducing diseases of onion caused by soil-borne diseases and by root knot nematode; 2) Mycorrhizae deter root-knot infection and improves plant vigor (by enhancing P and Co uptake); 3) VAM and organic composts are effective in reducing root-knot disease in onion and can enhance nutrient uptake thus improve plant vigor; 4) Currently available methods and rates of application are effective against root-knot nematode as well as pink root disease of onion.

**d. Description of research activity:**

*Influence of VAM fungi on growth and yield of Yellow Granex and Red Creole onions in root-knot/pink root infested soil.* Seedbeds will be prepared by burning rice hulls on the soil surface or by soil solarization. Root inoculant containing mixture of VAM fungi will be applied on seedbed before seeding Yellow Granex and Red Creole onions. Mychorrhizal and control plants of both types of onion will be transplanted in a field known to be infested with root-knot nematode and pink root disease. Plots will be arranged using split plot design. The best but cheaper fertilizer rates based on the results of Year 10 experiments will be applied.

*Evaluation of VAM fungi in combination with Bacillus sp. for their effectiveness against M. graminicola.* Mixture of VAM fungi and *Bacillus* sp. will be tested in the field. VAM will be applied on seedbed. Delivery system for *Bacillus* sp. will be based on the results of Year 10 study. Test plants will be transplanted in root-knot infested field. Data on nematode counts at monthly intervals will be collected. Growth and yield parameters will be measured at harvest.

*Evaluation of VAM in combination with animal manure under field conditions*. Field testing of VAM plus chicken or cow manure will be established in Bongabon Demo Farm. Based on the findings of Dr. Gapasin from his microplot experiments, chicken and cow manure reduced the *M. graminicola* populations in the soil. The following treatments will be used: 1) VAM alone; 2) VAM + chicken manure; 3) VAM + cow manure; and 4) control. VAM will be applied on seedbed and manures will be incorporated in the soil during the preparation of the plots. The treatments will be replicated four times and arranged in RCBD. Data on number of galls, nematode population in roots and in soil, VAM spore count, and percentage VAM infection will be gathered.

All experiments will be conducted in farmer's field with previous incidence of root-knot and/or pink root diseases on a bigger area as compared with last season.

Microplot studies in LSU. Microplots measuring 1 x 25m will be infested with *M. graminicola* eggs. Nematode population will be increased by planting susceptible rice var UPLRi 5. Rice plants will be harvested 60 days after planting and the initial nematode populations will be determined in each plot. The treatments are: 1) VAM alone; 2) Nematode (N) alone; 3) Nematode + VAM; 4) VAM + composted rice straw + N; 5) VAM + composted sawdust + N; 6) VAM + chicken manure + N; 7) VAM + cow manure + N; 8) Nematicide (Nemacur); 9) untreated control. Treatments will be replicated three times and arranged in RCBD. Data on biomass, number of galls, nematode population in roots and in soil, VAM spore count and percentage VAM infection will be gathered.

**e.** **Justification:** *Meloidogyne graminicola* is an important pathogen of onion causing root-knot disease. Since the use of nematicides is impractical and uneconomical for most farmers in the Philippines and resistant onion varieties are not available, it is important to find alternatives such as use of soil amendments that will not only control nematodes but also improve growth and yield of the crop. VAM can replace 50% to 60% of fertilizer rates in other crops. As shown in previous studies, VAM did not only reduce nematode populations but also improved seedling growth under greenhouse conditions.

**f.** **Relationship to other CRSP activities at the site:** Results of this experiment will complement the other management strategies against root-knot disease of onion.

**g.** **Progress to date:** VAM has shown great potential in improving growth of onion even in the presence of nematodes. Plants treated with mycorrhizae were taller with greater leaf and root biomass.

**h.** **Projected output:** 1) Identification of an alternative method of nematode management in rice-onion systems; 2) Additional method of improving seedling establishment in onion; and 3) Information on the effect of VAM on fertilization requirement of onion.

**i.** **Projected impact:** 1) Identification of additional non-chemical means of controlling soil-borne pathogens in onion; 2) Production of healthy seedlings ready for transplanting in the field; and 3) Reduced fertilizer rates for onion.

**j.** **Projected start:** October 2003

**k.** **Projected completion:** September 2004

**l.** **Projected person-months of scientists' time per year:** 4-5

**m.** **Budget:** PhilRice - $3,355

**I.9. Effect of Nitrogen on Bulb Rot Incidence in Onion In Storage**

**a**. **Scientists:** D.T. Eligio, R.T. Alberto – CLSU; S.A. Miller – Ohio State, S.E. Santiago – PhilRice

**b**. **Overall objective:** To determine the influence of nitrogen on bulb rot during storage. **Year 11 objective:** To evaluate the effect of N on the incidence of bulb rot and verify IPM CRSP recommended technology on the incidence of bulb rot in onion during storage.

**c**. **Hypothesis:** High nitrogen application enhances incidence of rot during storage

**d**. **Description of research activity:** Yellow Granex and Red Creole onion varieties will be used. Soil samples will be collected prior to land preparation. Three blocks will be prepared to be subdivided into eight equal plots where the treatment combinations will be randomly assigned. First half of the N rate will be incorporated in the soil during final harrowing. The second half will be broadcast at bulb initiation stage. N rates are: 0 (Control), 50 kg/ha,100 kg/ha and 200 kg/ha. Recommended IPM CRSP package of technology will be used.

Bulbs will be harvested at 120 days after sowing. Freshly harvested bulbs will be sundried for five consecutive days. Topping follows leaving 2 cm of the top portion above the bulb shoulder. Sample bulbs will be placed in mesh bags with 20 kg net capacity and stored under ordinary room temperature and in cold storage. There will be six bags per V x N combination per storage condition.

Preharvest experiment will be set up following the 2 x 4 factorial experiment in Randomized Complete Block design (RCBD) with 3 replications. Data to be gathered are: Size and weight of bulbs, moisture content, texture, total soluble solid, titratable acidity, days to rot incidence, incidence of bulb rot, incidence of sprouting and rot-causing pathogens during harvest.

**e.** **Justification:** Growers normally apply excessive amounts of fertilizer, especially nitrogen, to produce large bulbs without considering the vulnerability of onion to infection from rot-causing pathogens.

**f**. **Relationship to other CRSP activities at the site:** The project will use the recommended IPM CRSP technologies during storage.

**g.** **Progress to date:** On going, using farmer's practices.

**h.** **Projected output:** Increased bulb yield and reduced incidence of rotting during storage due to correct dosage of N applied during crop growth.

**i.** **Projected impact:** Higher income for onion growers

**j**. **Projected start**: October 2003

**k**. **Projected completion:** September 2004

**l.** **Projected person-months of scientists' time per year:** 4

**m.** **Budget:** PhilRice - $ 2,987; Ohio State - $4,536

## II. LABORATORY, GREENHOUSE, AND MICROPLOT EXPERIMENTS

### II.1. Biology, Life Cycle and Mass Rearing of *Spoladea recurvalis* as a Biocontrol Agent Against the Weed, *Trianthema portulacastrum*

**a.** **Scientists:** A.M. Baltazar – UPLB/PhilRice, E.C. Martin, M.C. Casimero, J.M. Ramos - PhilRice; S.K. De Datta, L.T. Kok – Virginia Tech, E.G. Rajotte – Penn State University

**b.** **Overall objectve:** To determine the efficacy of *S. recurvalis* as biological control agent against *T. portulacastrum*. **Year 11 objective:** 1) To develop artificial diet and techniques to mass-rear *S. recurvalis*; 2) To determine optimum time of releasing *S. recurvalis* into onion fields for efficient control of *T. portulacastrum*.

**c.** **Hypothesis**: Augmenting populations of natural enemies of *T. portulacastrum* can effectively reduce populations of this weed in onion fields.

**d.** **Description of research activity:**

<u>*Mass rearing on artificial diet*</u>. Larvae and eggs of *S. recurvalis* will be collected from onion fields in Nueva Ecija and reared in the laboratory. Rearing will be done in screen cages and plastic trays. Artificial diet will be developed and the most suitable diet will be used to mass-rear the insect.

<u>*Determining timing of insect release into onion fields.*</u> Mass-reared *S. recurvalis* adults or larvae will be released into onion fields at a time coinciding with population peaks of *T. portulacastrum* or during the critical period of competition between onion and this weed. The number of larvae per unit area will be based on results obtained from studies conducted the previous year.

**e.** **Justification**: In the Philippines, only two herbicides are available for selective control of *T. portulacastrum* when it grows with onion. This weed is controlled mainly by handweeding and cultivation, which are costly, time, and labor consuming. In onion fields at the NOGROCOMA/IPM CRSP Demo Farm, *S. recurvalis* has been observed in abundance, feeding voraciously on *T. portulacastrum* for the past several seasons during fallow periods between onion crops. If natural populations of this insect can be augmented with mass-reared larvae and/or adults and released into onion fields at the most competitive stages of the weed, its populations can be reduced to levels that will not reduce yields.

**f.** **Relationship to other CRSP activities at the site**: Results obtained from this study will complement chemical and cultural methods to control weeds in onion. Results of this study will be integrated with other weed control methods to develop an integrated weed management package for onion.

**g.** **Progress to date:** Initial results showed that 15 to 20 larvae of *S. recurvalis* consumed 40% of leaves of 30-day old *T. portulacastrum* within 24 hours. Within 14 days, 80 to 90% of the plants were consumed by 15 to 20 larvae.

**h.** **Projected output**: 1) Protocol for mass-rearing of *S. recurvalis* and other natural enemies; 2) Reduced populations of *T. portulacastrum* in onion fields.

**i.** **Projected impact:** Reduced production costs due to reduced handweeding and herbicide use.

**j.** **Projected start:** October 2003

**k.** **Projected completion:** September 2004

**l.** **Projected person-months of scientists' time per year**: 4-5

**m.** **Budget**: PhilRice - $ 2,602; Penn State - $3,150; Virginia Tech - $1,277

## II.2 BIOTECHNOLOGY PROJECT: Characterization of *Ralstonia solanacearum* Strains from Eggplant

**a.** **Scientists:** N.L. Opina – UPLB, R. Alberto, S.E. Santiago – PhilRice, and S.A. Miller – Ohio State

**b.** **Overall objective:** To characterize strains of *Ralstonia solanacearum*, a U.S. government-designated "select agent", from eggplant in the Philippines, by biological, molecular and physiological methods.

**c.** **Hypothesis**: 1) All strains of *R. solanacearum* in the Philippines are members of the race 1 group; 2) None of the *R. solanacearum* from eggplant in the Philippines are in the race 3 biovar 2 group, and are thus not "select agents"

**d.** **Description of research activity**

<u>*Survey of bacterial wilt incidence and effect of grafting*</u>. Survey of the incidence of bacterial wilt of eggplant will be made in eggplant growing areas. Bacterial wilt infected plants will be collected and each sample will be tested for the presence of the bacterium using ELISA and strip test. The causal bacterium from each sample showing positive reaction to *Ralstonia solanacerarum* will be isolated. The isolates will be classified into biovars using Hayward's biochemical test, and race determinations will be made at UPLB. Molecular characterization (rep-PCR) of DNA extracted from the isolates in the Philippines will be done at Ohio State University.

Dr. N.L. Opina will go to Ohio State for three months to identify and characterize *R. solanacearum* strains.

**e.** **Justification:** It is important to have a good understanding of the race structure of strains of *R. solanacearum* in the Philippines in order to develop and deploy resistant eggplant varieties. Further, with the inclusion of *R. solanacearum* on the U.S. list of "select agents", this pathogen may become an import/export issue for farmers in developing countries.

**f.** **Relationship to other CRSP activities at the site**: This activity is closely tied with other eggplant activities, especially I.3a.

**g.** **Progress to date**: A large collection of strains from eggplant field during the dry season has been established in Year 10.

**h.** **Projected output:** 1) Data on incidence of bacterial wilt in eggplant growing areas; 2) Identification of geographic distribution of strains of *Ralstonia solanacerarum*; 3)

**i.** **Projected impact:** Critical information on the race structure of R. solanacearum in the Philippines; data on incidence of bacterial wilt in wet and dry seasons, which will impact farmer decision making on the use of control measures (grafting, resistant cultivars).

**j.** **Projected start:** October 2003

**k.** **Project completion:** September 2004

**m.** **Projected person-months of scientists' time per year:** 4

**n.** **Budget:** PhilRice - $2,877; Ohio State - $ 15,750

## II.3 BIOTECHNOLOGY PROJECT: Development of Fruit and Shoot Borer Resistant Transgenic Bt Eggplant

**a.** **Scientists:** N.V. Desamero, G.S. Arida – PhilRice; S.A. Miller – Ohio State; E.G. Rajotte – Pennsylvania State; G. Welbaum, G. Norton, S.K. De Datta – Virginia Tech; Mohankumar - TANU

**b.** **Overall objective**: To develop and test fruit and shoot borer resistant *Bt* eggplant cultivars or breeding lines with horticultural traits and adaptability that will ensure their acceptability in various countries in south and southeast Asia. **Year 11 objectives:** 1) To evaluate the Co2 isoline which expresses Bt coded genes for reactions to insect pests and diseases in the Philippines; 2) To test Bt crystal coat protein genes for efficacy against fruit and shoot borer; 3) Develop Bt eggplant with resistance to fruit and shoot borer; 4) Compare the economic viability of *Bt* eggplant compared to alternative means of controlling *Leucinodes orbonalis*, and 5) To project the potential economic impacts of *Bt* eggplant in the Philippines.

**c.** **Hypothesis:** *Bt*-expressing transgenic eggplant will reduce damage of fruit and shoot borer, increase eggplant yields, and reduce use of insecticides for insect control in eggplant.

**d.** **Description of research activity:**

*Evaluation of Bt eggplant Co2 isoline for resistance to other pests and diseases*. While waiting for approval of transport of transformed *Bt* eggplant from India to Philippines, the non-transformed eggplant isoline (Co2) will be tested in the Philippines for resistance to other pests and diseases, specifically, the leafhopper, bacterial wilt, and Phomopsis blight. Also, Co2 plants will be grafted on bacterial wilt resistant rootstock to determine its grafting compatibility and reaction to bacterial wilt. (Reaction to bacterial wilt will be done by Dr. Nenita Opina as part of Activity II.2).

*Evaluation of Bt proteins for toxicity to fruit and shoot borer.* Cry1AB and Cry2Aa genes will be tested for toxicity to eggplant fruit and shoot borer in laboratory and greenhouse studies. The *Bt* proteins will be incorporated in the diet of fruit and shoot borer at various growth stages. Larval mortality and other toxicity symptoms on the insect will be recorded. The Cry2Aa, Cry1Ab proteins, protocol for mass rearing of fruit and shoot borer in potato, and protocol for incorporation of Cry proteins in artificial diet will come from Tamil Nadu Agricultural University (TNAU).

*Bt eggplant transformation.* In case of unavailability of transformed Bt eggplant from India, the Philippine site will transform it's own Bt eggplant using gene construct from other sources, possibly IRRI or AVRDC. Eggplant transformation protocols will be obtained from TNAU. Eggplant lines or varieties best suited for transformation will be determined and a regeneration system will be done.

*Assessment of potential economic impact of Bt eggplant in the Philippines.* The economic viability of *Bt* eggplant compared with other management strategies against the eggplant fruit and shoot borer and its potential economic impact under Philippine conditions will be assessed. This activity will be part of Activity III.2.

e. **Justification:** Eggplant, *Solanum melongena*, is an extremely important crop in south and southeast Asia. The fruit and shoot borer is a major pest of eggplant which bores into the shoots and fruits of eggplant, making control with insecticide impractical, unsuccessful and expensive and contributes to environmental loading and pesticide residues on the fruits. As much as 50 sprayings in a cropping season often fail to control this pest. One alternative to manage the fruit and shoot borer is the use of genetically transformed plants that express a gene from *Bacillus thuringiensis* (*Bt*) that kills certain insect pests. *Bt*-expressing transgenic rice, potato, and corn have been developed that show highly improved insect resistance. If effective, this novel approach would be an alternative to insecticide use, which often fails to control the fruit and shoot borer.

f. **Relationship to other CRSP activities at the site:** Use of transgenic *Bt* eggplant can be an additional management option to control the fruit and shoot borer. Testing of eggplant isolines against bacterial wilt will be part of Activity I.3 and assessing of potential economic impact of Bt eggplant and comparison with other management strategies against the shoot and fruit borer will be part of Activity III.2.

g. **Progress to date:** This activity was initiated recently in the Philippine site with a small amount of funding provided by the first biotechnology grant. This has included meetings at TNAU (Feb. 2003; Miller/Norton/Rajotte) and Virginia Tech (May 2003; Desamero, TNAU scientists, Virginia Tech biotechnologists, Miller, Rajotte, Norton, De Datta). Development of transgenic *Bt* eggplant and testing has started in India and the U.S., the other sites involved in this project. Eggplant plants have been transformed to express *Bt* genes by scientists in India, U.S. and Italy. However, the U.S. and Italian cultivars contain the *Cry3A* and *Cry3B* genes, which were developed to resist Colorado potato beetle and may not be completely effective against the fruit and shoot borer. Also, the Bt eggplant developed in India, which contains the Cry1Ab and Cry2Aa genes, appears to offer only partial control of the fruit and shoot borer.

**h.** **Projected output:** Development of transgenic eggplant with high resistance to fruit and shoot borer, good horticultural characteristics, and wide acceptability in south and southeast Asia.

**i.** **Projected impact:** Increased yields, higher incomes, reduced pesticide use, reduced pesticide residues in eggplant fruits, lower environmental hazards due to pesticide exposure.

**j.** **Projected start:** October 2003

**k.** **Projected completion:** October 2004

**l.** **Projected person-months of scientist time per year:** 6

**m.** **Budget:** PhilRice - $9,955; Ohio State - $9,649; Penn State - $ 6,058; Virginia Tech - $10,901

## III. SOCIOECONOMIC IMPACT ANALYSIS STUDIES

### III.1. Social Impact Assessment (SIA) of IPM CRSP Technologies

**a.** **Scientists:** S.M. Roguel – CLSU; R.B. Malasa, I. Tanzo, R. Relado – Philrice; C. Harris - Virginia Tech; and C. Sachs - Penn State

**b**. **Overall objectives**: 1) Determine the communities' perception on the use/adoption of IPM CRSP technologies; 2) Identify and assess the possible social effects and impacts of IPM CRSP technologies on the community; 3) Identify and suggest possible mitigation and enhancement measures of impacts of IPM CRSP technologies. **Year 11 objectives**: 1) SIA of Sex Pheromone Traps as Monitoring Device for Onion Pests; 2) SIA of Management of Bacterial Wilt in Eggplant: Grafting and Use of Resistant Cultivars; 3) SIA of Management of Eggplant and Fruit Shoot Borer; 4) To make an in-depth analysis of the 1998 follow-up survey data; 5) To assess socio-economic impact and perceptions of IPM CRSP technologies by conducting key informant interviews (KII) and focus group discussions (FGD) with scientist, administrators, farmers (both IPM CRSP cooperators and non-cooperators).

**c.** **Hypothesis**: The introduced IPM CRSP technologies will be socially acceptable and profitable to the farmers.

**d.** **Description of research activity:** The study will use a combination of research tools. The primary respondents will be men and women farmers in whose fields the IPM CRSP technology has been conducted and neighboring farmers of both sexes. Structured interviews will be used to gather basic socio-economic and demographic profiles of the respondents. Focus group discussions and key informant interviews will also be used for data gathering. An assessment will be made of the anticipated social environment, with and without the proposed technology. This process involves determining 1) what is likely to happen to the social environment; 2) who is likely to be affected by any change(s); 3) how they may be affected; and 4) how long these effects are likely to last. Suggestions will be made for mitigating negative impacts of the technologies or increasing positive impacts.

e. **Justification:** The impact of technology is always assumed to be beneficial if its effects on a community are economically positive. However, experience has shown that this is not necessarily the case. The effect of the technology on the community and people should also be seriously considered. This assessment will also provide timely feedback from farmers to researchers on how research and extension activities can be better designed to make technologies more adaptable to a given community.

f. **Relationship to other CRSP activities at the site:** This study will complement the economic and environmental impact assessment studies on promising IPM CRSP technologies.

g. **Progress to date:** Social impact analysis of rice hull burning, weed management, stale-seedbed technique and use of NPV has been done in previous years. Positve and negative impacts of these IPM practices have been determined and suggestions were made to enhance positive impacts and solutions to problems encountered with negative impacts.

h. **Projected output:** 1) Identification of negative or positive effects of IPM CRSP technologies, with report on the social impacts and implications of the IPM technologies; 2) Publications and paper presentations.

i. **Projected impact:** Widespread adoption of IPM CRSP technologies.

j. **Projected start:** October 2003

k. **Projected completion:** September 2004

l. **Projected person-months of scientists' time per year:** 3

m. **Budget:** PhilRice – $ 2,860; Penn State - $38,661; Virginia Tech - $ 639

### III.2. Economic Impacts of IPM Practices in Rice-Vegetable Systems

a. **Scientists:** S. Francisco, B. M.Catudan – PhilRice; G. Norton – Virginia Tech

b. **Overall objectives:** 1) To evaluate and project the impact of IPM practices generated from multidisciplinary field experiments on household income and on society as a whole once adopted; 2) Project the economic impacts of biotechnology research on rice and vegetables. **Year 11 objective: 1)** To conduct economic impact assessment studies on onion postharvest storage methods, eggplant grafting, sex pheromone traps, postplant herbicide application and other promising technologies developed in Year 10; 2) To consolidate and analyze economic impact of technologies generated by the IPM CRSP for the past three years; 3) To project economic impact of *Bt* eggplant technology.

**c.** **Hypotheses:** 1) Each of the tested IPM practices will be profitable to farmers; 2) Each of the tested practices will generate net economic benefit to society as a whole when adopted; 3) Each of the tested IPM practices will have significant economic benefits for small farmers and consumers, and will have significantly positive environmental effects through reduction in pesticide use.

**d.** **Description of research activity**: Budgets will be developed for current crop practices and for each of the alternative pest management practices being evaluated in field experiments. Information generated on cost changes per unit of output will be combined with projections on the level and timing of adoption of IPM practices and economic surplus analysis then used to project aggregate societal benefits. A database on costing of IPM CRSP technologies and crop yields will be developed by Bethzaida Catudan. Subsequent economic impact analysis and projections will make use of this database.

**e.** **Justification:** Knowledge of farm-level profitability of IPM practices per hectare and per farm-household is essential in designing pest management recommendations. Knowledge of aggregate social benefits helps research directors and others assess the merits of specific IPM activities. If a specific IPM activity reduces pesticide use and has significant environmental benefits and is therefore socially profitable but is not privately profitable, this information can be useful to policy makers in designing tax, subsidy, or regulatory programs to encourage adoption of IPM practices.

**f.** **Relationship to other CRSP activities at the site:** Other activities are underway to assess social and gender impacts of pest management technologies. This activity complements the other activities as the estimated economic impacts can be distributed by family members and gender. The economic impact assessment provides feedback on the profitability being tested in the other activities.

**g.** **Progress to date:** Report on economic impacts of IPM practices has been prepared and presented to the IPM CRSP. The report discusses which of the developed technologies has a yield-enhancing and cost-reducing effect over the current farmers' practice. An M.S. thesis student (C.B. Mamaril) studied the effects of rice biotechnologies and has completed his work and presented the results last January 2002. Bethzaida Catudan is currently gathering data from all researchers on costs and returns of IPM treatments and technologies to develop an economic database.

**h.** **Projected output:** 1) Identification of IPM technologies that provide economic benefits; 2) Identification of factors affecting technology adoption.

**i.** **Projected impact:** The results should influence decisions on: 1) which technologies to promote in training programs; 2) which IPM alternatives might justify further research; 3) pest management policies and regulations; and 4) information provided to the general public on the benefits and costs of biotechnologies.

**j.** **Projected start:** October 2003

**k.** **Projected completion:** September 2004

**l. Projected person-months of scientists' time per year:** 4

**m. Budget:** PhilRice - $ 6,545; Virginia Tech - $ 13,097

## III.3. Survey of Crops, Pests and Pest Management Concepts and Practices in Vegetable-Growing Areas in Mindanao

**a. Scientists:** S.R. Francisco, B. M. Catudan – PhilRice; G. Norton – Virginia Tech

**b. Overall objectives:** To determine possible areas of collaboration with the USAID local mission related to the transfer of IPM technologies in vegetable production. **Year 11 objective**: To conduct a participatory appraisal in Mindanao, particularly in areas where the USAID local mission project, GEM-2 (Growth and Equity in Mindanao-2) are located; to determine the crops, pests, and pest management knowledge, concepts and practices in the GEM-2 areas.

**c. Hypotheses:** Transfer of IPM CRSP technologies to other vegetable-producing areas in Mindanao will help Mindanao farmers manage pest problems in their vegetable fields which could improve their yields and increase their profits.

**d. Description of research activity:** A participatory appraisal will be conducted in GEM-2 USAID local mission areas. Key informant interviews and focus group discussions will be conducted. Farmers in selected villages will be interviewed based on questionnaires used during the PA held in Ilocos Norte, Pangasinan, and Nueva Vizcaya. GEM-2 survey areas and farmer participants will be determined after consultation with USAID local mission in charge of GEM-2 project. Where possible, LGUs and DA-RFU (Regions 11 and 12) personnel will be included in conduct of the surveys.

**e. Justification:** One of the activities under the GEM-2 program of the USAID local mission is the Targeted Commodity Expansion Program (TCEP) which aims to expand production and marketing of several commodities, including vegetables, in Mindanao. IPM CRSP can collaborate with the USAID local mission in disseminating IPM technologies to vegetable farmers in Mindanao to reduce crop losses due to pest damage and increase yields, reduce their crop protection inputs and increase net profits. To determine the areas where IPM CRSP inputs are most needed, information is needed on the status and constraints to vegetable production in Mindanao, focusing on the GEM-2 areas. This information will be determined through a participatory appraisal in the area.

**f. Relationship to other CRSP activities at the site:** This activity will be part of technology transfer and socio-economic impact assessment activities.

**g. Progress to date:** Not applicable (new activity)

**h. Projected output:** Identification of constraints to vegetable production in Mindanao.

**i. Projected impact:** Improved IPM practices in vegetable production, which will reduce production costs, increase yields and net profits of Mindanao vegetable farmers.

**j.** **Projected start:** October 2003

**k.** **Projected completion:** September 2004

**l.** **Projected person-months of scientists' time per year:** 3

**m.** **Budget:** PhilRice - $ 4,378

### III.4a. Village Level Integration of IPM Technology Packages in Onion and Eggplant

**a.** **Scientists:** all IPM CRSP project leaders and researchers

**b.** **Overall objective:** 1) To demonstrate efficacy of IPM CRSP package of technologies in farmers' fields; 2) To facilitate and enhance faster adoption of IPM CRSP technologies though the village level integration process

**c.** **Hypothesis:** 1) IPM CRSP package of technologies to manage pests in onion and eggplant can reduce yield losses due to pests, reduce production costs and increase net incomes better than those of existing farmers' pest management practices; 2) Integrating IPM CRSP technologies with farmers' existing practices and field conditions will enable farmers to understand the principles underlying the practice and increase the chances of adopting IPM CRSP technologies

**d.** **Description of activity:**

A set of technologies to manage pests in onion and eggplant will be used and evaluated for efficacy and suitability in farmer-cooperators' fields. IPM CRSP set of technologies will be evaluated at the same time as the farmers' current IPM practices. Crop yields, costs of inputs, and increase or decrease in net profits from the farmers' practices and from IPM CRSP technologies will be estimated and compared.

Combinations of technologies will depend on type of onion grown (bulb or multiplier, red or white cultivar) and on location (Palestina, Bongabon). In the case of eggplant, combinations of technologies will depend on the cropping season (dry or wet). There will be five farmer collaborators for each of the set of technologies, 5 each in Bongabon, Talavera and Palestina for bulb onions and 5 for multiplier onions in Palestina. For eggplant there will be five farmer collaborators in Abar and 5 in Pangasinan. Each field will have a researcher in charge to oversee the application of control practices based on a schedule/calendar for the whole cropping season. The researcher will also brief the agricultural technicians and the farmers regarding the principles and practices involved in the IPM CRSP technologies. A farm tour or field day will be conducted in January or February, to include farmers as well as policy makers and traders, NGOs and cold storage operators. A workshop with extension personnel and selected farmers will be conducted before planting in October 2003 and after harvest in May 2004.

The package of technologies is:

**Palestina: Bulb onion (Red Pinoy)**

*Seedbed:* Variety selection (Red Pinoy resistant to pink root), Rice hull burning 1.5 weeks before transplanting (BT), raised bed 1 wk BT, VAM + manure + *Trichoderma* 1 day BT.

*Field:* No spray for first 20 days; Stale seedbed 21 days BT (Option: one herbicide before RHB, 7 days BT), Rice hull burning 7 days BT, 1 plowing + 1 harrowing 6 in deep 3 days BT, place pheromone traps for *Spodoptera* at transpanting, broadcast *Trichoderma* at transplanting, insect trap counts 3 times a week (whole season), spray NPV if counts are > threshold, if rain, check for anthracnose, if yes, apply 2 fungicides at 2 week intervals (Captan or Benlate) 7-14 days after transplanting; Scout weeds 7-14 days AT, if broadleaf, apply Goal or Ronstar, if grasses, apply Onecide or Clincher, Handweed at 40 days after transplanting; Stop irrigation 10 days before harvest, Harvest when neck of onion is closed; If ambient storage, sun dry for 5 days, if cold storage, no curing.

**Bongabon: Bulb onion (Red Pinoy or Yellow Granex)**

*Seedbed:* Variety selection (Robbins resistant to pink root), Rice hull burning (if available) or deep plowing and solarization 1.5 weeks BT; raised bed 1 wk BT; VAM + manure + *Trichoderma* 1 day BT.

*Field:* No insecticide spray for first 20 days; Stale seedbed 21 days BT; (Option: one herbicide before RHB at 7 days BT); 1 plowing + 1 harrowing 6 in deep at 3 days BT; put pheromone traps for Spodoptera at transplanting; Broadcast *Trichoderma* at transplanting, Trap counts 3 times per week for the whole season, If > threshold, spray NPV. If rain threatens, check for anthracnose, If yes, use 2 fungicides at 2 week-intervals (Captan); Scout weeds at 5-14 DAT; if broadleaf weeds, spray Goal or Ronstar; if grasses apply Onecide or Clincher; Handweed 40 days after transplanting; Stop irrigation 10 days before harvest; Harvest when neck of onion is closed; In ambient storage, sun dry bulbs for 5 days, If cool storage, no curing needed.

**Eggplant (dry season)**

*Seedbed*: Variety selection: EG 203 + Abar (if San Jose); others: A300 (Tisay) or Casino with grafting to EG-203; if Pangasinan: Casino (grafted) + A-300 + egg-type eggplant; Grafting rootstock 21 days BT.

*Field*: Scout and remove damaged shoot 30 days AT, Remove damaged shoots and fruits weekly; Spray insecticide for fruit and shoot borer, Scout leafhoppers 30 days AT, if >5 per leaf, spray Actara.

**Eggplant (wet season)**

*Seedbed and field*: see technologies for dry season

**e.** **Justification:** Adoption of several promising IPM technologies developed by IPM CRSP research for the past 10 years can be enhanced through demonstration in farmers' fields where farmers themselves are involved in applying these practices. This activity will hasten as well as ensure widespread dissemination and adoption of IPM CRSP technologies.

f. **Relationship to other CRSP activities at the site:** Data from the other studies will be used in this activity. Extension and training materials will be also be used. This activity will be coordinated closely with the RBFS village level integration staff to minimize or avoid duplication and optimize use of resources and manpower.

g. **Progress to date:** New activity closely related to village level integration activity being conducted with the RBFS group.

h. **Projected output:** 1) Dissemination and adoption of IPM technologies by farmers in Nueva Ecija and neighboring provinces.

i. **Projected impact**: Reduced pesticide use, higher yields and net incomes

j. **Projected start**: October 2003

k. **Projected completion**: September 2004

l. **Projected person-months of scientists' time per year:** 6-8

m. **Budget:** PhilRice - $17,160; Ohio State - $ 3,213; Penn State - $2,544

### III.4b. IPM Technology Transfer and Feedback

a. **Scientists:** all IPM CRSP project leaders and researchers

b. **Overall objective**: To conduct activities to transfer IPM technologies and disseminate information on IPM on a wide scale to Filipino farmers. **Year 11 objectives**: 1) Conduct training courses on vegetable IPM for agricultural technologists and farmers; 2) Publish field guides on "Onion pests and their management" and "Eggplant pests and their management"; 3) Publish the training manual and training module on "IPM in Vegetables Grown after Rice"; 4) Publish technical bulletins, flyers, posters on IPM in vegetables; 5) Assess the impact of different technology transfer strategies.

c. **Hypothesis:** No research hypothesis

d. **Description of activity:** A multi-prong, multi-level approach will be used to intensify dissemination of IPM technologies addressing different audiences. These include: 1) IPM CRSP researchers to act as resource persons in training courses conducted by PhilRice and other institutions; 2) conduct of training courses on IPM in vegetables; 3) Publication of training and extension material 4) Conduct of village level integration project with the Rice-Based Farming Systems Program at PhilRice; 5) Observance of field days and farmer meetings in IPM CRSP on-farm sites; 6) Creating public awareness on IPM through print, radio, TV, videos, and similar materials, 7) presentation of research results in national and international fora and publication of research results in technical as well as popular publications.

To assess the impact of these technology transfer strategies, the following will be done: 1) pre-tests or post-tests will be conducted to assess knowledge gained, retained or diffused among training participants to assess the impact of training courses. Surveys will be conducted to gather information on the amount of pesticides used, crop yields and net incomes and will be compared before and after use of the IPM CRSP technology. A survey of farmers in villages where IPM techno demo farms and village level integration trials were conducted will be done to assess if other farmers in the area are adapting or "copying" the IPM CRSP technology.

e. **Justification:** This activity will ensure the spread of results of IPM CRSP research to farmers and other stakeholders and will provide feedback to the scientists of this project. It will increase awareness among farmers and the public on the need to practice IPM in vegetables using more sustainable and friendly farming practices. Assessing the impact of technology transfer strategies will enable researchers to compare and determine fast and cost-effective methods of delivery systems to transfer technology.

f. **Relationship to other CRSP activities at the site:** The technology transfer activities will draw upon IPM CRSP research results and technologies developed for the past 10 years. It will be done in collaboration with the other units in PhilRice, particularly, the Technology Promotion and the Rice-Based Farming Systems Programs and with other agencies involved in IPM advocacy. Activities involving training programs will complement the rice IPM training program of PhilRice. Information from the studies on impact assessment of different technology transfer strategies will complement those in Activities III.1 and III.2.

g. **Progress to date:** 1) Training courses: IPM CRSP scientists were resources persons and delivered lectures on management of various pests in vegetables to trainees of Muslim Mindanao extension workers conducted in January 2003; 2) Village level integration project: On-farm demo plots comparing IPM CRSP technologies and farmers' practices have been established in farmers' fields in San Jose and Bongabon, Nueva Ecija in 2001, 2002, and 2003 cropping seasons; 3) Training and extension materials: The PhilRice Newsletter IPM CRSP special issue was published in the first quarter of 2003; Field guides on onion and eggplant pests are in final drafting stages as well as the training manual on IPM in Vegetables. Target date for publication is December 2003; 4) Publications and paper presentations: About 80 research papers were presented by IPM CRSP scientists at local and international conferences and about 40 papers have been published in local and international journals and in semi-technical or popular publications to date.

h. **Projected output:** 1) Training manual and training module on IPM in vegetables; 2) two field guides on pests and their management in onion and eggplant; 3) a special issue on IPM CRSP of the PhilRice Newsletter; 4) Technical papers and popular articles on IPM methods and practices in vegetables; 5) IPM advocacy network: and 6) information on cost-effective methods of technology transfer.

i. **Projected impact:** 1) Increased awareness of IPM in vegetables; 2) Increased application of IPM principles and practices; 3) Reduced pesticide use and increased vegetable production particularly, onion and eggplant ; and 4) Reduced production costs, higher yields and more income for farmers.

j. **Projected start:** October 2003

k. **Projected completion:** September 2004

l. **Projected person-months of scientists' time per year:** 5-6

m. **Budget:** PhilRice PL480 funds

## Site Activity Summary – Philippines Site – Year 11

| ACTIVITY | SCIENTISTS | BUDGET ($) |
|---|---|---|
| **FIELD EXPERIMENTS (On-Farm and PhilRice CES)** | | |
| I.1. Population Dynamics of Purple Nutsedge in Different Weed Management Approaches in Rice-Onion Cropping Systems | A.M. Baltazar – UPLB/PhilRice; J.M. Ramos, E.C. Martin, M.C.Casimero – PhilRice; A.M. Mortimer – IRRI; S.K. De Datta – Virginia Tech. | PhilRice - $2,437<br>Virginia Tech - $1,277 |
| I.2. A Survey on Seasonal Abundance of Onion Leafminer, *Liriomyza trifolii* (Burgess), Incidence of Parasitism, and Effect of Trap Color on Attraction of Adults | G.S. Arida, E.R. Tiongco, B.S. Punzal, A.V. Duca – PhilRice, E.G. Rajotte - Penn State | PhilRice – $3,564<br>Penn State - $4,544 |
| I.3. Influence of Host Resistance and Grafting on the Incidence of Bacterial Wilt in Eggplant | N.L. Opina - UPLB, R.T. Alberto – CLSU, S.E Santiago - PhilRice, R.M Gapasin – LSU, S.A. Miller – Ohio State | PhilRice - $1,474<br>Ohio State - $1,449 |
| I.4. Combined Resistance of Eggplant, *Solanum melongena* L., to The Leafhopper *Amrasca biguttula* (Ishida) and Eggplant Borer, *Leucinodes orbonalis* Guenee | M. T. Caasi-Lit, R.G. Maghirang, M.A.A. Capricho – UPLB; N.S. Talekar – AVRDC; E.G. Rajotte – Penn State | PhilRice -<br>$550 |
| I.5. Management of the Eggplant Fruit and Shoot Borer *Leucinodes Orbonalis* (Guenee): Evaluation of Farmers Indigenous Practices | G.S. Arida, A.V. Duca, B.S. Punzal – PhilRice; E.G. Rajotte –Penn | PhilRice - $3,344<br>Penn State - $2,726 |
| I.6. Management of Anthracnose ( *Colletotrichum gloesporoides*), A Disease of Increasing Importance in Onion | R.T. Alberto – CLSU; M.S.V. Duca – PhilRice, S.A. Miller – Ohio State | PhilRice - $2,805<br>Ohio State - $2,741 |
| I.7. Sex Pheromones in Pest Management: Surveilance, Monitoring and Mass Trapping of Male Moths | G.S. Arida, B.S. Punzal, A.V. Duca - PhilRice, E.G. Rajotte - Penn State | PhilRice - $1,474<br>Penn State - $2,302 |
| I.8. Biological Control Of *Meloidogyne graminicola* and Other Soil Borne Pathogens in Rice-Vegetable Systems Using Specific Biological Control Agents Under Field Conditions | E.B. Gergon– PhilRice; R.M. Gapasin - LSU; M. Brown – UPLB; S.A. Miller – Ohio State | PhilRice - $3,355 |
| I.9. Effect of Nitrogen on Bulb Rot Incidence in Onion During Storage | D.T. Eligio, R.T. Alberto – CLSU, S.A. Miller – Ohio State; S.E. Santiago – PhilRice | PhilRice - $2,987<br>Ohio State - $4,536 |

| | | |
|---|---|---|
| **LABORATORY, GREENHOUSE, AND MICROPLOT EXPERIMENTS.** | | |
| II.1. Biology, Life Cycle, and Mass Rearing of *Spoladea recurvalis* As Biocontrol Agent Against *Trianthema portulacastrum* | A. M. Baltazar – UPLB; E. C. Martin, M. C. Casimero, J. M. Ramos – PhilRice; S.K. De Datta, L. T. Kok – Virginia Tech; E.G. Rajotte – Penn State | PhilRice - $2,602<br>Penn State - $3,150<br>Virginia Tech - $1,277 |
| II.2 Characterization of *Ralstonia solanacearum* strains from Eggplant | N.L. Opina – UPLB, R. Alberto, S.E. Santiago – PhilRice, and S.A. Miller – Ohio State | PhilRice/UPLB - $2,877<br>Ohio State – $15,750 |
| II.3 Development of Fruit and Shoot Borer Resistant Transgenic *Bt* Eggplant | N.V. Desamero, G.S. Arida – PhilRice, S.A. Miller – Ohio State, E. G. Rajotte – Penn State, G. Norton, S.K. De Datta – Virginia Tech | PhilRice - $9,955<br>Ohio State - $9,649<br>Penn State - $6,058<br>Virginia Tech - $10,901 |
| **SOCIOECONOMIC ANALYSIS** | | |
| III.1. Social Impact Assessment of IPM CRSP Technologies | S.M. Roguel - CLSU, R.B. Malasa, R. Relado, I. Tanzo – PhilRice, C. Harris - Virginia Tech; C. Sachs - Penn State | PhilRice - $2,860<br>Penn State - $38,661<br>Virginia Tech - $639 |
| III.2. Economic Impacts of IPM Practices in Rice-Vegetable Systems | S. Francisco, B. M. Catudan – PhilRice; G. Norton - Virginia Tech | PhilRice - $6,545<br>Virginia Tech - $13,097 |
| III.3. Survey of Crops, Pests and Pest Management Practices inVegetable Growing Areas in Mindanao | S.R.Francisco, B.M. Catudan – PhilRice;G. Norton – Virginia Tech | PhilRice - $4,378 |
| III.4a. Village Level Integration of IPM CRSP Technology Packages In Onion and Eggplant | All IPM CRSP Project Leaders and Researchers | PhilRice - $17,160<br>Ohio State - $3,213<br>Penn State – $2,544 |
| III.4b. Technology Transfer and Feedback | All IPM CRSP Project Leaders and Researchers | PhilRice,<br>PL 480 |

## YEAR 11 WORK PLAN FOR THE ASIAN SITE IN BANGLADESH

In year 11, the IPM CRSP will begin its sixth year of research in Bangladesh. Activities focus on rice/vegetable systems, with key crops including eggplant, cabbage, gourds, tomatoes, country bean and okra. The PIPM approach is being followed in which pest management problems and constraints are being diagnosed through crop/pest monitoring, and follow-up participatory appraisal and focus group activities are being undertaken that focus specifically on adoption issues, including gender. Multi-disciplinary on-farm pest management experiments are being conducted in Kashimpur and Sripur complemented by varietal screening, laboratory, and micro-plot experiments on station at BARI farm, Gazipur. Village level demonstrations and IPM technology transfer activities are being carried out in Sripur, Jessore, Comilla and Rangpur, which are the major vegetable areas in the country. Socioeconomic analyses address three primary issues: impact assessment, adoption, and market analysis. Linkages have been made with the local extension services in Bangladesh, such as CARE-Bangladesh, Mennonite Central Committee (MCC) and Helen Keller Institute, to facilitate farmer training based on lessons learned in the CRSP.

Research activities are planned and conducted in a multidisciplinary fashion. Bangladesh and U.S. scientists review progress and plan future activities in joint meetings with all disciplines contributing to the discussion. Biological scientists assist the social scientists by collecting cost and return data that is used in impact assessment. The site coordinator and his staff help coordinate the day-to-day research activities. They are housed with most of the scientists at the Bangladesh Agricultural Research Institute (BARI), the primary agricultural research institute in the country. They coordinate with scientists at the Bangladesh Rice Research Institute (BRRI), CARE-Bangladesh, with the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) and Bangladesh Agricultural University (BAU) for student training. International and U.S. institutions contributing to the IPM CRSP program in Bangladesh include AVRDC, IRRI, the National Crop Protection Center of the Philippines, Purdue University, Penn State, Ohio State, and Virginia Tech.

IPM CRSP research activities in Bangladesh will be carried out in year 11 under four major thematic areas: (a) crop/pest monitoring, (b) multidisciplinary on-farm pest management experiments, (c) multidisciplinary laboratory, greenhouse, and microplot experiments, and (d) socioeconomic analyses.

The research and development activities of year 11 workplan focus on a number of objectives that involve (a) training of NGO (CARE Bangladesh) technical staff for technology transfer; (b) multi-location demonstration of vegetable IPM technologies and farmer training; (c) creating market opportunities for farmers and traders for local as well as export markets; (d) production of pesticide residue free vegetable crops; (e) development of biotechnology to capitalize on production and marketing opportunities; (f) impact assessment of behavioral change of stakeholders, technology adoption rates, vegetable quality improvement and marketing opportunities; and (g) regionalization of technologies (grafting, biotech and varietal resistance).

The USAID mission in Dhaka is fully informed of our activities. The U.S. team of scientists, accompanied by Dr. Karim, the site coordinator, meets at least once per year with mission personnel. During these meetings, CRSP personnel brief USAID on the progress of experiments, contact with outreach bodies (extension, NGOs, etc.) and interactions with government agencies, research institutions and universities. In turn, USAID personnel inform us of opportunities in Bangladesh where IPM may play a role.

Most recently, USAID introduced us to their program, Agricultural Trade Development Program (ATDP). As Bangladesh develops its agricultural export markets, product quality standards of importing countries must be met. Many times, failure to meet quality standards is due to pest damage or pesticide residues. IPM programs in the producing country can alleviate this problem. Connecting the IPM program with ATDP will provide Bangladeshi farmers with tools to produce commodities appropriate for the export market.

We have also been negotiating to obtain PL480 funds to support IPM education and outreach. These funds should be available within the next year.

## I. Crop/Pest Monitoring

### I.1. Survey of Infestation Levels of Whitefly, *Bemisia tabaci*, and its Natural Enemies on Different Vegetable Crops

**a.** **Scientists**: S.N. Alam, M. A. Maleque, Ziaur Rahman, M. A. Rouf, M. A. Rahman, K. A. Kader – BARI; A.N.M.R. Karim, H. S. Jasmine – IPM CRSP; E. Rajotte – Penn State; Greg Luther – Virginia Tech; Robert Gilbertson – University of California-Davis

**b.** **Status:** Continuing

**c**. **Objectives:** (1) To determine the incidence pattern and infestation levels of whitefly on different vegetable crops. (2) To identify the damage variability, races, virus infection and most susceptible vegetable crop(s). (3) To identify appropriate researchable issues for developing IPM practices in vegetables. **Objectives in 2003-2004:** (1) To complete survey and monitoring in different crops, and identify damage variability, races and virus infection rates. (2) To identify appropriate researchable issues for IPM practices.

**d.** **Hypotheses:** Recently, whitefly, *B*. tabaci, has appeared to be a serious damaging pest in a number of major vegetable crops and farmers apply insecticide indiscriminately without knowing the pest, their infestation levels or damage potential. Knowledge of their incidence patterns, their damage intensity, races, virus infection patterns and identification of susceptible vegetables will enable us to determine the appropriate researchable issues for developing IPM practices for the vegetables.

**e.** **Description of research activity:** Trapping of whitefly will be done by setting up yellow sticky traps in the major vegetable crop fields (eggplant, tomato, beans, okra, etc.) at the BARI farm and Kashimpur (Gazipur), Jessore and Comilla. A locally prepared sticky gum will be used for the traps. The trapped white flies will be sorted out to identify the species and races, if any. Records will be taken on infestation, damage intensity and virus infection rates to determine the susceptibility of the infested crops.

f. **Justification:** The whitefly is becoming an increasingly damaging pest on different vegetable crops due to indiscriminate use of pesticides by the farmers. The whitefly has a wide host range, but its infestation rates and its ability to inflict virus diseases in different crops are not known. Appropriate pest management measures can be developed based on the identification of susceptibility status of the vegetable crops. The highly susceptible crop(s) can also be used as a trap crop(s).

g. **Relationship to other research activities at the site:** The survey activity will be useful for developing proper management practices of white flies in different vegetable crops. It will also help other research groups to identify appropriate researchable issues for the development of IPM technologies.

h. **Progress to date:** Survey and monitoring activities are continuing in several areas of the country. Preliminary results show that whitefly infests a number of vegetable crops and among the three crops surveyed to date, tomato crops have higher whitefly populations and virus infection than others. Studies on whitefly species composition are ongoing.

i. **Projected outputs:** Improved knowledge of (1) whitefly species composition, their incidence and infestation patterns, virus infection rates and damage potential; and (2) vegetable crop(s) susceptible to whitefly and ways to determine the appropriate control measures.

j. **Projected impacts:** (1) Better knowledge of whitefly incidence, their infestation patterns including virus infection rates and damage characteristics; (2) identification of appropriate research activities for developing appropriate measures for whitefly control.

k. **Projected start:** October 2002

l. **Projected completion:** September 2003

m. **Projected person-months of scientists time per year:** 8 person-months

n. **Budget:** $3,190 – BARI; $36,612 – Penn State

## II. Multidisciplinary On-farm Pest Management Experiments

### II.1a. Evaluation of Eggplant for Resistance to Bacterial Wilt, Fruit and Shoot Borer, Leafhopper (jassids) and Root-Knot Nematode and of Tomato for Resistance to Bacterial Wilt, Virus Disease and Root-Knot Nematode

a. **Scientists:** M.A. Rashid, Shahabuddin Ahmed, M.A. Rahman, S.N. Alam, M.H. Rashid – BARI; H.S. Jasmine, Nazneen A. Sultana, Bahauddin Ahmed – IPM CRSP; N.S. Talekar – AVRDC; G. Luther – Virginia Tech; Sally Miller – Ohio State; Robert Gilbertson – UC Davis

b. **Status:** Ongoing

**c.** **Objectives:** To (1) confirm the usefulness of previously reported bacterial wilt (BW) resistant eggplant and tomato cultivars and potential focus on *Solanum* rootstock in Bangladesh; (2) confirm previously reported fruit and shoot borer (FSB) resistant sources; (3) confirm root-knot nematode resistance in eggplant and tomato cultivars; (4) confirm TYLCV resistant sources. **Objectives in 2003-2004:** (1) To confirm the resistance of eggplant varieties selected in 2002-2003 against FSB, jassids, BW and root-knot nematode (RKN); (2) To re-evaluate tomato germplasm against BW, RKN and TYLCV to confirm their resistance; and (3) To make proposals for release of resistant varieties.

**d.** **Hypotheses:** (1) Based on previous work at BARI and AVRDC, BW resistant eggplant and tomato cultivars exist. Further selection in Bangladesh will lead to identification of cultivars that can be utilized by Bangladeshi farmers. Grafting susceptible eggplant and tomato varieties onto resistant *Solanum* sps. rootstocks is effective in controlling bacterial wilt. (2) Natural FSB and jassid resistance that occurs in *Solanum* sps. can be introgressed through breeding into eggplant cultivars. (3) Sources of TYLCV resistance are present in currently available cultivars that may be useful to Bangladeshi farmers. (4) Sources of RKN resistance are present in currently available cultivars that may be appropriate for on-farm use.

**e.** **Description of research activity:** The work will be done at HRC, BARI laboratory and infested nurseries. For eggplant, the preliminarily selected entries and those showing variable reactions will be re-evaluated in 2003-2004. Three resistant and five moderately resistant lines of eggplant, as well as three resistant and 14 moderately resistant lines of tomato, selected against BW in 2002-2003. The BW inoculum level will be enhanced to $10^8$ cfu/gm soil by incorporating highly BW infected eggplants in the nurseries prior to transplanting. Thirty-day old seedlings of eggplant and tomato will be uprooted, roots trimmed and transplanted into the infested nursery using 6x6 inch spacing. Plants will be observed closely. Plant mortality will be recorded at 3-day intervals. In years 10 and 11, the resistant eggplant and tomato varieties developed at BARI will be evaluated in farmer fields and a proposal for variety release will be initiated.

The study for FSB will be conducted at the BARI field to re-evaluate the selected resistant sources of eggplant and available new collections. Seeds will be sown in September 2003 and transplanted in October 2003. Twenty four eggplant varieties will be evaluated for their resistance to the natural population of FSB without application of insecticides. A replicated trial with 3 replications of 5 plants each will be arranged in RCBD using a spacing of 70x70 cm. Weekly observations will be made on fruits and shoots. Wilted shoots will be counted along with the total number of shoots per plant. Additionally, a mass culture of adults and 1$^{st}$ instar larvae will be collected from the infested fruits and will be released in cages having twigs of different eggplant lines in the screen house and in the field under confinement. Observations will be taken on the difference on egg laying and larval entry in different lines.

The study of TYLCV will be conducted in the screen house at HRC, BARI to re-evaluate and confirm the resistant sources and other major cultivated varieties. Seeds will be grown in 40cm x 30cm x 8cm tin trays and the seedlings at the age of 21 days will be infested with viruliferous whiteflies for TYLCV infection. Weekly observations will be made on TYLCV infection. Infected seedlings will be counted and discarded, and disease free seedlings will be transplanted in the field for seed multiplication. Data will be recorded 2 weeks and 8 weeks after the release of viruliferous insects. Dr. Gilbertson (UC Davis), an expert in plant virus identification and management, will provide training for scientists performing virus evaluations. In addition, his U.S. laboratory will be providing substantiating viral identifications. The equipment and processes for these identifications are not yet available in Bangladesh. Dr. Gilbertson is a resource to the entire IPM CRSP where viruses are determined to be key pests. In addition to Bangladesh, Dr. Gilbertson is working in the Mali site on similar activites.

The study of RKN will be made at BARI in infested nurseries. Thirty cultivars of eggplant, including those cultivars which have previously shown resistance and 35 cultivars of tomato, including the cultivars that previously showed moderate resistance, will be sown directly in the infested nursery and uprooted 60 days later and examined for severity of galling. Galling will be scored on a scale of 1-10. The results will be compared for confirmation and selection as possible varieties.

f. **Justification:** Bacterial wilt (*Ralstonia solanacearum*) is a devastating disease in eggplant and tomato in Bangladesh. No practical chemical control or cultural practices have been developed for successful control of this disease. Also, resistance is said to be site specific. Therefore, the BW resistant cultivars from other locations must be tested for usefulness in Bangladesh.

Eggplant fruit and shoot borer is a severe pest throughout Asia. A resistant variety is not yet available. For controlling this pest, farmers are using insecticides indiscriminately, which has potential harmful effects on the consumers and the environment. Development of pest resistant varieties will minimize the risks of pesticides.

TYLCV, which is transmitted by whitefly (*Bemisia tabaci*), is one of the serious diseases of tomato in Bangladesh and the yield loss is as high as 100%. Selection of a resistant variety is one of the cheap and effective methods to minimize the disease.

Nematode is a major problem of eggplant and tomato and no practical chemical controls or cultural practices have been developed for its control. Development of resistant varieties is one option for minimizing losses due to this pest.

g. **Relationship to other research activities at the site:** Identification of resistant varieties and grafting technology will be utilized in farmer field studies in combination with other IPM strategies.

h. **Progress to date:** In the 2002-2003 winter season, 24 germplasm/lines of eggplant were evaluated against bacterial wilt and RKN in sick-beds, and also in the field against FSB, BW and jassids at the BARI farm under natural conditions. The test varieties included a number of entries from AVRDC sources. Also 35 lines/varieties of tomato have been screened against BW. Several varieties/lines that have potential for release as farmer varieties have been selected in each case.

**i.** **Projected outputs:** (1) Confirmation of reported BW resistant sources under Bangladesh conditions; (2) identification of additional BW resistance sources; (3) confirmation of reported FSB resistant sources under Bangladesh conditions; (4) identification of additional FSB resistant sources; (5) confirmation of reported TYLCV resistant sources under Bangladesh conditions; (6) identification of additional TYLCV resistant sources; (7) utilization of their resistance for development of varieties; and (8) identification of RKN resistant sources.

**j.** **Projected impacts:** (1) Eggplant and tomato varieties/lines available to farmers will provide high levels of resistance to BW and reduce plant mortality in the hot wet season; (2) Improved yield; (3) Reduced losses caused by fruit and shoot borer; (4) Reduced use of insecticides; and (5) High level of resistance to RKN and reduced plant mortality.

**k.** **Projected start:** Eggplant-March 1999; Tomato- September 1999

**l.** **Projected completion:** September, 2004

**m.** **Projected person-months of scientist time per year:** 6 person-months

**n.** **Budget:** $12,540 – BARI; $4,410 – Ohio State; $6,058 – Penn State; $2,520 – Univ of California - Davis

## II.1b. Evaluation of Selected Pumpkin Varieties Against Watermelon Mosaic 2 Poty Virus (WM2V)

**a.** **Scientists**: M.A. Rashid, M.A.T. Masud, M.H. Rashid – BARI; M.A. Mannan Akand – BSMRAU; Nazneen A. Sultana, Bahauddin Ahmed – IPM CRSP; G. Luther – Virginia Tech; Robert Gilbertson – UC Davis

**b.** **Status:** Ongoing

**c.** **Objectives:** To (1) locate sources of WM2V resistance in pumpkin germplasm; (2) identify agronomically acceptable resistant line(s) for varietal release; and (3) use resistant sources in a variety improvement program. **Objectives in 2003-2004:** To confirm the resistance of the varieties selected in 2002-2003 and select improved ones for possible release as varieties.

**d.** **Hypotheses:** WM2V of pumpkin is a serious disease in Bangladesh and pesticide use for its control is neither effective nor safe for consumers. Use of resistant cultivars is the most effective tool for its control. A few moderately resistant pumpkin lines have been identified at HRC, BARI. Further screening of the existing pumpkin germplasm will lead to identification of resistant sources. There is a high chance of obtaining agronomically acceptable resistant line(s) for on-farm use and also for using them as resistant sources for developing pumpkin varieties having high yield and better quality (rich in $\beta$-carotene).

**e.** **Description of research activity:**

Plant materials: The varieties selected as resistant from 2002-2003 experiments and additional germplasm lines collected from local and exotic sources will be artificially inoculated to study their reactions against WM2V under epiphytotic conditions at the BARI farm. At the same time, other virus diseases also will be detected using the ELISA technique.
Inoculation: The young virus-infected leaves of the host plant will be ground with inoculation buffer [Na – phosphate buffer (0.03 M, $P^h$ 7.0 with Na – DIECA, $Na_2So_3$ and activated charcoal)] at the ratio of 1:4 (wt./wt) and filtered through 4 layers of cheese cloth. The test germplasm lines will be inoculated with the buffer solution containing the virus particles (WM2V). A pinch of carborundum powder will be sprinkled on apical leaves before inoculation to abrade the leaves and thus promote virus entry. Inoculation will be done on young apical leaves at two-leaf stage of the plant followed by washing with distilled water.
Data recording: Mosaic symptoms appear between 1 – 4 weeks after inoculation. Five leaves collected from the apical, middle and basal portions of the plant will be tested and graded o a 0 – 5 scale: (a) Highly resistant (HR): No infection – 0; (b) Resistant (R): Up to 1 % leaf area infection – 1; (c) Moderately resistant (MR): > 1 to 5 % leaf area infection – 2; (d) Moderately susceptible (MS): > 5 to 25 % leaf area infection – 3; (e) Susceptible (S): > 25 to 50 % leaf area infection – 4 (6) Highly susceptible (HS): >50 % leaf area infection – 5. Records will also be taken on disease incidence, characterization of the germplasm, fruits per plant, average fruit weight (Kg), fruit length and diameter (cm), cavity length and diameter(cm), flesh thickness (cm), flesh color, TSS (%), days taken for 1st male and female flower to open, and their position.

f. **Justification:** In Bangladesh, more than 1 million children have vitamin A deficiency and half of them suffer from night blindness (xerophthalmia). In addition, about 20 to 30 thousand children become blind every year due to chronic vitamin A deficiency. Pumpkin is a good and cheap source of vitamins, especially carotenoid pigments. Thus, pumpkin can contribute to improved nutritional status, particularly for vulnerable groups. It has the highest storability as mature pumpkins can be stored for 2-4 months under normal conditions and therefore can meet the demand for vegetables during the off-vegetable season.

g. **Relationship to other research activities at the site:** Mosaic-resistant pumpkin varieties may be grown by the farmers in combination with other IPM practices.

h. **Progress to date:** Preliminary results of the ongoing experiments show one line having high resistance (no virus infection) and 2 lines having resistance with 1 to 5% infection only.

i. **Projected outputs:** (1) Identification of WM2V resistant sources and utilization of agronomically acceptable resistant lines for cultivation by the farmers. (2) Use of resistance sources in a variety improvement program.

j. **Projected impacts:** (1) Minimized environmental pollution and the promotion of sustainable production by the use of WM2V-resistsant pumpkin varieties ; (2) higher yield and improved fruit quality; (3) enhanced income of the farmers; and (4) improved nutritional status of the people.

**k.** **Projected start:** November 2001

**l.** **Projected completion:** September 2004

**m.** **Projected person-months of scientist per year:** 6 person-months

**n.** **Budget:** $2,200 – BARI; $4,662 – Ohio State; $2,520 – Univ. of Califorina -Davis

## II.1c. Screening of Okra Germplasm against Yellow Vein Mosaic Virus (YVMV)

**a.** **Scientists:** M.A. Rashid, M.A.T. Masud, Shahabuddin Ahmed, H. Rashid – HRC (BARI), Md. Hossain – TCRC (BARI); Salim Uddin – Plant Breeding, BARI; Baha Uuddin Ahmed, Nazneen A. Sulatana – IPM CRSP; Robert Gilbertson – UC Davis

**b.** **Status:** On-going

**c.** **Objectives:** (1) To locate sources of resistance to YVMV in Okra germplasm. (2) To utilize the resistant line(s) for developing pest-resistant okra varieties. **Objectives in 2003-2004**: To confirm the resistance of the varieties selected in 2002-2003 and identify suitable varieties for on-farm use.

**d.** **Hypothesis:** Okra (lady's finger) is a major summer vegetable in Bangladesh. But the varieties currently grown in farmer fields are highly susceptible to YVMV. Farmers use insecticides frequently to control the disease without any success. Many land races are available in the country. It is assumed that extensive collection and screening of okra varieties will lead to identification of YVMV-resistant sources having satisfactory agronomic qualities. Development of pest-resistant okra varieties will be made through identification and utilization of the resistant sources.

**e.** **Description of research activities:** (1) Plant materials: A sizeable number of okra germplasm will be collected locally and from exotic sources, particularly those from India that are reportedly resistant to the virus disease. These will be inoculated by viruliferous whitefly adults to study their reactions against YVMV under epiphytotic conditions. (2) Culture of whitefly: A pure stock of whitefly species, *Bemisia tabaci*, will be reared and maintained in an insect-proof net house on jute or eggplant seedlings for transmission studies. (3) Vector transmission: The insects will be fed on YVMV infected leaves for 12 to 24 hours. Seedlings of the germplasm under study will be inoculated by viruliferous whitefly adults (10 whiteflies/seedling). (4) Symptoms: The YVMV symptoms will appear in 2 to 4 weeks after inoculation. (5) Data recording: a) Disease scoring will be noted as per established scale. b) Different horticultural traits of the germplasm along with yield will be recorded.

**f.** **Justification:** Vegetable production during the summer in Bangladesh is constrained due to high temperature, humidity and rainfall. But okra is one of the few important vegetables available during the summer and the rainy season. Okra is an excellent source of iodine, which acts against goiter, useful against chronic dysentery, and is a good source of vitamins A, B, and C. It is also rich in protein and mineral elements. Cultivation of YVMV-resistant okra will greatly help the farmers to obtain higher yield and economic returns and also alleviate malnutrition in children.

g. **Relationship to other research activities at the site:** YVMV resistant okra varieties may be grown by the farmers in combination with other integrated pest management practices.

h. **Progress to date:** The experiment is presently being carried out in the field; results will be available in August 2003.

i. **Projected outputs:** (1) Identification of YVMV resistant sources in okra germplasm; (2) release of YVMV-resistant okra with better yield and quality; and (3) resistant sources will greatly facilitate the okra variety improvement program.

j. **Projected impacts:** Use of okra varieties resistant to YVMV will: (1) minimize environmental pollution and promote sustainable production; (2) raise yield and improve fruit quality; (3) enhance income of the farmers; (4) improve nutritional status of the people; (5) generate employment; and (6) help diversify the export of agricultural produce.

k. **Projected start:** March 2003

l. **Projected completion:** August 2004

m. **Projected person-months of scientist's time per year:** 6 person-months

n. **Budget:** $2,200: BARI; $3,780 – Ohio State; $3,780 – Univ. of California - Davis

## II.2. Integrated Management of Weeds and Soil-borne Diseases in Tomato

a. **Scientists:** Anwar Karim, S.A. Khan – BARI; A.N.M.R. Karim, Mahbubur Rahman – IPM CRSP; A. Baltazar – NCPC/UPLB; Sally Miller – Ohio State; S.K. De Datta – Virginia Tech

b. **Status:** Continuing

c. **Objectives (current and overall):** (1) To evaluate the effects of soil amendment practices on weed proliferation and their role as latent hosts of soil-borne diseases; and (2) to demonstrate the usefulness of soil amendments for suppression of soil-borne diseases and effective, economic weed management.

d. **Hypotheses:** Organic soil amendments with poultry refuse and mustard oil-cake have been found to effectively control various soil-borne diseases in vegetable crops. But this practice has the potential to induce weed proliferation and also to act as a latent host of some soil-borne pathogens. In order to use a package for the management of weeds and soil-borne diseases, it is necessary to evaluate the effects of soil amendments to achieve the objectives.

**e.** **Description of research activity:** The demonstrations will be conducted in three farmer fields at Sripur on tomato with the following treatments: (1) Raising of tomato seedlings in seedbeds with soils incorporated with poultry refuse/mustard oil-cake and transplanting of one-month old seedlings in the main field 15 days after incorporating the soils with poultry refuse/mustard oil-cake; weeding operation by two hand weeding at 20 days and 40 days after transplanting, and (2) farmer practice (farmer's usual cultural and weeding operations without using poultry refuse/mustard oil-cake). Data will be recorded on (1) fresh and dry weight of weeds by species at 20, 40 DAT and 2 weeks before harvest, (2) tomato plant establishment and plant mortality, (3) crop yield and other yield components, (4) number of days to crop maturity, and (5) time spent for hand weeding (min/plot or hour/crop). Economic analyses for inputs and outputs will be done.

**f.** **Justification:** Crop production involves a number of management practices in order to achieve the desired yield. For management of weeds, diseases and other pests, farmers will usually look for a package of practices that may solve their problems. Organic soil amendments with poultry refuse and mustard oil-cake can effectively control soil-borne diseases, but their effects on weed management are little known. There is a need, therefore, to evaluate the effects of soil amendments for the management of weeds and diseases at the same time.

**g.** **Relationship to other research activities at the site:** This activity, if found effective, can be incorporated with other IPM practices to develop a suitable package for the management of weeds and other pests.

**h.** **Progress to date:** On-farm trials have shown that soil amendment practices did not induce weed proliferation, nor did the weeds serve as latent hosts of soil-borne disease to cause any increase in disease incidence. Mustard oil-cake treated plots with two hand weedings had minimum plant mortality and produced the highest yields. The results have shown that soil amendment with mustard oil-cake and poultry refuse is effective for weed and disease management.

**i.** **Projected outputs:** Cost effective weed and disease management schemes will be available to vegetable growing farmers.

**j.** **Projected impacts:** Development of a sustainable weed and disease management package, reduced production cost and increased profit.

**k.** **Projected start:** October 2002

**l.** **Projected completion:** September 2004

**m.** **Projected person-months of scientists time per year:** 6 person-months

**n.** **Budget:** $2,200 – BARI, UPLB collaborating, budget covered by BARI

## III. Multidisciplinary Laboratory, Greenhouse, and Microplot Experiments

### III.1. A Study of *Trichogramma chilonis* and *T. bactrae* for the control of *Leucinodes orbonalis, Maruca vitrata* and *Plutella xylostella*; B. Development of Mass Rearing Technique of *Cotesia plutellae* and Determination of its Effectiveness on DBM; C. Study on the Abundance and Parasitism Characteristics of *Trathala flavoorbitalis* on Rice Leaf roller and ESFB and Determination of its Host Preference

**a.** **Scientists:** S.N. Alam, Ziaur Rahman, A. Rouf – BARI; N.A. Sultana, A.N.M.R. Karim – IPM CRSP; N.S. Talekar – AVRDC; G. Luther – Virginia Tech; E. Rajotte – Penn State

**b.** **Status:** Continuing

**c.** **Objectives:** (1) To rear the egg parasitoids *Trichogramma chilonis* and *T. bactrae* on *Corcyra cephalonica* in the laboratory. (2) To determine the parasitism efficiency of *Trichogramma chilonis* and *T. bactrae* for the control of *Leucinodes orbonalis*, *Maruca vitrata* and *Plutella xylostella* in the greenhouse, microplots and field. (3) To develop mass rearing technique of *C. plutellae* on DBM larvae. (4) To determine the parasitism efficiency of *C. plutellae* on DBM. (5) To determine the abundance and parasitism efficiency of *Trathala flavoorbitalis* on rice leaf folder and FSB.

**d.** **Hypothesis:** Biological control will suppress the population of *Leucinodes orbonalis*, *Maruca vitrata* and *Plutella xylostella*

**e.** **Description of research activities:**

(1) Activity with *Trichogramma*: The egg parasitoid *Trichogramma chilonis* and *T. bactrae* will be reared on the eggs of *Corcyra cephalonica* by standardizing *Corcyra* eggs density and *Trichogramma* parasitoid density on cards. Both of the *Trichogramma* sp. will be tested on *Leucinodes orbonalis*, *Maruca vitrata* and *Plutella xylostella* eggs in the greenhouse, microplots and in the fields; comparison will be made between plots with *Trichogramma* release and plots with no release. Collection and rearing of *Leucinodes orbonalis*, *Maruca vitrata* and *Plutella xylostella* eggs will be continued to determine the existing egg parasitoid species in the field. Greenhouse, microplot studies will be done at BARI and field studies both at BARI and Jessore.

(2) Activities with *C. plutellae*: This larval parasitoid will be reared on DBM larvae. Mass rearing of DBM will be done on peachy leaves. *Cotesia* will be tested on the larvae of *Plutella xylostella* in the greenhouse, microplots and in the fields; comparisons will be drawn between plots with *Cotesia* release and plots with no release. Collection and rearing of *Plutella xylostella* larvae will be continued to determine the existing larval parasitoid species in the field. Greenhouse, microplot studies will be done at BARI and field studies done both at BARI, Jessore and Comilla.

(3) Activities with *Trathala flavoorbitalis*: Collection and rearing of *Leucinodes* infested shoots and fruits and leaf folder infested rice leaves will be done to determine the parasitism rate and seasonal effect on the parasitism of *Trathala* on *Leucinodes* and leaf folder.

*Trathala* will be tested on the larvae of *Leucinodes* and rice leaf folder in the greenhouse, in microplots and in the fields.

f. **Justification:** Bio-control methods can reduce the population of *Leucinodes orbonalis* in eggplant**,** *Maruca vitrata* in country beans and *Plutella xylostella* in cole crops (cabbage and cauliflower), thereby reducing environmental pollution from chemical control, and increasing yields to a great extent.

g. **Relationship to other research activities at the site:** Farmers will learn biocontrol methods and will be encouraged to use biocontrol methods in vegetable crops.

h. **Progress to date:** The larval parasitoid of eggplant FSB *Trathala flavoorbitalis* has been found to be highly effective in controlling FSB both in greenhouse and micro-plot trials. In the meantime, a successful technique has been developed to mass-rear *Trichogramma* egg parasitoids in the laboratory. Studies are now being conducted to test the efficacy of the parasitoids on bean pod borer and leaf-eating insects of cabbage.

i. **Projected outputs**: (1) Development of laboratory techniques to rear the parasitoids for their utilization in controlling insect pests of different vegetable crops. (2) Utilization of biocontrol agents for the control FSB, bean pod borer, and cabbage leaf-eating insects. (3) No or minimal pesticide use for growing healthy vegetables. (4) Higher economic benefits to the farmers.

j. **Projected impacts:** (1) Establishment of a parasitoid rearing technique. (2) Utilization of a biocontrol method for vegetable pest control. (3) Reduced pest infestation. (4) Production of pesticide-free vegetables and opportunities for vegetable exports to developed countries.

k. **Projected start:** October 1999

l. **Projected completion:** September 2004

m. **Projected person-months of scientists per year:** 12 person-months

n. **Budget**: $1,870 – BARI; $6,058 – Penn State

## IV. Evaluation of Bt Gene Proteins against Fruit and Shoot Borer (FSB) of Eggplant and Development of Eggplant Varieties with the Bt Resistance Gene in Bangladesh

a. **Scientists:** M. Al-Amin, M.A. Rashid, Shahabuddin Ahmad, Mosharraf Hossain, M. Nazimuddin, S.N.AlaM – BARI; N.S. Talekar – AVRDC; Mohankumar – TNAU; E. Rajotte – Penn State; Sally Miller – Ohio State; George Norton – Virginia Tech

b. **Status:** New

c. **Objective(s)**: (1) To evaluate the Co2 isoline which expresses Bt coded genes for their adaptability and reactions to other major pests and diseases in Bangladesh. (2) To test the efficacy of Bt crystal proteins against FSB of eggplant in Bangladesh. (3) To transfer Bt protein genes to commercial eggplant varieties of Bangladesh. (4) To conduct academic exchanges and train Bangladeshi scientists. (5) To compare economic viability of Bt eggplants with alternative means of controlling eggplant FSB and assess potential economic impacts of Bt eggplants in Bangladesh. **Objectives in 2003-2004:** (1) To evaluate the Co2 isoline which express Bt coded genes in Bangladesh for their adaptability and reactions to other major pests and diseases. (2) To test Bt crystal coat protein genes against F SB of eggplant. (3) To conduct academic exchanges and train Bangladeshi scientists.

**d.** **Hypothesis:** The eggplant fruit and shoot borer (FSB) is a difficult pest to control by using traditional and available measures. Use of transgenic eggplants with Bt genes that offer resistance to feeding of FSB is a novel approach. Toxin-producing genes from a bacterium, B*acillus thuringiensis*, which kill FSB, are inserted into eggplants killing the young larvae as they feed. The gene which codes for a protein (Cry 1AB) has already been identified at TNAU. The test of Bt crystal coat proteins against FSB will help identify the effective Bt gene(s) in order to develop transgenic eggplant varieties.

**e.** **Description of research activity:** (1) Evaluation of Co2 isoline in Bangladesh: The transport of Bt transformed eggplant line (Bt Co2) has not yet been approved. In anticipation of the transfer of the transformed eggplant (Bt-Co2) from India to Bangladesh, the non-transformed eggplant isoline (Co2) can be tested in Bangladesh for its adaptability and reactions to other major pests and diseases. The non-transformed Co2 plants will be tested in bacterial wilt sickbeds as well as in experimental fields at BARI using the standard procedures against bacterial wilt disease, root-knot nematode and leafhoppers. Additionally, the Co2 plants will be grafted on bacterial wilt rootstocks to determine its grafting compatibility and reactions to bacterial wilt disease. (2) Evaluation of Bt toxin protein: Bt Cry1AB proteins will be tested in the laboratory and greenhouse against the local strains of eggplant FSB. Bt proteins will be incorporated in the diet and FSB larvae of various stages will be allowed to feed. All the tests will be replicated. The cessation of feeding and the conditions leading to death will be recorded and the mortality percentage will be calculated.

**f.** **Justification:** Effective measures to control the eggplant fruit and shoot borer are lacking. Transgenic eggplants with Bt genes have been developed successfully in India for controlling the FSB of eggplant. The identified Bt proteins, if found effective against the FSB strain in Bangladesh can also be utilized to develop transgenic eggplants suitable for Bangladesh conditions. Ultimately, effective control of FSB will allow the production of eggplants without the use of pesticides, which is the normal practice of the farmers at the present time.

**g.** **Relationship to other activity at the sites:** Identification of effective Bt protein genes against FSB will lead to rapid transformation of the genes to cultivated varieties and develop transgenic varieties, which will open up the opportunities for successful cultivation of eggplant. This activity is also a component of a global IPM CRSP-funded project on transgenic eggplant. The global project coordinates the efforts of India, Bangladesh and Philippines as well as the U.S.

**h.** **Progress to date:** New project.

**i.** **Projected output:** Development of biotechnological methods to identify eggplant varieties with FSB-resistance and identification of Bt protein genes effective for FSB control.

**j.** **Projected impacts**: Identification of Bt gene(s) effective for FSB resistance and development of FSB-resistant transgenic eggplant varieties.

**k.** **Projected start**: June 2003

**l.** **Projected completion**: September 2004

**m.** **Projected person-months of scientists per year**: 12 person-months

**n.** **Budget**: $8,800 – BARI; $6,664 – Penn State

## V. Technology Transfer of IPM Packages for Healthy and High Production of Vegetables

### V.1. IPM Package for Healthy and High Production of Eggplant

**a.** **Scientists:** M. A. Rashid (Leader), S.N.Alam (co-leader), S. Ahmad, Ataur Rahman, Abdur Rahman – BARI; Ed Rajotte – Penn State; Greg Luther – Virginia Tech; Sally Miller – Ohio State

**b.** **Status**: Technology transfer

**c.** **Objective (Current and overall)**: To demonstrate and transfer the successful IPM practices in an integrated package for healthy and higher production of eggplants.

**d.** **Hypothesis**: On-farm research and demonstrations have shown that several IPM practices are effective for controlling BW, FSB and RKN in eggplant crop. These practices, when adopted as a package, can produce better results for the management of different pests and produce higher quality eggplant.

**e.** **Description of the research activities**: The package demonstration and technology transfer activities will be carried out at Jessore in five farmer fields and at Sreepur sites (Gazipur) in farmer fields from July 2003 to April 2004. Jessore farmers were already trained, but additional training will be arranged for farmers of both locations. The following technologies will be used in the IPM package for eggplant cultivation: (1) use of varieties resistant to FSB, BW, RKN and jassids (ISD-006, BL009, BL114 and BL083); (2) use of resistant eggplant grafts with resistant wild rootstocks (*S. torvum*/ *sisymbriifolium*); (3) use of soil amendments with decomposed poultry refuse/ mustard oil-cake for controlling various soil-borne diseases including BW and to improve soil fertility; (4) use of sanitation by removing FSB-infested shoots; and (5) use of two hand-weedings for optimum and economic weed control.

The IPM package demonstration will be established in two sets: one with resistant varieties and the other with grafted plants, both having the other IPM treatments. Each field will include one plot having farmer practice (without any of the above treatments).

Economic analyses will be carried out through the ATDP-II project to determine the production cost and market opportunities for the farmers to sell their produce at a better price.

**f.** **Justification**: Crop production involves a number of management practices in order to achieve the desired yield and economic returns. For management of weeds, diseases and other pests, farmers will usually look for a package of practices that may solve their problems. Use of different IPM practices that have proved successful is likely to solve various pest problems and produce better yields and give higher economic returns.

**g.** **Relationship to other research activities at the site**: The component technologies developed for different pests can be used in other crops having similar problems.

**h.** **Progress to date**: The IPM technologies developed in the past years for different pests of eggplant have produced successful results and have created an impact on the farming community. Integration of the IPM practices as a package is expected to create a positive impact at the farm level.

**i.** **Projected output**: A package of technology will be available to the farmers and its use will help to obtain a better crop stand, higher yields and a greater economic return.

**j.** **Projected impacts**: (1) Availability of an effective IPM package for eggplant production; (2) better crop; (3) relatively pesticide-free higher yield; and (4) higher economic returns.

**k.** **Project start:** July 2003

**l.** **Projected completion:** April 2004

**m.** **Projected person-month of scientists per year**: 12 person-months

**n.** **Budget**: $2,420 – BARI; $4,158 – Ohio State; $2,423 – Penn State; $1,277 – Virginia Tech

## V.2. Evaluation of Pilot Production of Grafted Tomato for Bacterial Wilt Control at Jessore and Sripur-Gazipur) and Training of Farmers and Nurserymen for Technology Transfer

**a.** **Scientists:** Shahabuddin Ahmed, M.A. Rashid, M.A. Gaffar, Ataur Rahaman,– BARI; M. Rafiquddin – RARS, BARI (Jessore); Baha Uddin Ahmed – IPM CRSP; G. Luther – Virginia Tech; Sally Miller – Ohio State

**b.** **Status**: Technology transfer

c. **Objectives (current and overall):** (1) Demonstrate and popularize tomato grafting technology for BW control through pilot production; and (2) disseminate tomato grafting technology through training of nurserymen and farmers.

d. **Hypotheses:** On-farm demonstration trials have proven that tomato grafting on BW-resistant wild *Solanaum* rootstocks is highly effective for BW control and the farmers are keenly interested in adopting the technique. Training of nurserymen and growers and pilot production of grafted tomato will help the diffusion and popularization of the technique.

e. **Description of research activity:** The activities will be carried out at Jessore and Sripur (Gazipur) starting from August 2003. Ten farmers and nurserymen, selected from each area, will be trained on grafting of cultivated tomato on bacterial wilt (BW)-resistant wild *Solanum* rootstocks. For this purpose two low-cost grafting houses will be constructed in each area. Seeds of the wild *Solanum* species (*Solanum torvum* and *S. sisymbriifolium*) will be supplied by BARI. The BARI tomato popular varieties will be used as scion. Grafting will be done by the trained nurserymen/growers under the supervision of BARI scientists. Five farmers will be selected from each area for pilot production of grafted eggplants and at least 500 plants will be established in each field starting in August 2003.

f. **Justification:** Bacterial wilt *(Ralstonia solanacearum*) is a devastating disease of tomato in Bangladesh and no BW-resistant cultivated varieties are available. Since tomato grafting on BW-resistant wild eggplant rootstocks has been proven highly effective for BW control in farmer fields, farmers are interested in adopting the technology. Training of nurserymen/growers and pilot production of grafted tomato will help rapid dissemination of the technology.

g. **Relationship to other research activities at the site**: Grafting technology can be utilized by the farmers in controlling BW disease of tomato in combination with other IPM practices.

h. **Progress to date**: On-farm demonstration trials of tomato grafting carried out at Sripur (Gazipur) in the 2002-2003 winter season showed that grafting was highly successful in controlling BW disease, establishing more than 95% plant populations, producing high yield and bringing about high economic returns.

i. **Projected output(s):** Utilization of grafting by the farmers will help to obtain a better crop stand, higher yields and greater economic returns.

j. **Projected impacts:** (1) Reduced plant mortality; (2) better crop stand; and (3) greater yield and economic return.

k. **Projected start:** August 2002

l. **Projected completion:** March 2004

m. **Projected person-months of scientists per year**: 12

**n.** **Budget**: $2,200 – BARI; $1,890 – Ohio State; $1,277 – Virginia Tech

## V.3. Evaluation of an IPM package for High and Economic Production of Tomato

**a.** **Scientists**: M. Mozammal Hoque (Leader), Shahabuddin Ahmad (Co-leader), M.A. Rashid, Abdur Rahman, Ataur Rahman – BARI; Ed Rajotte – Penn State; Greg Luther – Virginia Tech; Sally Miller – Ohio State; Robert Gilbertson – UC Davis)

**b.** **Status**: Technology transfer

**c.** **Objectives**: (1) To demonstrate the component technologies developed earlier in a package form for the control of different pests by grafting and soil amendment practices and by using improved varieties and other practices. (2) To establish an IPM package and transfer the technology to the farmers for high and economic production of tomato.

**d.** **Hypothesis**: Farmers deploy a number of practices for better and higher production of vegetable crops. For this purpose they need a package of IPM technologies and other practices that will enable them to adapt according to the situations they encounter. Exposure to the use of different improved practices will enhance farmers' knowledge to grow better crops of tomato.

**e.** **Description of research activities**: The trials will be conducted at Jessore and Sreepur, Gazipur from August 2003 to April 2004. Five farmers will be selected in each area and the following technologies will be used in the IPM package: (1) raising of tomato seedlings under nylon net cover to protect the seedlings from the attack of viruliferous whitefly, a vector of tomato yellow mosaic virus; (2) weekly monitoring for whitefly and application of pyrethroid insecticide (cypermethrin) after transplanting if white flies are seen; (3) soil amendments by using decomposed poultry refuse/mustard oil-cake in the seedbed nursery as well as in the main planting field for improving soil fertility and controlling soil-borne diseases; (4) use of bacterial wilt-resistant grafted tomato plants (grafted on wild *Solanum torvum*/*S. sisymbrifolium*) in the planting fields for bacterial wilt control; (5) two-hand weedings for effective and economic weed control; and (6) application of Rovral fungicide in case of early blight attack and Ridomil fungicide in case of late blight (December-January). Each farmer field will contain a plot of 'farmer practice' managed by the farmers without inclusion of any of the IPM practices. Economic analyses for costs of production will be determined and market opportunities for the farmers to sell their produce at better prices will be explored through the ATDP-II project.

**f.** **Justification:** BW, RKN, and TYLCV are the major pests of tomato which seriously damage the plants and severely reduce the production in Bangladesh. A number of IPM technologies have been developed during the past few years to control these pests by using grafted tomato plants and by organic amendment of the soils by using poultry refuse and mustard oil-cake. Moreover, a number of improved tomato varieties are available. Using these IPM technologies, improved varieties and other cultivation practices it is possible to obtain high and healthy production of tomato, and farmers will benefit from using an effective package of practices.

**g.** **Relationship to other research activities at the site:** The success of this package of IPM technologies will encourage farmers to grow tomato in different areas along with other practices.

**h.** **Progress to date:** Component technologies including improved varieties were demonstrated in farmer fields in Jessore and Sripur, and the results created interest among the farmers.

**i.** **Projected output(s)**: Use of package technologies will help to obtain a better crop stand, higher yields and greater economic return.

**j.** **Projected impacts**: Development of an effective IPM package for tomato production with better crop establishment, higher yield, no or minimal pesticide use and higher economic return.

**k.** **Projected start**: August 2003

**l.** **Projected completion**: September 2004

**m.** **Projected person-months of scientists per year**: 12 person-months

**n.** **Budget**: $2,090 – BARI; $2,438 – Penn State; $1,277 – Virginia Tech

## V.4. Evaluation of an IPM Package for Healthy and High Production of Cabbage

**a.** **Scientists**: M.A. Rahman (Leader), Ramizuddin Miah (Co-leader), Shawquat Ali Khan, Selim Reza Mollik, M. Nazimuddin – BARI; H.S. Jasmine – IPM CRSP; Greg Luther – Virginia Tech; Sally Miller – Ohio State

**b.** **Status:** Technology transfer

**c.** **Objectives**: To demonstrate in a package form the insect, disease, and weed management IPM practices in farmer fields and transfer the IPM package technology for growing better cabbage crops with higher yields, zero or minimal pesticide use and higher economic returns.

**d.** **Hypothesis**: Use of an IPM package for the management of diseases, insect pests and weeds in cabbage crops will enhance farmers' understanding about IPM practices and will lead to production of better crops with higher yields, minimal or zero pesticide use and higher economic returns.

**e.** **Description of Research Activity**: The trials will be conducted in Comilla and Jessore. At least 3 farmers will be selected for each location. Three IPM technologies will be integrated in a package form for management of insects, soil-borne diseases and weeds as follows: (1) The soils of the seedbed will be incorporated with well decomposed poultry refuse/mustard oil-cake about 10-15 days before sowing cabbage seeds; (2) One month old cabbage seedlings raised in the amended seedbeds will be transplanted in the main field; soils of the main field will also be amended as mentioned above; (3) Cabbage fields will be weeded by hand at 15 and 35 days after transplanting for effective and economic weed management; (4) Cabbage fields will be monitored every week for infestations of leaf-eating insects, and the infested leaves and the insects will be removed by hand-picking and destroyed immediately. Infestation of leaf-eating insects usually starts from the 3rd week after transplanting, and pest removal will be started accordingly and continued as long as the infestation persists; (5) A biopesticide (Bt preparation) will be used if hand-picking measure proves inadequate and the infestation exceeds 5%. Malathion 57 EC will be used to spot treat infested plants if the above measures fail (as in the case of severe infestation exceeding 10%); (6) Each farmer's field will contain a plot of 'farmer practice' managed by the farmers without inclusion of any of the IPM practices. Data will be recorded on plant mortality, weed infestation, insect infestation and yield. Economic analyses will be done to determine the cost of cabbage production and marketing facilities to sell the produce at better prices will be explored through prospective buyers.

f. **Justification**: Farmers face great difficulties in raising good cabbage crops and fail to obtain higher yields because of the damage caused by a number of soil-borne diseases, leaf-eating insects and various weeds. IPM technologies have been developed through on-farm trials to overcome these problems. Use of the effective technologies in package form will help farmers to economically grow better crops with higher yields with zero or minimal pesticide use.

g. **Relationship to other activities at the site**: Farmers will learn the usefulness of the IPM package and will be encouraged to adopt IPM in other vegetable crops.

h. **Project output**: Development of an IPM package for producing pesticide-free cole crops (cabbage and cauliflower) with higher yields and economic returns.

i. **Projected impacts**: (1) Establishment of an IPM package; (2) higher production of cabbage crops; (3) higher economic returns; (4) opportunities for export trade, and (5) reduction in pesticide use.

j. **Projected start**: September 2003

k. **Projected completion**: September 2004

l. **Projected person-months of scientists per year**: 10 person-months

m. **Budget**: $5,570 – BARI; $1,817 – Penn State; $7,347 – Virginia Tech

## V.5. Evaluation of an IPM Package for High and Healthy Production of Cucurbit Crops

a. **Scientists**: M. Nasiruddin (Leader), S. N. Alam (Co-leader), Ramizuddin Miah, Ziaur Rahman, N.K. Dutta, M.A. Rahman – BARI; A.N.M.R. Karim, H.S. Jasmine – IPM CRSP; E.G. Rajotte – Penn State; G. Luther – Virginia Tech

**b.** **Objectives:** (1) To demonstrate the component IPM technologies, such as fruit fly control by using pheromone and indigenous bait traps, and use of soil amendments for control of soil borne pathogens and to establish better crop growth in a package form. (2) To transfer the IPM technologies as a package for high and healthy production of cucurbits in fruit fly endemic areas.

**c.** **Status:** Technology transfer

**d.** **Hypothesis**: Use of pheromone and indigenous bait traps are highly successful for controlling fruit fly and producing high yields of cucurbit crops without pesticide use. Similarly, use of soil amendments with poultry refuse and mustard oil-cake controls the soil pathogens, reduces plant mortality and establishes better crop growth to produce higher yields. Integration of these technologies into a package will provide a high and healthy production of cucurbits without the use of pesticides.

**e.** **Description of research activity**: On-farm trials and demonstrations will be conducted in three locations of Sripur Gazipur, Jessore and Sitakund (Chittagong) on three cucurbit crops (sweet gourd, cucumber and bitter gourd). (1) Use of soil amendments for seedling raising and in planting fields: Cucurbit seedlings will be raised in polythene bags having a mixture of soil and decomposed poultry refuse/mustard oil-cake. Before transplanting the seedlings in the field, the pits will be prepared with well decomposed poultry refuse @ 3 tons /ha, and mustard oil cake @ 300 kg/ha, and the seedlings will be transplanted 15 days after preparing the pits with poultry refuse/mustard oil-cake. (2) Pheromone and indigenous bait trapping for fruit fly control: Pheromone (culure) bait traps and mashed sweet gourd (MSG) bait traps will be set at a distance of 10 $m^2$ alternating in the field. At all locations there will be two treatments laid out in five farmer fields. The treatments will include: (a) IPM package (Soil amendments + pheromone + MSG traps + sanitation); (b) farmer practice (use of insecticides or other measures). Data will be recorded on plant establishment and plant mortality. Weekly records will be made (after flowering) on the number of male and female flies caught, healthy (uninfected) fruits, partially infested but marketable fruits, and fully infested non-marketable fruits, and weather components (temperature and rainfall). Economic analysis for production cost and better marketing opportunities will also be done.

**f.** **Justification**: In order to protect the cucurbit crops from various pests and obtain economic yields, farmers use different types of practices. An effective IPM package will ensure that the farmers to achieve these objectives and gain higher economic benefits. Moreover, possible health hazards for the producers as well as the consumers will be drastically reduced due to the elimination of pesticide use.

**g.** **Relationship to other research activities at the site**: Use of an effective IPM package will encourage the farming community to apply the IPM approach in other crops.

**h.** **Progress to date**: The use of the IPM package is a new activity, but on-farm trials and demonstrations have produced highly successful results and have created deep impacts upon the farmers.

i. **Projected output**: Farmers will be able to implement an IPM package in cucurbit crops that will provide them higher yields and economic returns and healthy, pesticide free cucurbits will be available to the consumers.

j. **Projected impacts**: Development of an effective IPM package for higher and better quality production cucurbits and great reduction of pesticide use.

k. **Projected start**: September 2003

l. **Projected completion**: September 2004

m. **Projected person-months of scientists per year**: 12 person-months

n. **Budget:** $2,420 – BARI; $3,635 – Penn State; $1,277 – Virginia Tech

## VI. Socioeconomic Analyses

### VI.1. Measure Economic Impacts of Bangladesh IPM CRSP Research Activities

a. **Scientists:** M.I. Hossain, M.A. Monayem Miah, Nazrul Islam – BARI; Mahmuda Akter, Fakhrul Islam – BSMRAU; H.S. Jasmine, Nazneen A. Sultana, Mahbubur Rahman, Bahauddin Ahmed – IPM CRSP; G. Shively – Purdue; G. Norton – Virginia Tech

b. **Status:** Continuing

c. **Objectives:** (1) Evaluate and forecast economic impacts resulting from pest management strategies (PMS) developed by the IPM CRSP Bangladesh; (2) Estimate potential country-wide impacts of PMS developed by the IPM CRSP Bangladesh; and (3) Incorporate experimental and baseline survey data in a farm-level optimization model to analyze the potential farm level impact of IPM practices for representative farms. **Objectives in 2003-2004:** Continue and complete the evaluation of the farm level and aggregate impacts of the latest IPM strategies developed on the project, and preparation of a paper.

d. **Hypotheses:** (1) Tested IPM practices will result in higher incomes for farms that adopt IPM. (2) IPM practices will generate economic benefits to Bangladesh society as a whole.

e. **Description of research activity:** Individual scientists will collect data to be used to develop economic budgets for IPM components and packages, including production costs and financial returns. IPM packages will be assessed regarding their requirements of farm resources such as land, labor, and cash at specific times in the agricultural calendar. Economic surplus analysis will be used to project national-level impacts of IPM adoption.

f. **Justification:** Knowledge regarding the farm-level profitability of IPM strategies is necessary for promoting IPM and predicting likely patterns of adoption. Knowledge regarding potential aggregate social benefits of IPM adoption is necessary for informing national policy makers and research directors of the overall merits of IPM strategies and their economy-wide impacts. Information can also be used to develop specific policies to encourage IPM adoption. Technology transfer to other settings requires information regarding the likely settings in which adoption is expected to occur.

**g.** **Relationship to other research activities at the site:** This work is very closely related to research being conducted by other IPM CRSP scientists. This research critically depends on accurate and timely contributions of data from other research scientists. The activity specifically addresses issues related to the private profitability of IPM strategies being developed by other IPM CRSP scientists. It also complements other socioeconomic research that focuses on IPM adoption and the role of prices and marketing in pest management decisions for vegetables.

**h.** **Progress to date:** Partial work on the above objectives has been done up to 2002 and the impacts of three new technologies developed by IPM CRSP Bangladesh have been partially completed. An MS student is currently involved in this study for her MS thesis work.

**i.** **Projected outputs:** The profitability of IPM components and packages will be estimated and reported in a series of papers and presentations to the research community and policy makers in Bangladesh.

**j.** **Projected impacts:** Better decision making among researchers and policy makers regarding appropriate IPM technologies and likely on-farm impacts.

**k.** **Projected start:** September 2000

**l.** **Projected completion:** September 2004

**m.** **Projected person-months of scientists time per year:** 6 person-months

**n.** **Budget:** $2,860 – BARI; $1,277 – Virginia Tech; $5,850 – Purdue

## VI.2 Adoption Analysis of Integrated Pest Management Practices in Different Regions of Bangladesh

**a.** **Scientists:** M.I. Hossain, M.A. Monayem Miah, Nazrul Islam – BARI; Badiul Alam, S.A. Sabur – BAU; Baha Uddin Ahmed, Nazneen A. Sultana – IPM CRSP; C. Sachs – Penn State; G. Shively – Purdue; G. Norton – Virginia Tech

**b.** **Status:** Continuing

**c.** **Objectives:** (1) Assess the relative importance of agronomic, economic and social factors explaining observed patterns of crop and pest management practices. (2) Determine the effect of IPM practices on labor allocation (especially women's labor allocation) within farm households and potential repercussions for health and nutrition. (3) Determine the extent of adoption of vegetable pest management practices in different regions. (4) Assess the ways in which farm characteristics, socio-economic factors, and cropping decisions affect child nutrition and health. (5) Examine the effectiveness of IPM programs in facilitating improved pest management practices. **Objectives in 2003-2004:** To complete PRA and analyze the data of the PRA and the adoption practices followed by the farmers in different locations.

d. **Hypotheses:** (1) Probability of pesticide use rises as the intensity of vegetable production on a farm increases. (2) Socio-economic and demographic characteristics of households and their members affect adoption of IPM practices. (3) Adoption of IPM practices affect demand for labor use in farm households and may affect women's time allocation and health. (4) Regional differences in on-farm employment and labor availability of both men and women influences adoption of IPM practices. (5) A mother's education level and the nature of her work influences pest management practices and the child's health. (6) IPM adoption is higher in areas with significant NGO and extension programs.

e. **Description of research activity:** Data will be collected from three locations viz. Jessore, Manikganj and Gazipur. From each location, two villages will be selected considering the intensity of the vegetable growing areas. Again from each village, 5 focus groups will be interviewed: small farmers, medium farmers, large farmers, landless farmers, and women. Each group will consist of 8 members to determine their respective roles in pest management decision-making. Again, summer and winter season will be considered for the purpose. In total, 30 focus groups will be interviewed in each season. Data from the baseline survey will also be used to classify major pest management practices. Probability and extent of adoption of the practices will be assessed using statistical models (probit/logit, and/or other multiple regression methods). Data from the focus groups and the in-depth interviews will be analyzed to enrich the findings from the baseline survey.

f. **Justification:** Understanding of the factors associated with different pest management practices is necessary for formulating policies to promote new pest management practices or discourage undesirable practices.

g. **Relationship to other research activities at the site:** This work complements other socioeconomic research on the IPM CRSP in Bangladesh. Other activities related to this include the impact assessment and the price and marketing study. Data from the baseline study will be used as input.

h. **Progress to date:** PRA in three locations and data on adoption of IPM technologies by the farmers have been collected. Analysis of data and report writing will be completed by May/June 2003.

i. **Projected outputs:** Paper and presentations to the research community and policy makers in Bangladesh.

j. **Projected impacts:** Better understanding of pest management practices and improved policy making within the Department of Agriculture.

k. **Projected start:** September 2001

**l.** **Projected completion:** September 2004.

**m.** **Projected person-months of scientists time per year:** 6 person-months

**n.** **Budget:** $4,840 – BARI; $1,300 – Purdue; $12,855 – Virginia Tech;

## VI.3. Integration and Diffusion of IPM Technology

**a.** **Scientists:** M.I. Hossain, S.N. Alam, M.A. Monayem Miah, M. Nazrul Islam , M.A. Rahman – BARI; Abu Jafar Alponi, Habibur Rahman – BAU; Rayhanul Islam, Fakhrul Islam – BSMRAU; Nazneen A. Sultana – IPM CRSP; G. Shively – Purdue; G. Norton, G Luther – Virginia Tech; Madonna Casimero – IRRI

**b.** **Status**: Continuing

**c.** **Objectives**: To (1) test the most promising set of technologies developed by the IPM CRSP with the participation of farmers; (2) obtain farmers' feedback about these technologies including the constraints related to their implementation; (3) find the economic advantages of the technologies; and (4) facilitate diffusion of IPM technologies. **Objectives in 2003-2004:** To continue tests of the most promising technologies with farmer participation in three intensive vegetable growing areas and obtain farmers' feedback and assess economic advantages of the technologies.

**d.** **Hypotheses:** (1) IPM technologies will be accepted by the farmers; (2) Farmers' participation will enhance the expansion of IPM technologies; and (3) IPM practices will be economically advantageous to farmers.

**e.** **Description of research activity:** Three study areas, namely Jessore, Comilla and Rangpur, will be included in the study. Two villages will be included from each study district based on the related technology-based vegetable growing areas and five farmers will be selected from each village to participate in testing the IPM CRSP derived technologies. For the selection of the farmers, assistance will be provided by the NGOs involved in the areas. Additionally, aid will be provided by one vegetable scientist from RARS, Jessore and two vegetable scientists from the Headquarters. The farmers will be selected from small, medium and large farm categories. Before the actual start of the work in the farmer fields, the selected farmers will be trained on IPM-derived technologies which will be used in their fields. The information regarding the technologies, farmers' perceptions, constraints, etc. will be recorded on a regular basis by the enumerators. At the same time, the existing practices of the farmers with the selected vegetables in the areas will be recorded.

**f.** **Justification:** IPM scientists have developed a number of technologies that need to be disseminated to the farmers. In addition, feedback regarding these practices is needed for further improvement and policy making.

g. **Relationship to other CRSP activities at the site:** This has an important relationship to all other activities at the site, because this activity allows dissemination of technologies at the farmers' level.

h. **Progress to date:** In 2002-2003, organic soil amendments for soil-borne disease management in cabbage and eggplant, and fruit fly control in cucurbit crops by bait trapping were demonstrated and tested in Jessore, Comilla and Rangpur. In all tests, the technology proved very effective producing high economic returns. Tests are continuing in three districts. Two MS students are involved in these studies for their MS thesis work.

i. **Projected Outputs:** The results from this study will be helpful for scientists working in the field of IPM, as well as the extension workers and policy makers.

j. **Impacts:** This activity has a broad-based and long-term effect on the production of economically profitable, healthy vegetables and creates opportunities for the export market.

k. **Projected start:** October 2001

l. **Projected completion:** September 2004

m. **Projected person-months of scientist time** : 6

n. **Budget:** $5,170 – BARI; $1,817 – Penn State; $7,031 – Virginia Tech; $1,300 – Purdue

## Site Activity Summary – Bangladesh – Year 11

| ACTIVITY | SCIENTISTS | BUDGET ($) |
|---|---|---|
| **I. Crop/Pest Monitoring** | | |
| I.1. Survey of Infestation Levels of Whitefly, *Bemisia tabaci*, and its Natural Enemies on Different Vegetable Crops | S.N. Alam, M. A. Maleque, Ziaur Rahman, M. A. Rouf, M. A. Rahman, K. A. Kader – BARI; A.N.M.R. Karim, H. S. Jasmine – IPM CRSP; E. Rajotte – Penn State; Greg Luther – Virginia Tech; Robert Gilbertson – University of California-Davis | \$3,190 – BARI; \$36,612 – Penn State |
| *II. Multidisciplinary On-farm Pest Management Experiments* | | |
| II.1a. Evaluation of Eggplant for Resistance to Bacterial Wilt, Fruit and Shoot Borer, Leafhopper (jassids) and Root-Knot Nematode and of Tomato for Resistance to Bacterial Wilt, Virus Disease and Root-Knot Nematode | M.A. Rashid, Shahabuddin Ahmed, M.A. Rahman, S.N. Alam, M.H. Rashid – BARI; H.S. Jasmine, Nazneen A. Sultana, Bahauddin Ahmed – IPM CRSP; N.S. Talekar – AVRDC; G. Luther – Virginia Tech; Sally Miller – Ohio State; Robert Gilbertson – UC Davis | \$12,540 – BARI; \$6,058 – Penn State; \$4,410 – Ohio State; \$2,520 – UC-Davis |
| II.1b. Evaluation of Selected Pumpkin Varieties Against Watermelon Mosaic 2 Poty Virus (WM2V) | M.A. Rashid, M.A.T. Masud, M.H. Rashid – BARI; M.A. Mannan Akand – BSMRAU; Nazneen A. Sultana, Bahauddin Ahmed – IPM CRSP; G. Luther – Virginia Tech; Robert Gilbertson – UC Davis | \$2,200 – BARI; \$4,662 – Ohio State; \$2,520 – UC-Davis |
| II.1c. Screening of Okra Germplasm against Yellow Vein Mosaic Virus (YVMV) | M.A. Rashid, M.A.T. Masud, Shahabuddin Ahmed, H. Rashid – HRC (BARI), Md. Hossain – TCRC (BARI); Salim Uddin – Plant Breeding, BARI; Baha Uuddin Ahmed, Nazneen A. Sulatana – IPM CRSP; Robert Gilbertson – UC Davis | \$2,200 – BARI; \$3,780 – Ohio State; \$3,780 – UC-Davis |
| II.2. Integrated Management of Weeds and Soil-borne Diseases in Tomato | Anwar Karim, S.A. Khan – BARI; A.N.M.R. Karim, Mahbubur Rahman – IPM CRSP; A. Baltazar – NCPC/UPLB; Sally Miller – Ohio State; S.K. De Datta – Virginia Tech | \$2,200 – BARI |

| | | |
|---|---|---|
| **III. Multidisciplinary Laboratory, Greenhouse, and Microplot Experiments** | | |
| III.1. A. Study of *Trichogramma chilonis* and *T. bactrae* for the control of *Leucinodes orbonalis, Maruca vitrata* and *Plutella xylostella*; B. Development of Mass Rearing Technique of *Cotesia plutellae* and Determination of its Effectiveness on DBM; C. Study on the Abundance and Parasitism Characteristics of *Trathala flavoorbitalis* on Rice Leaf roller and ESFB and Determination of its Host Preference | S.N. Alam, Ziaur Rahman, A. Rouf – BARI; N.A. Sultana, A.N.M.R. Karim – IPM CRSP; N.S. Talekar – AVRDC; G. Luther – Virginia Tech; E. Rajotte – Penn State | $1,870 – BARI; $6,058 – Penn State |
| **IV. Evaluation of Bt Gene Proteins against Fruit and Shoot Borer (FSB) of Eggplant and Development of Eggplant Varieties with Bt Resistance Gene in Bangladesh** | M. Al-Amin, M.A. Rashid, Shahabuddin Ahmad, Mosharraf Hossain, M. Nazimuddin, S.N.AlaM – BARI; N.S. Talekar – AVRDC; Mohankumar – TNAU; E. Rajotte – Penn State; Sally Miller – Ohio State; George Norton – Virginia Tech | $8,800 – BARI; $6,664 – Penn State |
| **V. Technology Transfer of IPM Packages for Higher and Healthy Production of Vegetables** | | |
| V.1. IPM Package for Healthy and Higher Production of Eggplant | M. A. Rashid (Leader), S.N.Alam (co-leader), S. Ahmad, Ataur Rahman, Abdur Rahman – BARI; Ed Rajotte – Penn State; Greg Luther – Virginia Tech; Sally Miller – Ohio State | $2,420 – BARI; $2,423 – Penn State; $4,158 – Ohio State; $1,277 – Virginia Tech |
| V.2. Evaluation of Pilot Production of Grafted Tomato for Bacterial Wilt Control at Jessore and Sripur-Gazipur) and Training of Farmers and Nurserymen for Technology Transfer | Shahabuddin Ahmed, M.A. Rashid, M.A. Gaffar, Ataur Rahaman,– BARI; M. Rafiquddin – RARS, BARI (Jessore); Baha Uddin Ahmed – IPM CRSP; Greg Luther – Virginia Tech; Sally Miller – Ohio State | $2,200 – BARI; $1,890 – Ohio State; $1,277 – Virginia Tech |
| V.3. Evaluation of an IPM package for Higher and Economic Production of Tomato | M. Mozammal Hoque (Leader), Shahabuddin Ahmad (Co-leader), M.A. Rashid, Abdur Rahman, Ataur Rahman – BARI; Ed Rajotte – Penn State; Greg Luther – Virginia Tech; Sally Miller – Ohio State; Robert Gilbertson – UC | $2,090 – BARI; $2,438 – Penn State; $1,277 – Virginia Tech |

| | | |
|---|---|---|
| | Davis) | |
| V.4. Evaluation of an IPM Package for Healthy and Higher Production of Cabbage | M.A. Rahman (Leader), Ramizuddin Miah (Co-leader), Shawquat Ali Khan, Selim Reza Mollik, M. Nazimuddin – BARI; H.S. Jasmine – IPM CRSP; Greg Luther – Virginia Tech; Sally Miller – Ohio State | $5,570 – BARI; $1,817 – Penn State; $7,347 – Virginia Tech |
| V.5. Evaluation of an IPM Package for Higher and Healthy Production of Cucurbit Crops | M. Nasiruddin (Leader), S. N. Alam (Co-leader), Ramizuddin Miah, Ziaur Rahman, N.K. Dutta, M.A. Rahman – BARI; A.N.M.R. Karim, H.S. Jasmine – IPM CRSP; E.G. Rajotte – Penn State; G. Luther – Virginia Tech | $2,420 – BARI; $3,635 – Penn State; $1,277 – Virginia Tech |
| **VI. Socioeconomic Analyses** | | |
| VI.1. Measure Economic Impacts of Bangladesh IPM CRSP Research Activities | M.I. Hossain, M.A. Monayem Miah, Nazrul Islam – BARI; Mahmuda Akter, Fakhrul Islam – BSMRAU; H.S. Jasmine, Nazneen A. Sultana, Mahbubur Rahman, Bahauddin Ahmed – IPM CRSP; G. Shively – Purdue; G. Norton – Virginia Tech | $2,860 – BARI; $1,277 – Virginia Tech; $5,850 – Purdue |
| VI.2. Adoption Analysis of Integrated Pest Management Practices in Different Regions of Bangladesh | M.I. Hossain, M.A. Monayem Miah, Nazrul Islam – BARI; Badiul Alam, S.A. Sabur – BAU; Baha Uddin Ahmed, Nazneen A. Sultana – IPM CRSP; C. Sachs – Penn State; G. Shively – Purdue; G. Norton – Virginia Tech | $4,840 – BARI; $12,855 – Virginia Tech; $1,300 – Purdue |
| VI.3. Integration and Diffusion of IPM Technology | M.I. Hossain, S.N. Alam, M.A. Monayem Miah, M. Nazrul Islam , M.A. Rahman – BARI; Abu Jafar Alponi, Habibur Rahman – BAU; Rayhanul Islam, Fakhrul Islam – BSMRAU; Nazneen A. Sultana – IPM CRSP; G. Shively – Purdue; G. Norton, G Luther – Virginia Tech; Madonna Casimero – IRRI | $5,170 – BARI; $1,817 – Penn State; $7,031 – Virginia Tech; $1,300 – Purdue |

## YEAR 11 WORKPLAN FOR THE CARIBBEAN SITE

The research activities of the Caribbean site, centered in Jamaica but extending to other island nations in the region, are conducted under four main components: (1) IPM Systems Development, (2) Pesticide Use and Residues, (3) Social, Economic, Policy and Production System Analyses, and (4) Research Enhancement through Participatory Activities. The primary focus in the Year 11 workplan will continue to be on high value, non traditional export crops that are also in demand locally, with the three crops of major focus being high-pesticide-input leafy vegetable crops (with emphasis on crucifers), sweetpotato, and hot pepper. Essential IPM elements (sampling, monitoring, host-plant resistance, biorational pesticides integrated with resistance management, disease management integrated with insect vector management) are being emphasized in three specific cropping systems. Activities planned for Year 11 are: (i) finalizing of all IPM systems development and validation activities; (ii) focusing on IPM adoption impact assessment studies; (iii) conducting technology transfer within Jamaica and regionally; (iv) positioning for future collaboration with the USAID Mission projects in Jamaica and the Eastern Caribbean; and (v) biotechnology activities on (a) diagnostic probes to distinguish species in the gall midge complex; and (b) hot pepper viruses: molecular diversity and enhancement of resistance.

The priorities of the Jamaica Mission, which are consistent with the Caribbean Basin countries, are community policing, HIV/AIDS, disaster vulnerability, and enhancing competitiveness and trade capacity. The IPM CRSP activities fit most closely with the latter priority, which includes enterprise development, export and trade, and environmental issues related to trade and rural development. The Mission has also been funding a Ridge-to-Reef project that focuses on two watersheds in Jamaica, including pesticide runoff and use patterns in these watersheds, and is thus interested in our activies. Activities that are key to positioning the project for the next phase include institutional strengthening (pesticide residue analysis capacity, improved diagnostic capabilities through biotechnology, modified Farmer Field Schools, GIS applications, and training in weed management), IPM for environmental management (regional networking and contributing to mission priorities), and conducting participatory rural appraisals (PRAs) in several locations. Food safety issues related to pesticide residue and to microbial contamination are relevant for both residents and tourism in the Caribbean.

The program has created institutional linkages across the Caribbean. We were pivotal in the evolution of the PROCICARIBE Caribbean Integrated Pest Management Network (CIPMNET), public and private sector linkages for web/GIS monitoring, and biorational pesticide development, directly influencing safety at the farm level. Research partners include two Caribbean-wide and two Jamaican institutions. The Caribbean-wide institutions are the Caribbean Agricultural Research and Development Institute (CARDI), where we work with Jamaican Unit which is the CARDI IPM Centre and location of the Site Coordinator; and the University of the West Indies Mona Campus, including the Natural Products Institute and the Biotechnology Centre. The Jamaican institutions include the Ministry of Agriculture (MINAG), and the Rural Agricultural Development Authority (RADA), which is the extension and training delivery system, and the location of the IPM Coordinator for the Caribbean. We have regionalized to include CARDI and ministry personnel in other islands. In the United States, five institutions participate: Pennsylvania State University in vegetable crop IPM and monitoring programs including web/GIS; Ohio State University in pesticide residue analysis and new insecticides; the USDA's Vegetable Research Laboratory in Charleston SC in sweetpotato breeding and pest management, the University of California at Davis in socioeconomic/gender and marketing, and Virginia Tech in virus-vector management and GIS/GPS systems for pest management.

**I.** **IPM Systems Development:** The goal of this component is to develop IPM system components (i.e., biorational pesticides, sampling systems, decision support tools, and control tactics) and to combine these components into IPM systems for leafy vegetables, sweetpotatoes, and hot peppers. These high value export crops were identified as those in which Caribbean farmers had adopted systems of intensive pesticide application, using chemicals posing high risks to human health and the environment. The Caribbean research team is implementing a phased approach to demonstrate the benefits of decreasing use of these highly toxic materials. The first phase is to demonstrate that the new, biorational selective pesticides can produce comparable crop yields with smaller environmental and human costs and that they must be developed within a resistance management framework. The second and most important phase is to develop and implement IPM systems that are biologically intensive and environmentally benign. Regional monitoring, as an IPM systems component, is being integrated across cropping systems. Several components of hot pepper pest management have been developed separately, but these require integration across several pests for sustainable pepper production. Individual continuing and new projects follow.

**I.1.** **Threshold-based Management of Pests Affecting Leafy Vegetables with High Pesticide Input:** IPM CRSP-funded research has devised a sampling plan and threshold-based timing of pesticide applications with new selective modes-of-action for reducing this problem. This is being regionalized and applied to crucifer crops by training farmers throughout the region and conducting field experiments in three island nations (Trinidad, Barbados and Jamaica). Conservation biological control which protects natural enemies under conditions of use of the biorational insecticides in the Caribbean will be measured. The web-based monitoring program (IV.2), using GIS for regional views of pest pressure developed for gall midge IPM, will be adapted for monitoring several lepidopterans with pheromone-baited traps.

**a.** **Scientists:** D. Clarke-Harris – CARDI; P. Chung – RADA; S. Fleischer – Penn State Univ.; D. M. Jackson – USDA-ARS.

**b.** **Overall Objectives:** Regionalize the IPM systems approach for high-pesticide-input vegetable systems. **Objectives for coming year:** (1) Determine major pests and monitor populations of major pests on cabbage in three island nations; (2) Evaluate biorational pesticides on major Lepidoptera on cabbage in three island nations; (3) Determine the rate of conservation of biological control.

**c.** **Hypotheses:** (1) Lepidoptera species are major limiting pests on cabbage and leafy vegetables; spatial and temporal distribution of these lepidopterous pests on cabbage fluctuate throughout the growing season; pest monitoring and limiting sprays to times when densities exceed thresholds will reduce pesticide application frequency; (2) New biorational pesticides which were effective against Lepidoptera on vegetable amaranth will have similar efficacy against major Lepidoptera species on cabbage and other crucifers; (3) Conservation of predators and parasitoids result in significant lepidopteran pest control in cabbage, and that these natural enemies can be conserved when biorational/microbial pesticides are used and timed well with sampling protocols; (4) Row covers, which are effective for pest management in the US and in vegetable amaranth in the Caribbean, can be adapted for horticultural production; (5) Non-lepidopteran pests, including foliar and root-feeding species of beetles, are important in specific growing areas, and management will be improved with correct identification, crop rotation, and microbial materials; (6) Regional monitoring will help alert pest managers and help facilitate field-scale monitoring, and web, GIS, and pheromone technologies can be adapted to monitor lepidopteran pests over regional scales; and (7) Training of Caribbean scientists in the integration of pheromone, web, and GIS technologies for pest monitoring will facilitate IPM in leafy vegetables and be transferable to IPM in other crops.

**d. Description of research activities:**

**(1) Evaluation of biorational pesticides, thresholds, and exclusion for their effect on population dynamics of major Lepidoptera on cabbage, and on cabbage yield and quality.** Monitoring surveys will be conducted in Trinidad, Barbados, and Jamaica to record the incidence, dynamics, and economic importance of major pests on crucifers under varying management programs. Management programs to be evaluated include the use of two biorational pesticides (an insect growth regulator and a microbial metabolite), applied with and without threshold-based decision rules, and the use of agricultural row covers. Treatments will be evaluated in randomized complete block experiments in Trinidad, Barbados and Jamaica. Research collaborators were identified from Barbados and Trinidad during regionalization training workshops conducted in Year 9. Year 11 activities will provide a second field season of data.

**(2) Conservation biological control in cabbage.** Rates of parasitization of lepidopteran larvae and pupae in plots treated with microbial and biorational pesticides, and with grower standards and untreated controls, will be compared.

**(3) Monitoring lepidopteran pest pressure at a regional scale using web-GIS.** Traps baited with pheromones for lepidopteran pests relevant to cabbage and other vegetable crops (specifically diamondback moth, corn earworm, fall armyworm, and beet armyworm) will be established at multiple sites in Jamaica. Traps will be serviced weekly. The web–GIS program being established for gall midge, which can accommodate multiple pest species, will be adapted and used to track the dynamics of these lepidopterans over wide scales in Jamaica and other Caribbean countries.

**(4) Collection and identification of non-lepidopteran pest species**. Beetles, root aphids, and other species identified as pests by farmers will be collected and identified.

**(5) Training Caribbean researchers in web-GIS monitoring with pheromone traps.** The integration of using pheromone, web and GIS technology to monitor pest populations will be taught to pest management scientists in three Caribbean island nations, and software will be provided.

**(6) Assessment of the impact of training activities in vegetable IPM on farmer knowledge and produce quality.** Knowledge of extension officers and farmers engaged in training activities in vegetable IPM will be assessed. Questionnaires will be designed to capture the knowledge of new IPM technologies and principles among these two groups. Farmer practice within primary research areas will also be evaluated through administration of questionnaires and field observations to determine adoption of better farming practices. Observations will focus on (1) farmer ability to recognize major pest developmental stages, select natural enemies and parasitized/diseased pests; (2) adoption of key cultural practices that enhance natural enemy activity and dissuade pest activity; and (3) pest damage and marketable yield levels of produce. Extension staff skills will be assessed through observations on (1) ability to recognize major pest developmental stages, select natural enemies and parasitized/diseased pests and (2) delivery of training for farmers, in the subject area. This will involve the use of on-the-spot training session evaluations by scientists, looking at technical content, clarity, use of training aids and group dynamics, and organization of sessions. Data on pest interceptions on export produce between 1995 and 2003 will also be obtained from the Plant Quarantine Division of the Ministry of Agriculture and analyzed.

**e.** **Justification:** Crucifers have been identified as a leafy vegetable system grown universally in the Caribbean and plagued with pest and pest management problems similar to those of the vegetable amaranth. Of the 16 member countries of the Caribbean IPM Network, 11 listed the diamond-back moth on cabbage as a priority pest management issue. Implementation of an effective IPM strategy for this crop would therefore have far reaching impact for within the Caribbean Region.

Currently management, which relies on synthetic chemicals for lepidopteran pest control, is resulting in crop failures, and pesticide resistance is highly probable. Two management tactics - selective chemistries and exclusion - will be examined as alternatives. New biorational pesticides have, or are rapidly gaining, EPA registrations in leafy vegetable and cruciferous crops in the United States. They have novel modes-of-action that were effective against lepidopteran larvae infesting vegetable amaranth in the Caribbean, which were not being controlled by carbamates, organophosphates or pyrethroids. Maintaining registrations on biorational materials is more feasible and they improve farm-worker safety. Also, the newer biorational materials may result in significant conservation of natural enemies when deployed at a farm scale, and biological control is often an important IPM-systems component in crucifer crops. In addition to chemical/microbial options, the exclusion option should be easier to adopt for cabbage due to (a) it being a single-harvest crop, (b) existing literature on the use of exclusion for cabbage pest management, and (c) growth of the agricultural polymer/fabric industry making the material increasingly accessible.

Lepidopterans are an important part of the pest complex, and several lepidopteran species lend themselves well to monitoring with pheromone traps. Pheromone based monitoring helps time biorational pesticide application, and trap catch densities correlated with larval densities in amaranth in Jamaica. Accordingly, we will implement the use of pheromone traps as part of the pest-monitoring program in leafy vegetables, resulting in time-series data of pheromone trap catch. Time-series data can readily be geo-referenced, input into databases via the web, and displayed via the web. The Caribbean site is developing this technical capability as an IPM systems component for dealing with the gall midge in peppers, and this component easily translates across cropping systems. Progress in this represents development of technical infrastructure for IPM implementation. It is more easily developed with pheromone trap sampling methods, and thus can begin to be developed across the Caribbean region.

Training in the web-GIS technologies will facilitate its expansion into other Caribbean nations.

f. **Relationship to other CRSP activities at the site**: The main thrust is geared towards validation and implementation of the IPM model developed for rationalized pesticide use in management of lepidopteran pests on leafy vegetables, and is a focus of regionalization activities. IPM systems development on all commodities (hot pepper, leafy vegetables and sweetpotato) is now at the regionalization phase. These activities are promoting all the developed strategies to the various groups of farmers and other agriculturists targeted during training sessions. These groups would, therefore, be exposed to IPM in its broadest sense as the strategies developed for each commodity have different foci based on the principles of IPM.

g. **Progress to date:** IPM CRSP research conducted in Jamaica focused on addressing the problem of excessive pesticide use on a leafy vegetable. The resulting IPM strategy based on rationalized pesticide use, resistance management, and the use of new, selective, biorational pesticides has been successful on vegetable amaranth. These tactics can be readily adapted to use in cruciferous vegetables.

IPM CRSP research conducted in Jamaica, both in research plots and on-farm demonstrations, showed the potential of the non-chemical management tactic of pest exclusion in vegetable amaranth in the Caribbean. We achieved both pest exclusion and improved crop quality in vegetable amaranth. The development of pest exclusion as a management tactic progressed with the selection of a barrier material that would allow optimal growth. This approach should be easier to adapt to cruciferous crops than vegetable amaranth because crucifers are harvested only once. Published work in the US clearly shows that exclusion with agricultural fabrics and polymers is effective for lepidopteran management in crucifer crops. Horticultural adaptation for Caribbean conditions could provide an effective non-chemical approach to pest management.

Small plot trials continue to demonstrate dramatic increases in management of lepidopterans on vegetable amaranth with new biorational pesticide chemistries (two microbial metabolites - spinosad, and emamectin benzoate; and one insect ecdysone agonist - tebufenozide (Confirm®). We anticipate similar results in cabbage, possibly using the newer ecdysone agonist (Intreprid®). The new biorationals were introduced at the farm level in the latter part of Year 7 and results will be used in conjunction with resistance management techniques (sampling plan and decision making tool) and pesticide rotations. These results were instrumental in working with governmental agencies and industry to help move towards replacement of older, relatively nonselective insecticides with newer, more selective biorational chemicals and microbial metabolites.

Monitoring with pheromone traps has been developed for several lepidopteran pests in Jamaica, and adult trap-catch densities were correlated highly with in-field whole plant searches of immature life stages. Installation of web-GIS software and integration of using that across governmental agencies (RADA and CARDI), has been progressing as part of the gall midge project and can be readily adapted to leafy vegetable systems.

**h.** **Projected outputs:** (1) A system to effect rationalized pesticide use against lepidopterous pests of cabbage. (2) IPM researchers trained in a research approach to IPM system development. (3) An understanding of the natural enemies currently present in lepidopteran pests of cabbage in the Caribbean. (4) Initiation of a regional monitoring effort for lepidopterans.

**i.** **Projected impacts:** The successful development of a crop-scouting program integrated with the use of biorational controls will result in much fewer pesticide applications, which represents a very significant reduction in labor for these growers. This work will result in a gradual transition to biorational pesticide control options, with enhanced farm worker safety and reduced food safety concerns due to pesticide residues, as well as a reduction in pesticides that are targeted by the Food Quality Protection Act in the US. There will also be enhanced efficacy of control because the biorational pesticides have modes-of-action which are new to the pest complex in the Caribbean. The integration of the biorationals with the scouting will delay or prevent the development of pesticide resistance to the new materials.

Our previous efforts represent pioneering work in vegetable IPM in the Caribbean, and because of the polyphagous nature of the lepidopteran complex on callaloo, the technologies have relevance to other leafy vegetable systems in the Caribbean. The classical nature of this IPM model also makes it applicable to other cropping systems with excessive pesticide use.

Lepidopterous pests attacking cabbage and other crucifers in the Caribbean have exhibited symptoms of pesticide resistance, which is widespread globally. Major pests such as the diamond-back moth now cause severe damage to crops because contemporary pesticides fail to prevent attack. The development of an effective pest management strategy that reduces pesticide input in the cropping systems of cabbage and other crucifers of the Caribbean will result in increased income to farmers, safer food and reduced environmental pollution. From the proposed training, IPM researchers in the Caribbean will also have a research model, which they can apply to the development of

IPM for other high-pesticide-input vegetable crops not directly addressed by IPM CRSP activities.

**j.** **Projected start:** Continuation

**k.** **Projected completion:** September 2004

**l.** **Projected person months of Scientist Time per year:** Scientists: 7 months; Technicians: 7 months (CARDI); 2 months (Penn State)

**m.** **Budget:** IPM CRSP: $19,745 – CARDI (includes $4,000 for site coordinator); $2,035 – MINAG Barbados; $3,355 – MINAG Trinidad; $2,220 – USDA; $1,212 – Penn State.

**I.2.** **Integrated Pest Management (IPM) of Major Pests Affecting Sweetpotato in the Caribbean:** This section is divided into six sub-activities, each with an individual budget. The first three activities are budgeted in Year 11, and the last three are funded from carry-over funds. The total Year 11 budget for Activity I.2 is $26,515 with $18,480 for CARDI (includes $4,000 for site coordinator), $6,660 for USDA-ARS Vegetable Lab and $1,375 for regional collaborators. Sweetpotato pest management plans involve resistant varieties and use of biorationals for grub and weevil control, combined with pheromone and cultural practices for weevil control. A new project will assess mulches for weed management in Caribbean varieties. The promising new varieties are continuing to be evaluated across the region for both performance and utilization.

**I.2.a.** **Evaluation of the efficacy of combinations of IPM components to manage insect pests of sweetpotato**

**a.** **Scientists:** K. M. Dalip – CARDI Jamaica; P. Chung – RADA; D. M. Jackson, J. Bohac – USDA-ARS.

**b.** **Overall Objectives:** To use IPM tactics to manage a sweetpotato pest complex, including the sweetpotato weevil, *Cylas formicarius*, sweetpotato leaf beetle, *Typophorus viridicyaneus*, and cucumber beetle, *Diabrotica* spp., in Jamaica in order to reduce attack and damage to the crop. Over the past four years, this activity was geared towards management of sweetpotato leaf beetle (SPLB) but a more holistic approach has been adopted in which the management of other pests, including the sweetpotato weevil (SPW) and cucumber beetles, has also been incorporated. Pest management methodologies include conventional, biorational and botanical insecticides, together with resistant cultivars, cultural practices, biological control and attractant traps. This is in keeping with the overall aim of the project: i.e., IPM of major pests of sweetpotato. The ultimate goal of improving the yield and quality of tubers produced should result in the farmer realizing improved production and earnings, and to increase market competitiveness and trade capacity. **Objectives for coming year:** (1) To determine which combination of tactics is most effective in the management of the SPLB; (2) To refine an IPM package incorporating the management of the SPLB and SPW.

**c.** **Hypotheses:** (1) Biorationals and botanicals are potential management tactics for reducing sweetpotato weevil and sweetpotato leaf beetle larval populations and damage; (2) Host plant tolerance, physical control and cultural measures can be used as components of an IPM program.

**d.** **Description of Research Activity:** As a final experiment of this multi-year evaluation activity, the crop will be grown in two sweetpotato-growing parishes in Jamaica using agronomic practices currently employed by farmers. Treatments will be allocated in a randomized complete block with 3 replicates, 25 plants per treatment. A susceptible cultivar will also be included in the trial for comparison with the resistant varieties. Parameters measured will include pest incidence (pre- and post- treatments) and crown/root damage.

**e.** **Justification:** The first phase of this project focused on the development of IPM technology for the sweetpotato weevil. However, the SPLB emerged as a major pest and continues to be so, particularly in certain parts of the island. Hence, the evaluation of management tactics that include alternatives to conventional synthetic insecticides, such as biorationals, kairomones (floral components) and botanicals, has shown them to be effective against coleopterans on sweetpotato and crops similar to those present in Jamaica. Therefore, these will be evaluated for inclusion in the development of the IPM program for the sweetpotato pest complex.

**f.** **Relationship to other CRSP activities at the site:** Generally, the use of IPM tactics in the management of pests will be further emphasized. The options available to farmers for weevil and grub management will also be increased.

**g.** **Progress to date:** The last trial at Gibraltar, St Ann, was harvested in January, 2003 and the data are currently being collated and analyzed. However, preliminary indications are that imidacloprid and formulated neem insecticide were quite effective in reducing SPLB populations.

**h.** **Projected Outputs:** (1) Improved capability to forecast pest incidence and recommend IPM strategies for the research crops; (2) Increased tactics available for IPM package improving sweetpotato production.

**i.** **Projected Impacts:** At present, the major form of control for the SPLB is chemical. It is expected that the use of environmentally friendly chemicals (botanicals, biorationals) will reduce contamination of the environment and human health hazards and the holistic approach to management of the pest complex will be more economically viable.

**j.** **Projected Start:** Continuing

**k.** **Projected Completion**: September 2004

**l.** **Projected Person-Months of Scientists Time per Year**: 2

**m.** **Budget:** $12,100 – CARDI (includes $4,000 for site coordinator); $3,885 – USDA

**I.2.b. Evaluation of potential USDA and OECS sweetpotato varieties for yield, market acceptance and insect resistance in Antigua and St Kitts & Nevis**

**a.** **Scientists:** D. M. Jackson, J. Bohac – USDA-ARS; J. Ross – CARDI Antigua; J. Gore-Francis – Min of Agric., Antigua; L. Rhodes – CARDI St Kitts/Nevis/ Montserrat; K. M Dalip – CARDI Jamaica

**b.** **Overall Objectives:** To use IPM tactics (e.g., use of resistant plant varieties) to manage sweetpotato pest populations. It is expected that, if this were achieved, then both the quality and quantity of the harvested tubers would be improved, resulting in improved production and earnings for the farmer and, hence, increased competitiveness and trade capacity. **Objectives for coming year:** To introduce new cultivars and evaluate their potential under local growing conditions in Antigua, St Kitts & Nevis.

**c.** **Hypothesis:** Differential tolerance to pest attack exists in sweetpotato breeding lines.

**d.** **Description of Research Activity:** Local sweetpotato cultivars, OECS and USDA cultivars, previously identified as being resistant/tolerant from trials in Jamaica, USA and St Kitts, will be further evaluated for yield and quality under local growing conditions. Insect resistance will be measured by a rating scale developed under the project (weevil – scale of 1 - 5 based on degree of surface and internal damage; leaf beetle larvae – scale of 0 - 4 based on the length of tunneling). Treatments will be allocated in a random complete block design with four replicates with stands of 25 plants.

**e.** **Justification:** Sweetpotato is cultivated in Antigua for both the local and export markets. The main pest that affects the crop quality and yield is the sweetpotato weevil, *Cylas formicarius.* There are several OECS varieties already present in Antigua. In fact, Antiguan varieties have already produced favorable results in trials done in St Kitts. Therefore, the identification of tolerant varieties will be made easier, in addition to which, there is no preference given to one variety over another in the local market.

**f.** **Relationship to other CRSP activities at the site**: Generally, the use of IPM tactics in the management of pests will be encouraged to increase the quantity and quality of yield of the farmers' crop. This research is a part of the regionalization process of the IPM CRSP program and will fall under the regional mission's objectives of being improving competitiveness and trade capacity.

**g.** **Progress to date:** Local, OECS and USDA cultivars have shown promise in terms of yield and resistance traits. This technology can be regionalized by transferring germplasm to other Caribbean countries.

**h.** **Projected Outputs:** (1) Improved cultivars will be adopted in Caribbean countries; (2) Improved sweetpotato germplasm for IPM packages will advance sweetpotato production.

**i.** **Projected Impacts:** The inclusion of acceptable sweetpotato varieties tolerant to multiple pests, will increase the farmer's options when selecting varieties to grow. This, in addition to the other management measures, should lead to enhanced quality and quantity of production without deleterious effects on the environment through pesticide use.

**j.** **Projected Start**: October 2003

**k.** **Projected Completion:** September 2004

**l.** **Projected Person-Months of Scientists Time per Year**: 2

**m.** **Budget:** $1,100 – CARDI Antigua; $275 – CARDI St Kitts/Nevis; $777 – USDA

### I.2.c. Adaptation of organic and plastic mulches in sweetpotato IPM in Jamaica

**a.** **Scientists:** D. M. Jackson, J. Bohac – USDA-ARS; R. Thomas – Private Farmer; K. M. Dalip – CARDI

**b.** **Overall Objectives:** To transfer technology and adapt the use of organic (such as a leguminous cover crop) and biodegradable plastic mulches as alternatives to synthetic herbicide use in an IPM program. Weeds, which are a major pest of sweetpotato, are often neglected in IPM. **Objectives for coming year**: (1) To adapt technology and determine the effectiveness of organic and biodegradable plastic mulches in the management of weeds in sweetpotato IPM; (2) To compare the effectiveness of a synthetic herbicide to that of the mulches in the management of weeds.

**c.** **Hypothesis:** Using technology developed from USA models, sweetpotato can be cultivated under organic mulch and plastic mulch under tropical conditions.

**d.** **Description of Research Activity:** The crop will be grown in one sweetpotato-growing parish using agronomic practices currently employed by farmers, such as fertilization and irrigation practices. Treatments – (i) two sweetpotato varieties (Fire-on-Land and Quarter Million) commonly cultivated in the parish, and (ii) use of no ground cover, an organic (cowpea) and inorganic (plastic) mulches - will be allocated in a split-plot randomized complete block design with 3 replicates, 25 plants per treatment. Parameters measured will include: insect pest incidence, crown/root damage, sweetpotato yield and weed evaluations, using established evaluation techniques.

**e.** **Justification:** The management of weeds is an important aspect of pest management in sweetpotato cultivation, especially in the first 10 weeks after planting. The use of organic mulches in sweetpotato production systems has the potential to benefit the crop much more than the suppression of weeds. Organic mulches serve to also retain soil moisture, reduce soil erosion, enhance soil fertility (through use of leguminous organic mulch) and promote the growth of beneficial soil microorganisms. Biodegradable plastic mulches also have some of these benefits in common [such as retaining soil moisture, reducing soil erosion, enhancing soil fertility (through use of leguminous organic mulch) and promoting the growth of beneficial soil microorganisms]. Hence, the inclusion of organic and biodegradable plastic mulches in an IPM program is justifiable. The use of pest-resistant cultivars in these experiments is justified because it will help ameliorate the potential disadvantage of increased pest and disease organisms in organic mulch systems.

f. **Relationship to other CRSP activities at the site**: This work complements efforts on sweetpotato outlined in I.2.a above. The EEP report highlighted a need for increased efforts on weed management, which was in the Caribbean workplan until Year 7 when a reduced budget forced its elimination. This activity also addresses a local mission interest in organic agriculture.

g. **Progress to date:** N/A

h. **Projected Outputs:** Identification of another pest management tactic for inclusion in a sweetpotato IPM program, and baseline data for the next phase of the project.

i. **Projected Impacts:** The inclusion of organic and biodegradable plastic mulches for sweetpotato will provide the farmer with viable alternatives to chemical weed management and should result in reduced contamination of the environment and improved quality and quantity of production.

j. **Projected Start:** September 2003

k. **Projected Completion:** September 2004

l. **Projected Person-Months of Scientists Time per Year:** 4.5

m. **Budget:** $6,380 – CARDI; $1,998 – USDA

**I.2.d. Development of value-added products from sweetpotato**

a. **Scientists:** D. M. Jackson, J. Bohac – USDA-ARS; K. M. Dalip – CARDI Jamaica; L. Rhodes – CARDI St Kitts/Nevis/Montserrat; others from Dept of Agric. (Nevis) and Min. of Agric. (St Kitts)

b. **Overall Objective:** To produce value-added products and diversify regional use of sweetpotato, which will improve local economics, trade and human health. **Objective for coming year**: To asses the feasibility of using non-export quality sweetpotato tubers for the production of value-added items.

c. **Hypotheses:** (1) Local and introduced sweetpotato cultivars have the characteristics necessary for the production of value-added products; (2) Different sweetpotato varieties are suitable for making cooked/baked dishes.

d. **Description of Research:** The screening of different sweetpotato cultivars for desirable culinary traits, which began in Year 10, will continue. Selected cultivars will have characteristics suited for processing to make different products, namely chips, flour, pancake mixes and puddings.

e. **Justification:** There is a growing interest in the development of value-added products and a realization of the great adaptability of sweetpotato to a variety of preparations and uses. Hence, the decline in sweetpotato cultivation seen in past years may be reversed and start to grow once more.

f. **Relationship to other CRSP activities at the site:** The transfer of the IPM technology will be encouraged and the use of roots for purposes other than for sale to the fresh market will further encourage the farmers to cultivate the crop in accordance with recommended IPM practices.

g. **Progress to date:** Identification of suitable cultivars has started, and recipe collections were completed in Year 10.

h. **Projected Outputs:** Sweetpotato cultivars identified for processing purposes. Sweetpotato recipe book will be published and enhance sweetpotato use.

i. **Projected Impacts**: The inclusion of sweetpotato cultivars that may not be suitable for the fresh produce market but may be suitable for processing will increase the farmer's choice of available cultivars that he can grow. This should result in a diversification of the market targeted and provide less competition for the same market among the farmers.

j. **Projected Start:** Continuation

k. **Projected Completion:** September 2004

l. **Projected Person-Months of Scientists Time per Year:** 3

m. **Budget**: $1,210 – St. Kitts and Nevis (carryover funds)

**I.2.e. Assessment of IPM technology in reducing damage to sweetpotato due to *Euscepes postfasciatus* in St Vincent and the Grenadines**

a. **Scientists:** D. M. Jackson – USDA-ARS; P.Titus – CARDI, St Vincent and the Grenadines; S. Edwards – Min. Agric., St Vincent and the Grenadines; K. M. Dalip – CARDI Jamaica

b. **Overall Objective:** To use IPM tactics to manage sweetpotato pest populations, particularly West Indies sweetpotato weevil *E. postfasciatus*, in order to reduce damage to the crop.

c. **Objective for coming year:** To evaluate the potential of different cultural practices in the reduction of weevil and grub damage to sweetpotato.

d. **Hypotheses**: Cultural practices will be effective against the West Indies sweetpotato weevil.

e. **Description of Research Diffusion Activity:** The sweetpotato weevil IPM technology developed in Jamaica will be evaluated in a small pilot test consisting of three farms using the best IPM practices and three farms using traditional production techniques. At harvest, the effect of the introduced technology on *E. postfasciatus* populations, root damage and improvement in marketable yields will be measured.

f. **Justification:** Sweetpotato is grown in St Vincent on small farms for the local and export markets. However, damage to roots caused by tuber-feeding pests accounts for crop losses estimated at 20 - 50%, thus limiting the production of the crop. The focus of the IPM technology in the earlier years of the program in Jamaica was on the management of the sweetpotato weevil, *Cylas formicarius*, a major component of which is the use of pheromone traps. Fortunately, the biology of the two weevils is similar so the investigation of recommended cultural practices will, therefore, provide the foundation on which the IPM technology should be built.

g. **Relationship to other CRSP activities at the site:** The use of IPM tactics in the management of this major pest will provide farmers with viable options available for the management of the WI sweetpotato weevil, whereas before they would not have been aware of these options. This is a step toward improvement of competitiveness and trade capacity.

h. **Progress to date:** Trials were planned for Year 10, but have not yet been started.

i. **Projected Output:** Identification of tactics available for IPM package to improve sweetpotato production.

j. **Projected Impacts:** The identification of suitable and complementary cultural practices will provide the farmer with alternatives to management of sweetpotato pests and should, ultimately, result in enhanced quality and quantity of production.

k. **Projected Start:** Continuation from Year 10

l. **Projected Completion:** September 2004

m. **Projected Person-Months of Scientists Time per Year**: 2.5

**n.** **Budget:** $4,598 – CARDI – St. Vincent/Grenadines (carryover funds)

**I.2.f. Follow-up reassessment of IPM systems on the yield and quality of sweetpotato production (Jamaica)**

**a.** **Scientists**: D. M. Jackson – USDA-ARS; J. Momsen – U. Calif. Davis; P. Chung – RADA; K. M. Dalip – CARDI Jamaica

**b.** **Overall Objective:** To assess adoption and effectiveness of sweetpotato IPM technologies developed and implemented under IPM CRSP. **Objectives for the coming year:** (1) To determine if farmers have been using the IPM technology; (2) To determine if the technology has been effective in reducing damage and/or increasing yield.

**c.** **Hypothesis:** Farmers have adopted IPM technology in the management of sweetpotato pests.

**d.** **Description of Research Activity:** Surveys will be conducted in parishes/areas where training of farmers and extension officers were carried out to determine the level of adoption of the IPM technology. This will include a "post-project" survey of growers' practices and attitudes. Assessments of yields will also be carried out on selected sweetpotato farms to determine the extent of crop loss to the weevil and grub in order to compare to figures obtained earlier in the project. The marketing of the tubers will also be assessed to determine if there have been any modifications in marketing practices.

**e.** **Justification:** The reassessment of sweetpotato production systems in Jamaica is necessary to determine the effectiveness and impact of IPM technologies developed under this project. Socioeconomic and technological factors associated with adoption or non-adoption of IPM technologies need to be assessed through farmer surveys. The survey will help us identify and overcome obstacles in the implementation and acceptance of these technologies.

**f.** **Relationship to other CRSP activities at the site:** This survey will produce an overview of the success of sweetpotato IPM technologies developed under this project.

**g.** **Progress to date:** Questionnaire is being finalized. However, this activity will need to be extended to Year 11 without additional funding.

**h.** **Projected Output:** Quantitative evaluation of impact and acceptance of sweetpotato IPM.

**i.** **Projected Impacts:** Strengths and weaknesses of sweetpotato IPM technologies developed under this project will be identified and assessed so that suitable IPM technologies can be institutionalized in sustainable sweetpotato production systems in the Caribbean.

**j.** **Projected Start**: Continuing

**k.** **Projected Completion:** September 2004

**l.** **Projected Person-Months of Scientists Time per Year:** 2

**m.** **Budget:** Carryover from Year 10

**I.3.** **Assessment of Virus Incidence in Superior Caribbean Sweetpotato Varieties**

**a.** **Scientists:** K. M. Dalip – CARDI; D. M. Jackson, J. Bohac – USDA-ARS; S. Tolin – Virginia Tech

**b.** **Overall Objective**: Consistent with development of sweetpotato IPM, new varieties with excellent resistance to insects have been identified among varieties grown locally in Jamaica. The objective of this activity is to assess the status of these varieties relative to virus infection, and to eliminate those viruses decreasing sweetpotato performance from the germplasm. **Objective for coming year**: Determine the status of Jamaican sweetpotato varieties relative to natural infection from common sweetpotato viruses, using available technology from U.S. and international (CIP) testing programs.

**c.** **Hypotheses:** (1) Local varieties are likely to carry a background of common sweetpotato viruses, most likely sweetpotato feathery mottle virus, and are causing unrecognized yield losses or changes in reactivity with other organisms. (2) Viruses may be eliminated from varieties and improve their yield and productivity.

**d.** **Description of research activity:** Information will be collected on the availability of rapid virus identification tests for the common sweetpotato viruses. We will purchase antiserum or virus-testing kits, and train CARDI researchers in methodologies of sampling and testing for viruses. Specifically, we will test the varieties that have been shown to perform well and resist major insect pests. Jamaican varieties that may be included, based on their resistance to insect pests are: Sidges, Fire-on-Land and Quarter Million.

Observations will be made of sweetpotato performance (both of foliage and roots, since sweetpotato roots can also show symptoms of some of these viruses) and symptoms associated with the main viruses that are detected. The need for a virus detection program in the propagation of sweetpotato mother plants will be assessed and whether selection of plants free of damaging viruses for distribution to farmers will increase sustainability.

**e.** **Background/Justification:** Worldwide, viruses have been shown to have effects on the yield and productivity of sweetpotato. Major viruses include sweetpotato feathery mottle virus strains. There is currently no knowledge of the virus status of the local Jamaican varieties. Although no viruses have been recognized as being present and yields of sweetpotato have decreased, foliar symptoms have been observed in several fields.

f. **Relationship to other CRSP activities at the site:** Sweetpotato has been a crop examined in the IPM CRSP since the beginning of the project. IPM strategies have been developed and implemented for sweetpotato weevil and soil grubs. Superior varieties have been identified. Elimination of viruses from these varieties will complement this activity.

g. **Progress to date:** A few sweetpotato varieties grown in Jamaica have been identified from past varietal trials as having desirable insect resistant and/or yield characteristics. Cuttings of some varieties were sent to the USDA Plant Introduction Station for testing viruses of quarantine significance for the USA.

h. **Projected output:** Information on the incidence of sweetpotato viruses in Jamaican varieties and their impact on yield.

i. **Projected impacts:** An incremental improvement in yield of sweetpotato varieties well adapted to the region. An understanding as to whether presence of virus influences attack/damage by other pests.

j. **Projected start:** September 2001

k. **Projected completion:** September 2004

l. **Projected person-months of scientists time per year:** 2

m. **Budget:** $ 5,108 Carryover funds - Virginia Tech

**I.4 – I.8. Hot Pepper IPM Projects:** Hot peppers can be grown sustainably and profitably for the export market as fresh produce, and have a lesser value in processed form. Major constraints include viruses (addressed in I.4 and I.5), broad mites (addressed in I.6), and the gall midge complex (addressed in I.7 and I.8). Reduced production and productivity of hot peppers due to virus problems have been partially managed through introduction of the virus-tolerant West Indies Red variety to supplement the highly susceptible, but preferred, Scotch Bonnet variety, but new strains may be overcoming this tolerance. Management plans to avoid high losses due to early infection of plants have been devised from knowledge of aphid vector activity, and will be tested (I.4). A biotechnology project included first in the Year 9 workplan (I.5) will focus on virus diversity and new resistance strategies. Heavy insecticide use in attempts to control virus has increased problems with broad mites, necessitating studies on new approaches to their management (I.6). Since the gall midge complex has been declared a "quarantine pest" by the United States, hot peppers have been removed from the pre-clearance list and fumigation is required. Conditions conducive to gall midge have been identified through surveys and GIS analysis, areas of low-pest risk are more predictable, and a traceability system is in place through the mission-funded work under I.7. Emphasis is now being placed on these pests, including continuation of a regional web/GIS monitoring program. Negotiations are under way to define conditions whereby hot pepper may again be shipped to the USA without methyl bromide fumigation. Molecular probes to accurately diagnose these tiny pests are funded under biotechnology (I.8).

## I.4. Integrated Pest Management (IPM) of Viruses Affecting Hot Pepper (Scotch Bonnet and West Indian Varieties)

a. **Scientists:** D. Clarke-Harris**,** K. Dalip – CARDI; T. Williamson, J. Goldsmith – MINAG; P. Chung – RADA; W. McLaughlin – U.W.I.; S. Tolin – Virginia Tech; C. Edwards – OSU

b. **Objectives:** (1) Determine the relative efficiencies of *Aphis gossypii, A. amaranthi* and *Uroleucon ambrosia* in transmitting TEV and PVY to pepper; (2) Evaluate the efficiencies of various methods of weed management in managing TEV (and PVY); (3) Validate a risk management model for reducing TEV (and PVY) in hot pepper in the Bushy Park/Bodles areas of St. Catherine; (4) Develop a multi-pest integrated pest management system for hot peppers.

c. **Hypotheses:** (1) *A. gossypii, A. amaranthi* and *U. ambrosiae* are all efficient in transmitting TEV and PVY from pepper to pepper; (2) Effective weed management can significantly reduce the build up of TEV (and PVY) inoculum and/or their aphid vectors thereby reducing the spread of these viruses to hot pepper; (3) Farmers can reduce and delay the spread of TEV (and PVY) in hot pepper by employing various combinations of risk reducing tactics in an integrated management program.

d. **Description of Research Activities:**

**(1) Vector efficiencies of three selected aphid species.** *A. gossypii, A. amaranthi* and *U. ambrosiae* are the most common aphid species collected in pan traps from hot pepper farms. The former is a known vector of TEV but while the latter two have not been tested for their ability to transmit TEV, their presence has been associated with the incidence of the virus. The aphids will be reared on pepper, callaloo and whitetop, respectively. Non-viruliferous aphids will be allowed to make short acquisition probes (15-60 seconds) on virus infected pepper plants before being transferred to uninfected pepper plants. Transferred aphids will be allowed to remain on these uninfected plants for 24 hours after which they will be killed. Inoculated plants will be assessed for symptom development and the virus will be confirmed serologically.

**(2) Weed and aphid management to manage viruses.** Weeds are a major constraint in hot pepper production. The lack of expertise in weed management in the Caribbean region has been a major impediment to the development of technology in this discipline. One weed in particular hosts an aphid whose population was correlated with increased infection of Scotch Bonnet peppers with TEV. Replicated field experiments will be initiated to evaluate efficacy and cost effectiveness of a chemical herbicide, manual weeding, organic mulches, vermicomposts, and managed ground cover. Treatments will be allocated in a randomized complete block design with four blocks, four treatments and 50 plants per treatment (n = 800). Blocks will be separated by corn barriers. Parameters measured will include percentage virus incidence, aphid abundance, yield and quality of fruit, and cost of production. Virus incidence will be measured fortnightly throughout the course of the experiment. Aphid abundance will be measured with yellow sticky traps or water traps. Yield data (total and marketable fresh weight of fruit) will be measured from the innermost row of pepper plants as well as the entire treatment unit over five to eight weekly harvests. Appropriateness of low input applicators will be evaluated.

**(3) Establishing risk indices for various components of a model for managing aphid-borne pepper viruses.** As part of her dissertation, one of our graduate students proposed a risk management model for reducing the incidence and impact of TEV (and PVY) in hot pepper. The relative risk-reducing indices were subjective and need to be determined scientifically. The proposed model was a modification of that developed for management of tomato spotted wilt virus (TSWV) in peanuts in Georgia (Brown *et al* 2001). The tomato spotted wilt virus risk index has proven successful in Georgia where farmers have adopted it. A risk management model for TEV holds promises for Jamaica where production of the preferred, Scotch Bonnet, variety is severely limited by the virus.

Model components for reducing risks of TEV and (PVY) infections include application of stylet oil, reflective mulch, straw mulch, barrier crops, weed management, removal of old crops and other vector/virus sources, and modification of planting dates. It was proposed that risk indices would be developed in year 9 for model that include application of stylet oil, reflective mulch, straw mulch, and combinations of stylet oil and aluminum and straw mulches. This experiment was deferred to year 10, but excessive rainfall and flooding interfered with the tests, now being proposed for year 11. Six treatments will be allocated in a randomized complete block design with three blocks and 40 plants per treatment (n = 720). The control will lack use of oil and mulch. The experiment will be conducted during September-February to account for the period of high aphid abundance and during June to November to account for low aphid abundance during the early growth phase of the crops. Parameters to be measured will include aphid abundance, virus incidence, broad mite incidence, fruit yield and quality, cost of production.

**e.** **Justification/Background:** Virus infection is so prevalent in hot peppers that the farmers consider it normal. The newly introduced West Indian Red variety has some tolerance since infected plants grow vigorously and yield prolifically. However, Scotch Bonnet remains the preferred variety because of its superior flavor and the higher price it commands on both export and domestic markets. Its production continues to be diminished by virus. Variety resistance to specific viruses must be a long-range goal that should be initiated. The current activities suggest a management plan can be devised so the Scotch Bonnet variety can be grown sustainably.

**f.** **Relationship to other CRSP activities at the site:** Hot peppers have three major pest problems in Jamaica: virus attack, gall midge and broad mite. We have IPM components in place for all three problems. We now plan an integrated IPM protocol to cover all three pests. The activities conducted will assist greatly in improving the options available to farmers and in addition assist with the regionalization of the IPM CRSP in hot peppers.

**g.** **Progress to date:** Basic information on the effect of viruses on yield and seasonal incidence of the major pests affecting hot pepper production in three major producing areas has been determined. Experiments have shown that early TEV infection of Scotch Bonnet pepper causes significant losses in yield. Sampling aphids in pepper fields in Bushy Park and Bodles, St. Catherine, for almost two years has shown that peak aphid flights begin during September, shortly after pepper seedlings are transplanted (that is, during stage of greatest yield loss, if infected). Over 30 species of aphids have been collected from within Bushy Park and Bodles, five of which are known vectors of TEV. Twelve species were previously unidentified in Jamaica. Two were associated with increased virus infection times. TEV within field spread occurs by secondary means. Stylet oil and aluminum mulch together have been effective in delaying the spread of viruses in the field under heavy virus pressure. Weekly application of stylet oil to manage TEV appeared to also have reduced broad mite incidence in treated plots.

**h.** **Projected outputs:** (1) Determination of TEV transmission efficiencies of the three most common aphid species found on pepper farms; (2) Identification of a cost effective weed management program for pepper farmers; (3) Establishment of risk indices for various components of a model for managing aphid-borne pepper viruses; (4) Extension and farmers trained in IPM technology and training materials, (5) Journal publications and reports.

**i.** **Projected impacts:** Increased number of options will be made available to farmers cultivating hot peppers in Jamaica in spite of high virus pressure. This will ultimately lead to an improvement in the quality of hot peppers. For TEV, a farmer can use the risk analysis process to determine the best time and method to plant to minimize the chance of early virus infection of peppers and increase profits at minimal management costs. An integrated management program will be developed for management of TEV, PVY, and broad mite simultaneously using stylet oil and other components. Hot peppers are valuable export commodities.

**j.** **Projected start:** Continuation

**k.** **Projected completion:** September 2004

**l.** **Projected person-months of scientist time per year:** U.S. Scientist -2 months; Jamaican Scientist - 4 months

**m.** **Budget:** $ 6,600 - CARDI (includes $2,200 for site coordinator); $18,440 - Virginia Tech (carryover)

## I.5. Biotechnology: Characterization of Potyviruses in Caribbean Hot Peppers and Management through Resistance

**a. Scientists:** S. Tolin – Virginia Tech; W. McLaughlin – U.W.I.; D. McGlashan – MINAG; P. Chung – RADA; D. Clarke-Harris, K. Dalip – CARDI

**b. Objectives:** (1) Characterize Jamaican isolates of tobacco etch virus (TEV) and other potyviruses from selected hot pepper fields; (2) Develop alternate strategies for management of virus diseases in hot pepper, such as induced systemic resistance or resistance developed through breeding and genetic engineering.

**c. Hypotheses:** (1) TEV in Jamaican hot peppers are identical to previously described and sequenced type isolates of TEV; (2) Hot peppers with greater resistance to TEV can be developed.

**d. Description of Research Activities**

**(1) Characterization of Virus Complex:** In order to validate the virus and vector management work, it is appropriate to confirm the identity and examine molecular diversity of the Jamaican isolates from the "type" strains of potyviruses. Virus-infected hot peppers will be collected from the location of previous test sites in Kingston (CARDI, Mona), St. Catherine (Bushy Park and Bodles), and St. Mary parishes in an attempt to collect representative isolates of TEV and PVY, as detected by serological methods. Viruses will be cultured in hot peppers or tobacco in Jamaica. Molecular biology methods, including RT-PCR and nucleotide sequencing, will be used to examine coat protein and 3' untranslated regions which are known to be important in virus classification and demonstration of diversity. Sequencing will be performed at UWI or Virginia Tech, and analyses done by standard methods.

**(2) Biotechnology-enhanced development of virus resistance:**
(a) Genetic resistance*:* MINAG scientists have an on-going program to select for virus resistance from crosses of Scotch Bonnet pepper with other peppers known to have resistance to TEV. Training in virus identification, and assessment methods will be given by Virginia Tech on a short-term basis in this area. The use of molecular marker-assisted selection and quantitation of virus to define phenotypes will be explored to enhance the process.
(b) Pathogen-derived resistance*:* In this process, a portion of the viral genome is engineered into the pepper genome, providing a nucleic-acid-based resistance. We will begin the first steps of this process, namely developing candidate sequences of the virus for insertion and establishing a tissue culture protocol for plant regeneration that is a prerequisite for genetic engineering. As no work to date had been done on regeneration for Scotch Bonnet peppers, methodology for closely related plants such as bell pepper (*Capsicum annum)* will be utilized initially to see if it is applicable to *Capsicum chinense* cv. Scotch Bonnet. There are reports in the literature of successful regeneration of bell peppers showing shoot formation from rooted hypocotyls, and even regeneration following wounding at specific sites.

(c) Induced systemic resistance. In initial experiments at U.W.I., six indigenous bacteria isolated from pepper rhizosphere and a *Pseudomonas putida* strain were evaluated for their ability to promote growth and induce resistance to potyvirus (likely either TEV or PVY) in pepper cv. Scotch Bonnet. In our screening experiments growth parameters evaluated were stem length and shoot dry weight up to 8 wk in a plant growth chamber with diurnal conditions set at 16 h light, 8 h dark at 28°C and 24°C, respectively. Two isolates, *P. putida* and *Bacillus* sp. (UWI-3) significantly increased stem length by 57% and 30%, respectively ($p>0.05$). Four isolates, *P. putida*, *Serratia marcescens* (UWI-2), *Bacillus* sp. (UWI-3), and an uncharacterized isolate (UWI-5) increased shoot dry weight by 46%, 17%, 77%, and 79%, respectively ($p>0.05$). Plants inoculated (bacterized) with *P. putida* and *Bacillus* sp. (UWI-3) were more tolerant to potyvirus infection than non-bacterized plants. Bacterized plants had delayed symptom development and greater plant growth compared to the non-bacterized and potyvirus inoculated control plants. Work will be continued on this effort using characterized isolates of TEV and PVY, and will be related to previous plant nutrition experiments.

**e.** **Justification:** Virus infection is so prevalent in hot peppers that the farmers consider it normal. The newly introduced West Indian Red variety has shown some tolerance since infected plants grew vigorously and yielded prolifically in the first few years of culture. However, Scotch Bonnet remains the preferred variety because of its superior flavor and the higher price it commands on both export and domestic markets. Its production continues to be diminished by virus. The West Indian Red seems to be affected by virus more in some areas. Variety resistance to specific viruses must be a long-range goal that should be initiated. This activity was proposed in Year 9 and Year 10 as a global or biotechnology activity.

**f.** **Relationship to other CRSP activities at the site:** Hot peppers have three major pest problems in Jamaica: virus attack, gall midge and broad mite. We have IPM components in place for all three problems. We now plan an integrated IPM protocol for all three pests. We, however, need molecular characterization of the viruses, and new approaches to developing resistance in order to complete the work. It is also our intent to work closely with virologists in the Central American site of the IPM CRSP, who have expertise in whitefly-transmitted geminiviruses (J. Brown, Arizona) and tobamoviruses (M. Deom, Georgia). The Caribbean site will focus on the aphid-transmitted potyviruses and will share isolates and diagnostic techniques with this site.

**g.** **Progress to Date:** Obtaining molecular information on the Jamaican pepper viruses has been in the workplan since Year 9, but lack of funding has precluded initiation of this objective. Basic information on the effect of viruses on yield and seasonal incidence of the major pests affecting hot pepper production in three major producing areas has been determined. Experiments have shown that early TEV infection of Scotch Bonnet pepper causes significant losses in yield.

**h.** **Relationship to other IPM CRSP activities at the site:** The activities conducted will assist greatly in improving the options available to farmers and, in addition, will assist with the regionalization of the IPM CRSP in hot peppers.

**i.** **Expected Outputs:** (1) Molecular characterization data from Jamaican isolates of TEV and other potyviruses. (2) Improved resistance of hot peppers to viruses; (3) Journal publications and reports; (4) Graduate students trained; (5) Sabbatical training of a Jamaican scientist.

**j.** **Projected Impacts:** Increased number of options will be made available to farmers cultivating hot peppers in Jamaica in spite of high virus pressure. This will ultimately lead to an improvement in the quality of hot peppers. For TEV, a farmer can use the risk analysis process to determine the best time and method to plant to minimize chance of early virus infection of peppers and increase profits at minimal management costs. In addition, characterization of TEV strains will validate the virus management program scientifically, and will provide specific virus isolates for breeders and molecular biologists for developing virus-resistant Scotch Bonnet peppers.

**k.** **Projected Start:** Continuation

**l.** **Projected Date of Completion:** September 2004

**m.** **Projected Person-Months of scientist time per year:** 10

**n.** **Budget:** $2,750 – MINAG Jamaica; $8,800 – UWI; $28,444 - Virginia Tech

### I.6. Factors Affecting Broad Mite Incidence on Hot Peppers; Effects of Biorational Pesticides and Moisture on Mite and Predator Populations, and Damage and Pesticide-Use Threshold Development

**a.** **Scientists:** C. Edwards, M. Schroeder (Graduate Student), OSU; D. Clarke-Harris, K. M. Dalip – CARDI; D. McGlashan, J.Goldsmith – MINAG; S. Tolin – Virginia Tech

**b.** **Overall Objectives:** (1) To continue studies on the relative incidence of broad mite and its predators in sprayed and unsprayed farm fields during both dry and wet weather seasons; (2) To finalize the identification and use of those biorational pesticides that are least toxic to natural enemies of broad mites. **Specific Objectives:** (1) To test pesticide-use thresholds for the use of acaricides to control broad mites, using damage ratings, to assess the validity attack level methods developed in Year 10; (2) To test the use of the biorational insecticides, abamectin and hexathiazox, which gave good results in Year 10, in a second season and to test other biorationals and low environmental impact acaricides, for their effects on broad mites and natural enemy populations (also on aphid populations); (3) To develop peer-reviewed and extension publications on broad mite management.

**c.** **Hypotheses:** (1) Heavy attacks by broad mite in recent years are due to the suppression of natural enemies (especially predatory mites) by acaricides and insecticides; (2) Biorational acaricides with a narrow spectrum of activity will minimize damage to natural enemies and control broad mites better and with fewer treatments; (3) The use of a rating-based assessment of damage criteria will facilitate the adoption of pesticide threshold population levels and minimize pesticide use.

**d.** **Description of Research Activities:**

**(1) Confirmation of effects of selected biorational pesticides on populations of broad mites and their natural enemies**. The biorational pesticides, which were most effective in Year 10, i.e. abamectin, hexathiazox and neem, will be tested again in a field experiment for their effects on broad mites and predators. Additionally, the effects of stylet oil (which is useful for control of aphid transmission of TEV to hot peppers) will be included as a treatment. Plot size design and layout will be as in Year 10. The weekly sampling pattern used in Year 10 will be changed to sampling every two weeks with double the numbers of samples (20 plants) used in Year 10 on each sampling date. This will make statistical differences between the experimental treatments easier to distinguish. This experiment, together with threshold damage for pesticide use studies, will enable us to finalize a broad mite IPM management protocol to be used in an overall hot pepper IPM program. To achieve this aim, changes in aphid populations in response to the pesticide treatments will also be assessed.

**(2) Utilization of thresholds for the timing of control measures for broad mite**. Incidence studies on broad mites in Year 10 demonstrated clearly that the incidence of broad mite was linked strongly to periods of rain and moist conditions. We need to link the size of early broad mite populations with the development of damage symptoms through the growing season to confirm the effectiveness of pesticide use threshold levels developed in Year 10, taking into account weather predictions. We will study the development of broad mite populations in ten fields, by sampling leaves from the upper, middle and lower parts of ten plants and washing mites and predators from them in the laboratory. Sampling will be at 2 monthly intervals. The progressive development of lesions and other symptoms of attack will be followed by scouting plants on the same sampling dates. Data on mite populations and damage will be correlated. The way in which lesions are caused by mites will be studied as a thesis project.

**(3) Farm surveys on the incidence of broad mites and their predators.** In Year 10 only five farms with heavy pesticide use and five using no pesticides were surveyed for incidence of broad mites and its predators. The reason for this was a shortage of farmers who were not spraying pesticides. For Year 11 we have identified 10 farmers who will not spray and 10 farmers with heavy pesticide use. Populations of broad mites and predators on 10 plants (top, middle and bottom leaves) will be sampled four times in the year and extracted in the laboratory to follow changes in populations in the wet and dry seasons that were indicated in Year 10.

**e.** **Justification:** These complementary research activities will investigate those factors that are responsible for large broad mite populations, the major natural enemies of the pest, and means of controlling broad mites with minimum effects on natural enemies as components of an IPM strategy.

**f.** **Relationship to other IPM CRSP activities at the site:** Hot peppers have three major pest problems in Jamaica: virus attacks, gall midge and broad mite. We have good IPM components in place for all three pest problems. We now plan to develop an integrated IPM protocol to cover all three pests. As an example, if broad mites were controlled by the same management tactic as aphids, aphid management for virus control would also contribute to broad mite management, as would the direct effects of broad mite biorational pesticides on aphid populations. Hence, all of the hot pepper IPM will be integrated into an overall program in Year 11.

**g.** **Progress to date:** In Years 9 and 10 we demonstrated that those farmers that used the most pesticides had the highest infections of broad mite and we plan to assess that this pattern is continuing in Year 11. This defined a need for identification of pesticides that are effective in broad mite control and have the east effects on populations of the natural enemies of broad mite. It also demonstrates a need for farmer education on the timing of pesticides and other IPM measures which may be needed.

**h.** **Projected outputs:** A strategy for the IPM management of broad mite will be developed, as part of an overall IPM program for hot peppers. Broad mite can cause total losses of hot pepper crops; hence reduction of losses from broad mite attacks will have large positive economic impacts on farmers.

**i.** **Projected Impacts:** Hot peppers are valuable export commodities. Broad mite can cause total looses of hot pepper crops; hence the economic impacts of broad mite attacks on farmers are large. Management of this serious pest would increase overall yields.

**j.** **Projected Start:** This work was started in Year 9.

**k.** **Projected Completion:** The overall aim is to develop an integrated management program for broad mites by 2004 (Year 11). This will be incorporated into an overall IPM program for hot peppers

**l.** **Projected person months of scientist time:** U.S. Scientist – 3 weeks; U.S. Student – 1 month (identifications); Jamaican Scientist/Technician – 4 months

**m.** **Budget:** $2,200 – CARDI (for site coordinator); $7,700 – MINAG Jamaica; $8,012 – OSU

**I.7.** **An IPM Strategy to Combat the Gall Midge Complex Affecting Hot Pepper:** The goal of this activity is to address fundamental issues surrounding the emergence of new pests, the gall midges (*Contarina lycopersci* and *Prodiplosis longifilia),* and their impact on the hot pepper export market. It is a Technical Assistance/Mission project and supports the Gall Midge Taskforce.

**a.** **Scientists:** D. Clarke-Harris – CARDI, Jamaica; C. Thomas – MINAG; P. Chung, J. Lawrence – RADA; D. Geoghagen – Food Storage and Prevention of Infestation

Division, Agri-Business Council, USDA/APHIS; S. Tolin – Virginia Tech; S. Fleischer – Pennsylvania State Univ.; D. M. Jackson – USDA.

**b.** **Objectives:** The activities are outlined under six major components: (1) Determine the biology and taxonomy, behavior and ecology of the gall midge complex; (2) Develop an Integrated Pest Management strategy; (3) Improve post-harvest technology and its application in export fruits; (4) Transfer IPM technologies to farmers and extension officers; (5) Make the public aware of the importance of the gall midge complex; (6) Monitor and analyze the introduced IPM technologies.

**c.** **Hypotheses:** (1) An IPM strategy for management of the gall midge complex can be developed; (2) Hot peppers can be returned to the preclearance list for export products, through application of IPM, farmer and public education, and quarantine risk analyses.

**d.** **Description of Research Activities:**

**(1) Biology, behavior and ecology of the gall midge complex:** Information will be gathered on the life stages of the insects that result in damage to plant parts, and conditions conducive for survival and replication. Gaps exist in information regarding duration of life stages and mode of reproduction, i.e. oviposition vs. larviposition. The infestation patterns of the pest in relation to crop phenology, variety, agroecology (temperature, rainfall, humidity), and cropping systems will be investigated. Farms representing various cropping systems within major pepper growing areas will be monitored for adults and larval infestations within fruits. The precise taxonomy of the midges will be determined, since the difference between the species quarantined by the U.S., *Contarina lycopersci*, and that found in the U.S., *Prodiplosis longifilia*, is very little. Contact will be made with quarantine officials to assess these data and the risks associated with introduction of the midges into the U. S.

**(2) Development of an IPM strategy:** This component will seek to identify and evaluate potential chemical, cultural and biological approaches, and evaluate which can be combined into a cohesive strategy for the long-term reduction of gall midge infestation levels. Trials will be established which compare cultural practices (stripping, pruning, removal of crop residues) in combination with various chemical insecticides ($\lambda$-cyhalothrin, malathion, diazinon, imidacloprid, fipronyl, neem formulation) to reduce midge populations and fruit damage. Persistence of chemical pesticides on various plant parts and soil will also be determined. A spray application guide will be developed for farmers, based on adult population levels and/or fruit infestation levels. Populations will be monitored with sticky traps and levels compared to fruit infestation levels in order to develop action thresholds and the most efficacious chemicals. Biological strategies for pest management will be initiated and will begin by surveys to identify natural endemic enemies, and to explore techniques to augment their incidence and suppression of gall midge populations. Commercial microbial entomopathogenic bacteria and fungi will be tested initially in the laboratory, and promising candidates will be field-tested. As information on IPM tactics is generated, data will be analyzed and the Best Management Practices identified and evaluated on farms in a continuous process.

**(3) Post Harvest Technology:** Research on the most effective and environmentally sound fumigation methods will be conducted, mainly comparison of methyl bromide with less toxic fumigants such as magnesium phosphide (Magtoxin®), which is registered in the U.S. Data to be collected include larval mortality, persistence of the fumigant on fruit, and emission of the fumigant into the atmosphere, as well as effects on various pepper varieties, fruit maturity and various storage conditions. A procedural module on proper post harvest management practices will be included in a handbook for farmers and exporters. Present methods for harvesting peppers result in destruction of fruit stalks and damage of fruit. The importance of proper sorting and grading for export at the field level and in the pack houses will be emphasized to maintain quality standards and to prevent insect-infested or damaged fruit from entering shipments.

**(4) Technology Transfer**: IPM technologies will be disseminated to farmers and extension officers in major hot pepper districts by methods revolving around farmer groups and individual farm visits. Priority will be placed on infested areas growing for the export trade. Topics include quarantine/market considerations; hot pepper production as a business; pest biology, ecology and damage; and pre- and post-harvest management. Demonstration plots will be established in seven major growing areas for use as training aids as well as to assist in field investigations. Farmer knowledge and practices will be assessed and integrated into the training methodologies.

**(5) Public Awareness:** The major public groups that interface with farmers growing for export are the exporters/agents that expedite shipments. Existing information will be used to prepare fliers, leaflets and posters to alert those in packing houses, farm stores and other strategic rural community locations, and will be modified, as new information becomes available. A public media program is being developed involving both electronic (radio, television) and a printed pamphlet. Jamaica Information Service is expected to provide air-time *gratis*, indicating the importance of this issue to the country.

**(6) Monitoring and Analysis of Introduced Technologies:** Pest interception levels will be monitored at the two major local ports, Montego Bay and Norman Manley (Kingston). A traceability system is being developed and implemented by the Jamaican Exporters Association to enable the origin (farmer, location) of each box of pepper being shipped to be identified. This system, coupled with monitoring of interception levels, will provide data to assist in determining areas/farms where problems exist, as well as those from "clean" areas. Extension will provide data on problem areas so that appropriate interventions can be made to manage pests in those areas.

**(7) Training in Quarantine Issues.** The experiences of this intervention to address gall midge on Jamaican Hot Pepper provide a case study which can be used to address future emergent problems and revisit current and past quarantine-based bans on exports to the USA. Training activities can seek to sensitize major stakeholders to possible ways of seeking to reverse such bans.

**e.** **Justification:** The gall midge pests not only affect the quality of the commodity but also are of extreme quarantine importance to Jamaica's major trade partner, the United States.

The USDA-APHIS issued a first warning to the Jamaican Ministry of Agriculture because this pest was detected, and negotiated a time frame of six months to appreciably reduce the level of interceptions of the midges. In response, Jamaica established a Multi-Agency Task Force (whose members are listed above) which has developed a national strategic plan for this issue. Because the situation was much more involved than originally envisaged, including conflicting information from the USDA as to identification and quarantine status, USDA then removed hot pepper from the pre-clearance list for shipment to the U.S. and required mandatory fumigation of peppers before entry into the U.S. The IPM CRSP will cooperate with this Task Force in this activity and provide technical assistance for many of the object research activities.

f. **Progress to Date:** Activities continue to focus on monitoring and surveillance of the pest both at the field level and at the ports of exportation. Since the pest complex is of quarantine importance it is believed that strengthening the ability to know where and when the pest is present and intercepting it would be the best way to regain the confidence of USDA quarantine officials. There have been significant advances in the development and implementation of a traceability system for tracking pest-free and hot spot farms. A nine-digit code has been assigned to over 400 export farmers. This code links the farmer to a district and commodity, which allows for direct intervention by pest management personnel if pest interceptions on his crop become a concern. A web-based system for regional monitoring of the pest at the field level has also been developed and is currently being implemented. The web page is up and is being populated by data being collected island-wide. Major emphasis has also been placed on farmer training on the biology and management of the gall midge.

Progress related to fumigation included, (1) establishing adjustable volume methods and (2) studying Mg and Al phosphide as alternatives to methyl bromide. The tarpaulin method enabling variable volume fumigation is now operational at the Montego Bay facility. The fumigation facility at the Norman Manley Airport remains a fixed volume facility.

Field management studies are continuing – they integrate cultural (fruit stripping), chemical/biorational, and monitoring methods. Monitoring is linked to traceability via databases, and the task force has worked to develop data acquisition systems that meet field operational needs and pest quarantine needs. Farmers, middlemen, and exporters participated in designing a 7-digit code that enables backtracking to the farm of origin. The code utilized the Extension Districts and Local Areas of RADA, and can be assigned by the exporter. Approximately 400 farmers are now registered in a national database.

Interceptions have dramatically decreased - from 104 in 1998, to 0 in 2000, and 10 in 2001 – and based on the foregoing USDA APHIS agreed to review the quarantine requirement. A team visit occurred in December 2001; this, plus follow up efforts have now led to a list of a proposed 10-point conditional removal of the quarantine which is being reviewed by local stakeholders. The major points involve: (1) All participating growers must be registered; (2) RADA / Plant Quarantine farm visits; (3) Exporters must buy from registered farms; (4) Colored posters placed at packinghouses (education efforts); (5) MINAG could do all pre-inspections; (6) No fumigation at point-of-entry; (7) Interceptions: if rejection rate reaches 15%, then all peppers must be fumigated; (8) Phytosanitary certificate.

The Task Force recognizes the national implications of this process for establishing and building competitiveness and trade capacity for multiple agricultural crops for export and markets from the tourism industry. Currently, reviews are considering these national implications. Draft modules are being developed to compile a handbook of protocols that outline local monitoring and surveillance procedures, and recommended production and post harvest practices for farmers, exporters and extension officers.

**g.** **Relationship to other IPM CRSP activities at the site:** One major component of the IPM CRSP is development of IPM programs for hot pepper. The gall midge activity will be integrated with other research objectives with hot pepper IPM, including technology transfer aspects. GIS and GPS technologies are being applied.

**h.** **Expected Outputs:** (1) Improvements in the quality and quantity of exportable and locally consumed hot peppers. (2) Development of IPM options for managing gall midge populations. (3) Improvements in the knowledge base of farmers in pest management. (4) Increased number of farmers/extension trained in IPM. (5) Knowledge of the relation of the gall midge with respect to phenology of the crop and agroecology. (6) Identification of an action threshold for relation of gall midge populations to economic injury. (7) Handbook of protocols for monitoring and surveillance procedures and pre-and post harvest management of gall midges.

**i.** **Projected Impacts:** (1) Reduced fumigation of exported produce, reducing the environmental hazard. (2) Increased hot pepper production, resulting in increased income to producers. (3) A traceability system for hot peppers grown for export. (4) Improved coordination and information flow among persons within the hot pepper industry.

**j.** **Projected Start:** September 1999

**k.** **Projected Date of Completion:** September 2004

**l.** **Projected Person-Months of scientist time per year:** 6

**m.** **Budget:** $47,410 – CARDI **(**through Technical Assistance and the USAID Jamaica Mission with subcontracts to members of the Gall Midge Taskforce) (carryover funds); $5,442 – Virginia Tech (carryover funds)

## I.8. Biotechnology: Molecular Probes to Distinguish Gall Midge Species

**a.** **Scientists:** S. Fleischer, L. Cui, B. Lovett – Penn State; D. Clarke-Harris – CARDI.

**b.** **Objectives:** We plan to develop a molecular probe that will distinguish *Contarinia lycopersici* and *Prodiplosis longifila* (or the un-named new species) collected as either larval, pupal or adult life stages. We plan to then use this probe to help determine the geographic distribution of these cecidomyiids in areas of the Caribbean and the U. S., and help improve our understanding of how management influences pest presence and population dynamics. We will also train two Caribbean scientists that currently work in IPM in molecular biology techniques.

**c.** **Hypothesis:** Molecular probes can be developed that identify and distinguish between species of the gall midge complex.

**d.** **Research Activities:** We will collect both species from hot peppers in Jamaica. Collections will be from immature stages (larvae and pupae) in field trials that are currently underway at CARDI, and from grower's fields [e. g., through collaborations with work described in I.7.e(1) and I.7.e(2), above]. Collections will also be coordinated with survey efforts that are underway with RADA. Material will be reared to adults on pepper, aspirated, stored in alcohol, and transported to Penn State by CARDI.

A graduate student in Entomology at Penn State (B. Lovett) will develop a molecular probe. Adults will be identified using methods and descriptions in Gagne (1986, 1989, 1994, 1998) and Pena et al., (1989). If we are dealing with a new species, the morphological work, which has already been initiated at CARDI, will be completed and published so this new species can be recognized. This requires dissection of male genitalia, and care will be taken to maintain parts together. Specimens will be sent to specialists for confirmation and as voucher specimens.

We will develop a simple molecular method to distinguish the two midge species. DNA will be extracted from approximately 50 of each taxa using standard protocol (Cui et al., 2000). We will first amplify a few house-keeping genes (e.g., genes encoding the ribosomal RNAs and actins) using the polymerase chain reaction (PCR) with degenerate primers based on conserved sequences of these genes from related insect taxa. The PCR products will be cloned and sequenced. Sequences will be compared to reveal regions where sequences have greatest variations or length polymorphism. Specific primers targeting unique sequences for each species will be designed. Since it appears that the two gall midge taxa are from different genera, it should not be difficult to identify housekeeping genes with sequence variations suitable for designing species-specific primers. These primers will be further tested by PCR using confirmed taxa identified by morphological characters. For future species identification, DNA from individual midges will be extracted by grinding and boiling in Tris-EDTA buffer. We have previously shown that DNA prepared in this manner is suitable for PCR. This PCR-based method for species identification has been developed and used for distinguishing many morphologically similar species including the closely related *Anopheles* mosquito species from Africa and different human malaria parasite species from the world (Scott et al., 1993; Snounou et al., 1993). Moreover, the PCR method is easy to perform and extremely sensitive to allow sufficient amplification from small amount of DNA extracted from the midges.

This molecular probe will be used on a series of collections from Jamaica and from collections taken from related taxa to help verify the specificity of the probe. In Jamaica, we will focus on areas where monitoring and management programs are being developed as part of current IPM CRSP objectives. This will help us determine the relative efficacy of these monitoring and management programs between the two species, and may help elucidate ecological differences between the species. We will also work closely with exporters and use the probe to help determine the relative frequency of interceptions from each species over time and among geographic areas.

**e.** **Justification/Background:** Hot pepper is an important crop to the Caribbean nations, which has a long tradition of excelling in pepper production. In Jamaica alone, it provides employment and income for 3,000 persons, injects US$5 million into the local economy, and attracts the attention of entrepreneurs. Peppers of various species are also very important in the US, where approximately 105,100 acres grossed approximately $623 million annually, making *Capsicum* spp. the 3rd (fresh-market) to 4th (fresh plus processing) most valuable vegetable crop (NASS data). In the US, the hot sauce market alone is now valued at approximately $550 million (Wall Street Journal 5/2000). Unfortunately, the ability of Caribbean farmers to capitalize on the growing export potential of their pepper crops is in jeopardy due to repeated interceptions of two species of gall midges at US ports. These were initially identified as *Contarinia* and *Prodiplosis longifila*, although recent taxonomic work suggests that at least one may be a new species. Only C. *lycopersci* is known to exist in the US, and APHIS imposed a quarantine to protect the US interests. This impedes economic growth in the Caribbean, and exports have declined dramatically. Also, the threat of the non-US species finding its way into the US regardless of the quarantine is a concern given the close proximity and travel between countries.

**f.** **Relationship to other CRSP activities at the site:** Other activities are described in I.5. A multi-agency and international task force initiated efforts to combat the gall midge complex in September, 1998. Progress has been made to identify and determine duration of life stages and plant damage. Results were used to investigate cultural (fruit stripping) and chemical control tactics in field trials, and to develop field sampling methods (based on sticky traps for adults) and thresholds. Significant temporal and geographic variations in pest infestation were determined to exist throughout the island using GIS, and a regional monitoring program is now being established with web and GIS technologies. These IPM programs helped reduce densities, but not totally eliminate pest presence or threat of infestations being transported to the US. Therefore, additional studies are comparing fumigation methods, which are effective, but reduce shelf life and compromise fruit quality. To date, field and management studies are conducted on the pooled complex of the two species because there is no practical way to separate them, and no way to separate immature stages. The inability to distinguish species compromises the ecological and management value of the fieldwork, especially work most directly tied to interceptions because most interceptions occur as pupae. We will use the research conducted here, along with the training of Caribbean scientists and work related to plant virus research, to plan a lecture-based workshop on molecular tools for IPM in the Caribbean in later years.

g. **Progress to date:** The graduate student at Penn State began his lab work, and extracted DNA from some collections of gall midges from Jamaica. Two Caribbean scientists currently working with the IPM CRSP attended a 2-week intensive laboratory workshop on "Techniques in Molecular Biology" at Penn State University. The workshop covered purifying DNA, analyzing DNA by restriction enzymes, gel electrophoresis and nucleic acid hybridization, generating nucleic acid probes, cloning and screening for desired clones, DNA sequencing, PRC amplification, and protein analysis by western blotting. Lectures and discussions covered basic principles behind the techniques, their applications, related techniques, and current development.

h. **Projected output:** A molecular probe will be developed that distinguishes between the two species of gall midges that are infesting hot peppers in the Caribbean.

i. **Projected impacts:** This probe will enable plant protection workers who are not taxonomic specialists in the cecidomyidae to determine which species is causing the interceptions that are resulting in the quarantine. This tool will enable the monitoring and management efforts that are current CRSP objectives to be conducted at a species level (as opposed to a level where the data are grouped for the two taxa), and may reveal differences in how the species respond to the monitoring and management efforts, or ecological differences between the two species. Finally, this will also help the U.S. and Caribbean workers determine progress in their efforts to prevent infestation into the U.S. of a species that is not currently known to exist in the U.S., and train Caribbean IPM scientists in molecular biology techniques.

j. **Projected start:** September 2002

k. **Projected completion:** September 2004

l. **Projected person-months of scientists time per year:** 8

m. **Budget:** $27,112 – Penn State; $2,200 – CARDI. $16,660 – Penn State; $8,250– CARDI (all of this funding is carryover from the prior 2 years).

## II. Pesticide Use, Residues, and Environmental Impact: Persistence and Fate of Pesticides Used on Export Hot Peppers and Cabbages in the Caribbean Region

a. **Scientists:** C. Edwards – OSU; D. Robinson – Univ. West Indies; K.M. Dalip, D. Clarke-Harris – CARDI

b. **Overall Objectives:** The purpose of the activities described is to quantify pesticide residues that can either cause environmental or human health problems or result in produce rejection of hot peppers and cabbages at the export site. In Year 11, work will focus on human and environmental elements of pesticide risk analyses from the five most popular pesticides used on hot peppers and cabbages in order to make more specific recommendations for their safe use in the Caribbean. This work, which in the past has been done mainly at Ohio State University, will emphasize transferring this activity to the Pesticide and Pest Research Group (PPRG) on the Mona Campus of the University of the West Indies (UWI) in Jamaica. This unit has the best capability in pesticide residue analyses and toxicological research for the Caribbean region. The work proposed will focus on all analyses being done at the UWI, with advice and consultation from Clive Edwards (OSU). **Specific Objectives:** (1) To ensure that callaloo, hot peppers, and cabbages for export or local sale, are not contaminated with pesticide residues; (2) To identify the pesticides that leave pesticide residues on these crops; (3) To continue to improve local capabilities for pesticide residue analysis and coordinate in-country and regional capabilities on pesticide residues.

**c.** **Hypotheses:** (1) Some callaloo, hot peppers, and cabbages for export will have pesticide residues at levels that may restrict their import into the U.S; (2) Some pesticides are much more persistent on plant foliage and in soil than others and likely to cause problems; (3) The "half life" values for most pesticides under humid tropical Caribbean conditions will be much less than those in temperate climates.

**d.** **Description of Research Activities**

**(1) Pesticide persistence on hot peppers.** The persistence of the commonly used pesticides: fipronyl, imidacloprid, ?-cyalothrin, diafenthuron profenofos, diazinon and malathion on hot peppers in the field, will be determined in both rainy and dry seasons. Treatment plots with 16 plants will be laid down and the pesticides applied at fruit set, taking care to confine treatments to treated plots. Leaf samples will be taken at 0, 3, 7, 14, and 21 days after pesticide application and fruit samples will be taken at harvest and extracted and analyzed by GLC to determine $T_{50}$ values.

**(2) Pesticide persistence on cabbages.** Similar experiments to those on hot peppers will assess the persistence of pesticides used commonly on cabbages on foliage and in the soil using similar experimental design. Pesticides to be used are profenos, diafenthurion, diazinon, and methomyl.

**(3) Pesticide persistence in soil**. These experiments will continue in Year 11. The soil in small plots 2 m x 2 m will be treated directly with the same insecticides used in the previous section on callaloo, hot peppers and cabbages and pesticide residues analyzed 2 weeks, 4 weeks, and 8 weeks after pesticides applications. The residues will be extracted from soil samples and analyzed by GLC.

**(4) Training and upgrade of pesticide residue analytical capabilities in Jamaica.** The University of West Indies residue laboratory currently has capabilities to analyze for diazinon, malathion, chlorpyrifos, ethoprophos, profenos, deltamethrin, ?-cyhalothrin and permethrin. We will provide standards and plan to upgrade their capabilities to cover all relevant synthetic halogenated pesticides, those containing a phosphorous group, or those based on pyrethroids. The University of West Indies has appropriate analytical equipment for the residue analyses but needs support for obtaining essential materials such as glassware, solvents and gases, etc., not readily obtainable in Jamaica.

**e. Justification/Background:** The intent of this project has been to assess the extent to which pesticides most commonly used on callaloo, peppers, and cabbages leave residues on the export crop in particular and also on crops for domestic consumption. We have past evidence that significant residues of many of these pesticides can be detected on produce in local and export market marketplaces. Increasing stringency in acceptable residues on import crops to USA and Europe make local and regional pesticide residue analytical capabilities essential. There is a dearth of information on the persistence of most pesticides in soil and on plants under humid tropical condition although they are known to differ from those in temperate climates. Knowledge of pesticide residues on food crops is also quite important to the health of local people.

**f. Relationship to other CRSP activities at the site:** The aim of CRSP activities is to implement IPM programs that minimize pesticide use and food contamination. Decreasing pesticide residues on local and export food crops demonstrates success of the IPM programs.

**g. Progress to date:** Continuing activity with changes of emphasis. Not all Year 10 objectives have been attained to date due to financial constraints on residue analyses and to one experiment being delayed. All Year 10 and Year 11 objectives will be completed in Year 11. The facilities for pesticide residue analytical capabilities have been improving in Jamaica and Dr. Dwight Robinson's laboratory now has several competent residue chemists and technicians. We have accumulated considerable data on pesticide residues on peppers and vegetables from market basket surveys and sampling export crops. The current study will eliminate the need for residue analyses of those pesticides which are relatively transient on foliage, fruit, or in soil, and which therefore present little hazard to the consumer. In Year 11, we will complete the residue studies on callaloo and the hot peppers trials will be organized and sampled and residues extracted from them.

**h. Projected outputs:** Elimination of the need for analyzing pesticide residues of a number of pesticides. Identification of spraying harvest intervals for pesticides that are commonly used on hot peppers and cabbages.

**i. Projected Impacts:** Facilitation of pre-clearance exports of hot peppers and cabbages. Minimization of contamination of all hot pepper and cabbage crops is an important environmental issue.

**j. Projected Start:** Continuation project

**k. Projected Completion:** September 2004

**l. Projected person months of scientist time per year:** U.S. Scientist – 2 weeks; UWI Scientist – 2 months; UWI Technician – 2 months

**m.** **Budget:** $8,800 – CARDI

## III. Social, Economic, Policy and Production System Analyses

Social, economic, policy, and institutional systems (human systems) have been shown to sometimes present overwhelming barriers to implementing IPM practices. The goal of this topic is to identify those components of human systems that constrain IPM adoption. The systems evaluated by the Caribbean research team include domestic and export markets and policies and practices associated with those markets, institutions and the policy environment of Jamaican agriculture, and farmgate economics as it relates to pepper, callaloo, and sweetpotato production and marketing (local and export).

### III.1 Socioeconomic surveys of farmers in Jamaica, Trinidad and Barbados and preliminary visits to St Kitts and Montserrat

**a.** **Scientists:** J. Momsen – UC-Davis; D. Clarke-Harris – CARDI; V. Lopez – CABI, Trinidad

**b.** **Overall Objectives:** This year marks a transition in two ways: the study of a new crop in Jamaica; and the extension of the project to the Eastern Caribbean. These changes each require new baseline socioeconomic data covering demographic, land tenure and agricultural issues among farmers and the marketing of vegetables in relation to the use of IPM. Gender differences will be an important part of this analysis. It will be especially important in the Eastern Caribbean where there are more women farmers. **Objectives for coming year:** (1) Develop survey instrument building on collaboration with CABI in Trinidad. (2) Carry out surveys among cabbage farmers in Douglas Castle, Jamaica and in Trinidad and Barbados.

**c.** **Hypothesis:** Farmers' attitudes about IPM are related to socioeconomic patterns.

**d.** **Description of Research Activity:** This will involve hands-on training for West Indies students in social survey methods. It will also involve working with the Geography department at UWI Mona for both the surveys and for GIS.

**e.** **Justification:** This work provides baseline data on socioeconomic issues for the IPM scientific work of the CRSP, and will utilize, where possible, on data collected in the early years of the project.

**f.** **Relationship to other CRSP activities at the site**: This work is supportive of the USAID mission's priorities in the Caribbean, particularly in relation to rural development, trade, competitiveness and disaster vulnerability. Food safety issues will also be considered in relation to both exports and to food for tourists.

- **g.** **Progress to date:** Preliminary discussions with Michael James of the Ministry of Agriculture, Barbados. Visits have been made to field sites in Barbados. Discussions about working with the Geography Department at UWI in Jamaica held with the Head of the Department, Prof. Elizabeth Thomas-Hope. A visit was made to field site in Douglas Castle, Jamaica.

- **h.** **Projected Outputs:** Participatory assessments of farmers and their socioeconomic situation at sites where IPM projects are to be conducted.

- **i.** **Projected Impacts:** Baseline data for IPM work. This should make it easier to get acceptance of scientists' recommendations by farmers and thus enhance the impact and increase the success of improving the farm products.

- **j.** **Projected Start:** September 2003

- **k.** **Projected Completion:** September 2004

- **l.** **Projected Person-Months of Scientists Time per Year**: 2 months

- **m.** **Budget:** $ 6,600 – UWI; $14,805 – UC-Davis

**IV.** **IPM Enhancement:** The goal of this topic is to address the fundamental problems that are encountered when conducting interdisciplinary, multinational, collaborative IPM research. These include: (1) Constrained communications due to distance, language, and culture; (2) The ability of scientists from the U.S. and developing countries to understand the technical and practical aspects of research problems and components of those problems; (3) Sensitivity of scientists to the diversity of opinions and perspectives that characterize these types of research teams. (4) The lack of expertise in certain discipline areas, such as weed science and management, and information technologies.

### IV. 1. Research Enhancement through Training in Weed Management

- **a.** **Scientists:** D. Clarke-Harris – CARDI; D. Robinson, J. Cohen – UWI; Weed Scientists at Pennsylvania State Univ. and /or Virginia Tech

- **b.** **Objectives:** (1) To provide support for a candidate for an advanced degree in weed science or management. (2) To conduct short-term training in weed management.

- **c.** **Hypotheses:** Education of individuals within the region in relevant aspects of weed science will enhance capability in IPM in the Caribbean.

- **d.** **Description of Research Activity:** Both short term and long-term training efforts will be undertaken. A graduate student will be funded at UWI with integration of short courses by US weed scientists. The two possibilities are a Master of Science degree in Plant

Production and Protection with a weed science component or a degree in Weed Science depending on the interests of the suitable candidate identified. US weed scientists will provide training in technologies available for managing weed species for relevant personnel within agricultural organizations.

e. **Justification:** IPM technologies need to be developed which address the tremendous weed pressure in the tropical areas of the Caribbean. Formal training in weed science and integrated weed management approaches is lacking.

f. **Progress to Date:** Past attempts to start a Caribbean graduate student in the US failed, and reviving that model could run into time constraints. Alternatives were, therefore, discussed and the above short term strategy was proposed for a current graduate student to study at UWI and benefit from expertise and training from US weed scientists. The current Plant Production and Protection program in place at UWI was reviewed, with emphasis on the Master of Science program. Curriculum content, costs, and timing were overviewed and would be enhanced by the addition of some weed science content. The integration of this component will be accomplished via short courses by U.S. weed scientists at UWI. A weed science student for this approach was identified, and she is currently registered in the weed science masters program at UWI. Her work has strong ties to weed science, and plant ecology in agroecosystems, and will be upgraded to a Ph.D. program of two additional years beginning September 1, 2003. Information relevant to the logistics of this approach in the UWI system was examined.

g. **Relationship to other IPM CRSP activities at the site:** Activities with sweetpotato and hot pepper have a weed management component, which will provide a research opportunity for the student to work with IPM scientists. During the candidate's studies, valuable information will be added to help refine present IPM technologies.

h. **Expected Output:** (1) Completion of an advanced degree in weed science; (2) Knowledge gained to assist in capacity lectures.

i. **Projected impacts:** Studies undertaken within the program will provide additional information on weed systems and their management within the Caribbean context and human resource base in weed science in the region will be enhanced.

j. **Projected Start:** September 2003

k. **Projected Date of Completion:** September 2005

l. **Projected Person-Months of scientist time per year:**

m. **Budget:** $2,750 – CARDI; $3,300 – UWI; $5,452 – Penn State; $1,532 – Virginia Tech. $22,235 – UWI (carryover funds); $1,916 – Virginia Tech (carryover funds)

## IV.2. Integration of World-wide Web and GIS for Real-time Monitoring, Communication, and Dissemination of Pest Management Information

**a. Scientists:** S. Fleischer, B. Miller – Penn State Univ.; P. Chung – RADA; D. Clarke-Harris – CARDI; S. Tolin, L. Grossman, A. Roberts – Virginia Tech;

**b. Objectives:** Expand the regional capability for use of geo-informational technologies in IPM into the eastern Caribbean, with emphasis on Geographical Information Systems (GIS). Develop and implement real-time pest monitoring, mapping, and web display of both maps and time-series over geographic areas, using the gall midge as the model system, with applicability to other pest monitoring programs. Identify pest-free or low pest incidence areas to reduce quarantine restrictions for export. Identify high pest incidence areas for more rapid responses by Extension agents and researchers. Expand the capability of exploring the significance of spatial relationships among pest management variables (e.g., pest densities, pesticide applications) and environmental and socio-cultural variables, as a means of advancing economic development and environmental stewardship. Develop on-line information and management guides relating to IPM technologies being evaluated, as a means of information dissemination and exchange.

**c. Hypotheses:** (1) Mapped displays of pest monitoring data over wider geographic areas linked to time series information at local sites will help identify pest-free areas and areas in need of more intensive management and education. (2) Web-access to mapped displays linked to local time series will facilitate linkages and communication among public and private sectors involved with pest management, crop marketing and economic development, and environmental stewardship. (3) The factors affecting the spread and control of pest problems are a function of the interrelations among environmental, agricultural, and Socioeconomic patterns that can be analyzed through using GIS.

**d. Description of research activities:** Through training programs, in-country capabilities for GIS, global positioning systems (GPS), and rapid web-based mapping will be strengthened in the western Caribbean, and expanded to IPM scientists in the eastern Caribbean. We will conduct a four-day workshop in either Trinidad or Mona with approximately 10 to 15 participants. At the workshop, each participant will have access to a computer and relevant software. Participants will learn how to use the GIS software program ArcView, the most widely used GIS desktop program in the world. They will learn how to incorporate into GIS their own data that they have collected in the field. They will also learn how to analyze their data in relation to other environmental, agricultural, and socioeconomic data available in GIS format. We will provide instruction on how to use GIS to store information in a database, and how to populate that database remotely through the web. The database can be used to analyze both current patterns and changes over time. The GIS database can serve as a structured archive that can be explored as new questions and hypotheses are generated in the years to come. Participants will also learn how to interpret, create, and print computer-generated maps for their reports. Such use of GIS will enhance participants' abilities to develop hypotheses, analyze data, and publish the results of their research. The Virginia Tech team will also prepare a written manual and on-line tutorial to assist participants in learning to use GIS.

Because of the importance of spatial relations in GIS, it is essential to be able to record accurately the precise locations of data collection sites in the field and enter such coordinates into a GIS. Thus, participants will also learn how to use Global Positioning Systems (GPS) units in field exercises.

Data on gall midge infestation rates in Jamaica will be entered into MS Access tables through an Active Server Pages (ASP) application that is accessible via the CIPMNET website. Data will be collected from four targeted areas on a weekly basis. Sampling will involve collection and dissection of fruit and buds, using three locations for the dissections. Spatially referenced password-protected data input will occur via ASP forms on the web, routed through the RADA server, and will automatically update a spatially referenced database on the RADA server. A Delphi application will download this database, and be implemented routinely to create new maps of pest infestation rates, and clickable views of the time series at local sites. All maps and time series will be ported to a website. We envision this type of information infrastructure as part of the gall midge program in the IPM CRSP, to be useful for other pest monitoring and management programs in the future. We also envision this to facilitate cooperative linkages among research and extension agencies.

**e.** **Justification:** In the Caribbean, the PROCICARIBE network has been established to provide for exchange of information in pest problem identification and management strategies. It is a natural extension of the IPM CRSP project to assist in the development and operation of information systems technologies for IPM. IPM also influences issues related to economic development and trade. Use of GIS will assist in analyzing the complex relationships among environmental, horticultural, socioeconomic, and pest management variables. It could also be valuable in tracking invasive species.

**f.** **Relationship to other IPM CRSP activities at the site:** These activities will greatly accelerate the regionalization of the IPM CRSP in the Caribbean, and greatly accelerate pest monitoring of other pests in multiple Caribbean sites. The development of integrated web/GIS for pest monitoring using distributed data-entry, update and geographic display also has utility in many IPM CRSP sites. The development in the Caribbean site will serve as a study of prototype development for other sites, enabling development of appropriate and relevant software, and a better understanding of necessary training, resources and infrastructure.

**g.** **Progress to Date:** Within the Caribbean, we are building from a multi-agency workshop, a RADA baseline survey and a GIS thesis, all of which were completed in Year 8, and from GIS training that occurred in the western Caribbean prior to Year 8. The earlier training provided a basis for IPM scientists to utilize spatially referenced databases in pest monitoring programs. A multi-agency workshop (RADA, MINAG, CARDI, Penn State, UWI, Agro Grace, H&L Agri & Marine Co., Agricultural Chemicals Plant, Pesticide Control Authority) reviewed application software for the integration of web and

GIS for pest monitoring and identified target areas for implementation. These target areas were prioritized by pest infestation rates, level of hot pepper exports, and variation in factors that statistically influenced models of infestation rates (elevation, farmer crop and pesticide practices). The four targeted areas were St. Mary, Westmoreland, southern St. Catherine, and southern Clarendon. Spatially referenced databases began to be populated in year 10; and this training and development helped facilitate a plan for regaining pre-clearance status for export. This work will regionalize the GIS capability into the eastern Caribbean. IPM in the wider Caribbean is already linked through CIPMNET, which, in itself, is an organizational structure that was facilitated through the activities of scientists involved in the IPM CRSP.

**h.** **Projected outputs:** Project scientists will be able to use GIS and GPS techniques to record and analyze their data and produce reports on their research. They will gain an effective means to manage data over time by using the database elements of GIS. A Web-based GIS system for recording pest distribution and implementing management practices will be available across the Caribbean. Web publication of pest management guides.

**i.** **Projected impacts:** Preparation of electronic pest management guides will assist in improving the knowledge base of extension and researchers inter- and extra-regionally. WEB/GIS will provide spatial and textual information on pest distribution and impact management strategies. Management inputs will be more targeted to specific geographic areas. Pest-free areas will be defined and may be useful for reduced quarantine restrictions.

**j.** **Projected start:** September 2003

**k.** **Projected completion:** September 2004

**l.** **Projected person-months of scientist time per year:** 2 months

**m.** **Budget:** $9,867 – CARDI; $5,937 – Penn State; $9,705 – Virginia Tech

## Site Activity Summary – Caribbean Site – Year 11

| ACTIVITY | SCIENTISTS | YEAR 11 BUDGET ($) | OTHER BUDGET ($) |
|---|---|---|---|
| **I. IPM SYSTEMS DEVELOPMENT** | | | |
| I.1. Threshold-based Integrated Management of Pests Affecting Leafy Vegetables with High Pesticide Input | Jamaica: D. Clarke-Harris – CARDI; P. Chung – RADA; | 19,745 | |
| | Barbados/Trinidad&Tobago: MINAG | 5,390 | |
| | United States: S. Fleischer – Penn State Univ., | 1,212 | |
| | D. Michael Jackson – USDA-ARS | 2,220 | |
| I.2. IPM of Major Pests Affecting Sweetpotato in the Caribbean<br>a. IPM Efficacy<br>b. Variety evaluations<br>c. Organic mulch<br>d. Value-added products<br>e. WISPW Assessment<br>f. Impact Assessment | Jamaica: K. Dalip – CARDI; D. McGlashan – MINAG; P. Chung - RADA | 18,480 | |
| | St Kitts/Nevis/Montserrat -L. Rhodes – CARDI | 1,375 | 1,210 |
| | Antigua: J. Ross – CARDI; J. Gore-Francis - MINAG | | |
| | St Vncent and the Grenadines- P. Titus – CARDI; S. Edwards - MINAG | | 4,598 |
| | United States: J. Bohac, D. M. Jackson – USDA; | 6,660 | |
| | C. Edwards, Ohio State; J. Momsen, UC-Davis | | |
| I.3. Assessment of Virus Incidence in Superior Caribbean Sweetpotato Varieties | Jamaica: K. Dalip – CARDI; United States: D. M. Jackson, J. Bohac – USDA; S. Tolin, Virginia Tech | | 5,108 |
| I.4 Integrated Pest Management (IPM) of Viruses Affecting Hot Pepper (Scotch Bonnet and West Indian Varieties) | Jamaica: D. Clarke-Harris, K. Dalip – CARDI; J. Goldsmith, T. Williamson – MINAG; P. Chung – RADA; W. McLaughlin – UWI; | 6,600 | |
| | United States: C. Edwards– Ohio State; S. Tolin, VT | | 18,440 |
| | | | |

| | | | |
|---|---|---|---|
| I.5. **Biotechnology**: Characterization of Potyviruses in Caribbean Hot Peppers and Management through Resistance | Jamaica: D. Clarke-Harris, K. Dalip – CARDI; D. McGlashan – MINAG; Bodles; P. Chung – RADA; W. McLaughlin, U.W.I.<br>United States: S. Tolin, Virginia Tech | 11,550<br><br><br>28,444 | |
| I.6. Factors Affecting Broad Mite Incidence on Hot Peppers | Jamaica: D. Clarke-Harris, K. Dalip – CARDI; D. McGlashan, J. Goldsmith – MINAG<br>United States:<br>C. Edwards, M. Schroeder– Ohio State; S. Tolin, Virginia Tech | 2,200<br>7,700<br><br>8,012 | |
| I.7. **Mission:** An IPM Strategy to Combat the Gall Midge Complex Affecting Hot Pepper | Jamaica: D. Clarke-Harris – CARDI; C. Thomas – MINAG; P. Chung, J. Lawrence – RADA; D. Geoghagen, Agri-Business Council; USDA-APHIS<br>United States: S. Tolin – Virginia Tech; S. Fleischer – Pennsylvania State; D. M. Jackson – USDA-ARS | | 47,410<br><br><br><br>5,442 |
| I.8. **Biotechnology**: Molecular Probes to Distinguish Gall Midge Species | Jamaica: D.Clarke-Harris - CARDI;<br>United States: S. Fleischer, L. Cui, B. Lovett – Pennsylvania State | | 10,450<br>16,660 - yr 1<br>27,112 - yr 2 |
| **II. PESTICIDE USE & RESIDUES** | | | |
| II.1. Persistence Use, Residues, and Environmental Impact: Persistence and Fate of Pesticides Used on Export on Hot Pepper and Cabbages in the Caribbean Region | Jamaica: D. Clarke-Harris; K. Dalip – CARDI; D. Robinson – UWI;<br>United States: C. Edwards – Ohio State | 8,800 | |

| | | | |
|---|---|---|---|
| **III. SOCIAL, ECONOMIC, POLICY, AND PRODUCTION SYSTEM ANALYSES** | | | |
| III.1. Socioeconomic surveys of farmers in Jamaica, Trinidad and Barbados and preliminary visits to St Kitts and Montserrat | Jamaica: D. Clarke-Harris – CARDI; E. Thomas-Hope, U.W.I,<br>Trinidad: V. Lopez - CABI<br>United States: J. Momsen - UCDavis | 6,600<br><br><br>14,805 | |
| **IV. IPM ENHANCEMENT** | | | |
| IV.1. Research Enhancement through Training in Weed Management | Jamaica: D. Clarke-Harris – CARDI; D. Robinson, J. Cohen – UWI; student at UWI<br>United States: Weed Scientists at Pennsylvania State and Virginia Tech | 2,750<br>3,300<br>5,452<br>1,532 | 22,235<br><br><br>1,916 |
| IV.2. Integration of World-Wide Web and GIS for Real-Time Monitoring, Communication, and Dissemination of Pest Management Information | Jamaica: P. Chung, RADA; D. Clarke-Harris, K. Dalip, CARDI<br>Trinidad & Tobago: V. Lopez, CABI; W. Ganpat, MINAGLMR; D. Dolly – UWI<br>United States: J. Momsen – UCDavis; S. Tolin, Virginia Tech | 9,867<br><br>5,937<br>9,705 | |

## YEAR 11 WORKPLAN FOR THE WEST AFRICAN SITE IN MALI

In IPM CRSP Year 11, the last year of Phase II, the Mali site will conclude its first phase with a primary focus on peri-urban export horticulture and complete its secondary focus on innovative research for control of *Striga*, a parasitic weed on basic food crops. Three crops have been the focus of the horticultural research: green beans, hibiscus, and tomatoes. This research has been developing in stages over the five years of Phase II: the first stage emphasized component development from primary on-farm research; the second stage focused on the testing of pest management techniques as integrated packages; and, the third stage involves disseminating farmer-tested IPM packages.

This year we will continue with the third stage, disseminating integrated packages for green bean and hibiscus. We will also be developing biotechnology-based methods for combating the growing problem of tomato yellow leaf curl virus (TYLCV) and other similar viruses in tomatoes. This latter activity is a USAID/Mali priority and has received substantial Mission support to reinforce their Accelerated Economic Growth Strategy (SO9) by increasing the "sustainable production of selected agricultural products in targeted areas" (IR 9.1). This year gender-sensitive technology transfer will be a major theme, as will positioning stakeholders to capitalize on marketing opportunities, transferring the IPM packages and component technologies through Farmer Field Schools (FFS) or alternative methods, and developing a team of private and public sector extension agents to transfer IPM technologies as effectively, but more efficiently than the FFS program. We will also be determining the state of knowledge concerning geminiviruses and their whitefly vectors across West Africa.

These research efforts serve to support the development of a system to reduce pesticide residues on agricultural products in collaboration with the new Environmental Quality Laboratory (EQL) of the Central Veterinary Laboratory (LCV). The USAID/Mali Mission has provided 5 years of funding for pesticide residue analysis, laboratory development and technician training. This activity supports IR 9.2, "Trade of selected agricultural products increased" by providing (1) science-based information on produce quality, and (2) pesticide safety training to improve farmers' knowledge concerning proper application techniques as well as the understanding of the dangers inherent in pesticide use. The IPM CRSP West Africa program combines on-farm research, pesticide residue analysis, and pesticide safety training to yield marketable supplies of quality produce verified to meet international food safety standards and maximum residue levels (MRLs), and insure the safety of farmers using pesticides.

This program is being carried out with three Malian institutions playing a leading role: the agricultural research institution Institut d'Economie Rurale (IER), the extension organization Opération Haute Vallée du Niger (OHVN), and the toxicology laboratory of the Central Veterinary Laboratory (LCV). OHVN works with the private sector in production and marketing of export horticultural crops, including green beans exported to France and hibiscus exported to Senegal, Germany, and the United States. The Institut Supérieur de Formation et de Recherche Appliquée of the University of Mali is collaborating in training of a Ph.D. student and two masters' students.

In the United States, four institutions will contribute to the collaborative research program: Purdue University, contributing expertise in vegetable IPM; the University of California-Davis, contributing expertise in tomato virology; North Carolina Agricultural and Technical University, contributing expertise in economics of horticultural production and export markets; and Virginia Tech, contributing expertise in weed science, rural sociology, pesticide residue analysis, pesticide safety education, and quality assurance. A parallel USDA-funded international experience program for undergraduates will be lead by Montana State University in collaboration with Chief Dull Knife Memorial College.

## I. Positioning Stakeholders to Capitalize on Marketing Opportunities

**a.** **Scientists:** *Principal investigators*: K.Gamby – IER; I. Sidibé – OHVN; K. Moore - Virginia Tech; A.Yeboah, - North Carolina A & T. *Collaborating scientists*: B. Dembélé, M. N'diaye, M. Noussourou, A. Théra, H. Sissoko, P. Sow - IER; M. Diallo - OHVN; Rick Foster - Purdue; Jim Westwood - Virginia Tech.

**b.** **Overall Objective(s)**: To build on the strengths of IPM CRSP/Mali program activities in order to improve the delivery of quality of IPM research and services. In the OHVN zone, the major problem with production of green beans is damage from insect pests that leads to production losses. Exporters wish to assure insect control with the use of the insecticides, Decis and others. However, the new IPM package for green beans has been proven to successfully manage pests and does not involve pesticides or synthetic fertilizer.

**Objective(s) for the coming year:** To promote organic certification for green beans and analyze alternative marketing channels to determine how best to target quality assurance program activities.

**c.** **Hypothesis**: Improved understanding and coordination among green bean exporting stakeholders (farmers, exporters, researchers, extension agents, etc.) will increase the application of IPM practices, decrease rejection of exported crops, and improve incomes in the sector. It is hypothesized that they can receive higher prices than they did for chemically produced produce by marketing their produce as organic.

**d.** **Description of research activity**: U.S. and Malian researchers and their OHVN, EQL and NGO colleagues are conducting discussions with green bean exporters working in the targeted villages about how collaboration to improve the conditions for increased and profitable green bean exportation. A case study approach will identify and explore (1) the key players besides the economic operators (exporters) and the farmers, (2) the importance of price and quality in grower-exporter-importer relations, (3) organic certification, (4) seasonal variation in availability and market windows, (5) the extent of and access to market of organic consumers, (6) priorities and concerns of exporters with organic produce, (7) creating a new organizational structure, (8) standardizing the product, and (8) standardizing packaging and labeling of produce.

**e.** **Justification:** Exporters play an important role in shaping farmer decision making concerning pest and pesticide management practices. Increased communication and understanding between exporters, researchers, extension agents and regulatory bodies will help to better integrate the sector facilitating the adoption of the most effective, profitable and safe pest management practices. The ability to sell their produce is key to sustaining the producers and exporters of Malian green beans. This work will help to realize the potential benefits of IPM CRSP biological research.

**f.** **Relationship to other CRSP activities**: This activity will serve to confirm or provide the basis for adapting results from the biological experiments in the development of IPM technology packages for green beans, hibiscus and tomatoes. It will also reinforce work conducted by the quality assurance program.

**g.** **Progress to date**: An Evaluation Survey of FFS conducted last year in green bean producing villages demonstrated that farmers participating in IPM CRSP program activities were adopting improved practices. A survey of Malian exporters highlighted their concerns about price and quality monitoring issues at the point of entry of their produce in France. Interviews with importers at the Rungis international market in France brought out that they were impressed with the quality of Malian green beans, but that they had concerns about the capacity to maintain a large sustained supply necessary for stable market relations. It was learned that importers would consider organic green beans, but currently did not have a market for them.

**h.** **Projected Outputs**: (1) Improved dissemination of IPM technologies leading to more consistent quality and production levels in horticultural export crops. (2) Increased quantity and quality of Malian green bean production marketed in Europe.

**i.** **Projected Impacts**: An IPM research and extension system that is more responsive to producer and agribusiness needs.

**j.** **Start**: October 2000

**k.** **Projected Completion**: September 2004

**l.** **Projected person-months of scientist time per year**: 2-3 person-months.

**m.** **Budget**: $2,310 - IER/Sotuba; $5,060 - OHVN; $9, 200 - University of Mali; $6,499 – Virginia Tech.

## II. Transferring Integrated Weed Control Strategies for Vegetable Production

**a.** **Scientists**: _Subactivity leaders_: M. N'Diaye - IER; J. Westwood - Virginia Tech
_Collaborating scientists_: B. Dembélé, K. Gamby, H. Sissoko, P. Sow - IER

**b. Overall Objective(s):** To develop integrated weed control strategies for irrigated vegetable (primarily tomato) production systems.

**Objective(s) for coming year**: (1) To confirm previous results on the effectiveness of straw mulch as a weed control strategy; (2) To quantify the reduction in watering needed for mulched plots; (3) To expand the scope of research from green beans to tomato production.

**c. Hypotheses**: 1) Straw mulch at least 15 cm thick reduces weed growth and provides high yields as compared to standard farmer practice. 2) Straw mulch conserves water in the soil and reduces watering needs as compared to techniques that leave the soil exposed.

**d. Description of Research Activity**: Mulches provide good weed suppression by blocking sunlight that promotes weed germination and growth. This is especially true for the most problematic weed in Malian vegetable gardens, *Cyperus rotundus*, which thrives in high light and disturbed soils. A secondary benefit of mulch is the conservation of moisture in soil covered by mulch. Research activities will address aspects of using mulch in Malian gardens. Experiment 1: The quantity of mulch needed for effective weed control will be confirmed by testing 0, 5, 10 and 15 cm depths of straw mulch in a green bean crop. Experiment 2: The efficacy of transferring the mulch protocol to a tomato production system will be evaluated in comparison to current farmer practices. For all experiments, parameters measured will include number and biomass of the most prevalent weed species, and crop yields. In addition, the effect of straw mulch in holding water in the soil will be measured to quantify the value of mulch in saving labor in vegetable production. Experiments will be replicated four times and repeated on farms in three villages.

**e. Justification**: Weeds can cause significant yield reductions in vegetable crops if they are not controlled. *Cyperus rotundus* is one of the primary weeds of irrigated vegetables in Mali and is especially difficult to control. Most of the labor involved in irrigated vegetable production during the growing season is needed for watering and weed control. Mulching can reduce labor for both of these activities. Mulch can be collected from wild grasses growing abundantly adjacent to the gardens, thus representing a convenient, free, organic control method. Although labor is needed to cut and apply the residues, very little weed control is required for the remainder of the season, a significant time savings as compared to the current practice of weekly weeding. In addition, crops are normally watered once or twice a day, but farmers using mulch in the previous year reported that this labor was cut in half following mulch application.

**f. Relationship to Other CRSP Activities in Mali**: Mulching is a technique that is easily incorporated into integrated pest management systems already developed. It does not impact other pest control strategies, although it can possibly affect disease incidence (although generally only under conditions of excessive moisture, which is not likely under controlled irrigation conditions). A plant pathologist will be consulted to evaluate disease incidence during the growing season.

**g**. **Progress to Date**: The major weed species in vegetable production have been characterized and several control strategies have been tested. Straw mulch has been shown to be very effective in controlling weeds and maintaining high yields in one year of research trials. These results will be confirmed in the present study.

**h**. **Projected Outputs**: High yields of green bean and tomato crops, with reduced labor expenditure through efficient weed control and reduced watering needs in vegetable production systems. Assuming confirmation of previous results, data will be published in a regional weed control or IPM journal and the technique extended to farmers through farmer field schools and other appropriate channels.

**i**. **Projected Impacts**: Improved weed control and more efficient crop production. This will give farmers more time to either expand their growing areas or attend to other activities.

**j**. **Start**: October 1999

**k**. **Projected Completion**: September 2004

**l**. **Projected Person-Months of Scientists Time per Year**: 3 person months.

**m**. **Budget**: $2,640 – IER-Sotuba; $1,430 – OHVN; $9,000 - University of Mali; $5,172 - Virginia Tech.

## III. Promoting Adoption of Innovative Techniques for Striga Management

**a.** **Scientist(s)**: _Subactivity leaders_: B. Dembélé - IER; J. Westwood - Virginia Tech _Collaborating scientists_: M. Kayentao, D. Dembélé, K. Gamby, H.T.Sissoko, P. Sow - IER.

**b**. **Overall Objective(s)**: *Striga* is one of the primary limitations to cereal production in sub-Saharan Africa. Our objective is to identify new strategies for *Striga* control that can be incorporated into an integrated pest management program for protecting sorghum and millet from devastation by *Striga*. The specific area we are working on is the use of herbicidal control methodology that employs seed coating, a familiar concept to most farmers and one that requires low investments of time and resources.

**Objective (s) for coming year**: To field test results of previous year's research on herbicide seed treatments for controlling *Striga* in sorghum.

**c**. **Hypotheses**: (1) Applying small doses of the herbicide 2,4-DB to seeds of sorghum will protect the crop from early parasitization by *Striga*. (2) Alternative application methods could increase the margin of selectivity between crop and parasite. (3) Combining herbicide use with crop varieties having some resistance to *Striga* will significantly increase yields.

**d. Description of Research Activity**: This research represents the culmination of previous work that indicated the potential of herbicide seed treatments to prevent parasitism early in the life of the crop. Initial laboratory studies identified five candidate herbicides with selectivity in sorghum and millet. Subsequent field tests with these herbicides demonstrated that 2,4-DB reduces *Striga* emergence on sorghum. Despite the promise of this technology, problems persist with respect to precisely balancing the herbicide dose needed for *Striga* control with herbicide safety to the crop. Studies will evaluate whether farmers are able to follow this seed-treatment protocol with sufficient precision to allow safe extension of the technique. Alternative techniques that provide a greater window of selectivity will also be explored, such as 1) performing seed treatment immediately prior to planting; 2) applying doses of herbicide to the planting hole at the time of planting; and 3) applying herbicide to the soil just after crop emergence. The latter trials will also include the herbicide dicamba, which has more soil activity than 2,4-DB. The use of *Striga*-resistant sorghum plants that were determined to be low producers of germination stimulant will also be advocated to farmers as a way to minimize the amount of *Striga* in their fields.

**e. Justification**: The participatory assessment conducted in July, 1994 and the farmer evaluation of 1996 indicated that *Striga* was one of the two highest priorities for farmers of millet and sorghum. The impact of *Striga* will only be diminished by sustained integrated control efforts, all of which contribute to control of the weed. Among the most effective and appropriate strategies are those aimed at increasing host resistance to *Striga*. In addition, new approaches to herbicide application have shown promise in recent years for control of *Striga*, and the proposed research seeks to combine these strategies in order to provide an effective integrated control program.

**f. Relationship to Other CRSP Activities in Mali**: This work will be compared to other *Striga* control practices (intercropping) developed during Years 1-6. *Striga* is also a major problem at the Uganda IPM CRSP site and research on this approach to *Striga* control is being coordinated with Uganda site counterparts. Close collaboration between IPM CRSP and INTSORMIL CRSP also occurs in Mali. Research activities of the INTSORMIL CRSP to breed Striga resistance into crops (activity of Dr. Aboubacar Touré, sorghum breeder, IER, Mali) are conducted in cooperation with IPM CRSP PI Bourema Dembélé.

**g. Progress to date**: Results from the sorghum study indicated that seeds soaked in a 0.5% solution of 2,4-DB for five minutes resulted in plants that were parasitized significantly less ($P<0.05$) than control plants. Additional research on this compound indicates that the seed treatment has a positive effect on reducing parasitism by *Striga*, although the effects occur early in the growth of the host and higher rates may result in toxicity to the sorghum or millet. Experiments are continuing to refine application methodology to take advantage of the beneficial effects while minimizing risk of crop injury. Studies of *Striga* resistance in sorghum cultivars in the laboratory have been conducted. During this time several obstacles to growing sorghum in the polyethylene bag system have been overcome, and at least two different mechanisms appear to be operating in different varieties, one based on low stimulant production from the host, and another occurring after parasite attachment.

h. **Projected Outputs**: Data will be generated on the efficacy of a new strategy for inclusion in integrated *Striga* management programs. Researchers at IER will have increased capacity for answering important research questions about sorghum and millet interactions with *Striga*. A manuscript on the seed treatment protocol is in preparation.

i. **Projected Impacts**: *Striga* infestation will be reduced with minimal pesticide use, allowing farmers to obtain greater yields and enabling them to meet subsistence needs with more surplus available for market sale, thereby contributing to transition from largely subsistence-based production to mixed subsistence-market based production.

j. **Projected Start**: October 1998

k. **Projected Completion**: September 2004

l. **Projected Person-Months of Scientists Time per Year**: 2-3 person months.

m. **Budget**: $2,640 – IER-Sotuba

## IV. Disseminating Green Bean IPM Packages Through Farmer Field Schools

a. **Scientists**: *Subactivity leaders*: K. Gamby - IER; R. Foster - Purdue; A. Théra, M. N'Diaye - IER; I. Sidibé - OHVN. *Collaborating scientists*: P. Hipkins, J. Westwood - Virginia Tech; B. Dembélé, H. Sissoko - IER

b. **Objective(s)**: To disseminate IPM technologies for peri-urban green beans.

**Objective(s) for the coming year:** To continue disseminating a curriculum for Training of Trainers (TOT) and farmers on IPM technologies for green beans using an adapted Farmer Field School (FFS) methodology.

c. **Hypothesis**: The FFS approach permits the quick introduction, dissemination, and adoption of IPM technologies.

d. **Description of research activities**: The FFS will involve 10 villages in the Ouelessebougou area within 50 kilometers of Bamako. The FFS permits participants to have directed experiences implementing and monitoring crop production using IPM technologies and local farmer practices on a weekly basis. Trainers will include IER and OHVN technicians and previously trained farmers. Dissemination will also involve farmer-to-farmer visits in 20 villages with recently trained peasant trainers on green bean IPM package. The FFS experiential training involves two plots (farmer practice and

IPM) separated by two meters. The IPM plot will demonstrate the IPM package for green beans. Technicians and farmers will compare the evolution of these two plots over the course of the growing season. Lessons in pesticide safety will be included in this program, as well as information on HIV/AIDS. FFS evaluation survey results from last year will be analyzed and updated.

**e.** **Justification**: Research findings from years 7 through 9 demonstrated that the IPM technologies for diseases, insects and weeds reduced pesticide use and pest damage. Experimentation with the Farmer Field School approach in years 8 through 10 suggests that this method improves the production of horticultural crops and speeds the introduction and adoption of IPM technologies.

**f.** **Relationship to Other CRSP Activities at Site**: This activity is the result of previous and ongoing studies of green bean IPM technology components included in this study.

**g.** **Progress to date**: Preliminary results from the FFS evaluation survey of years 8 and 9 demonstrate speedy dissemination and adoption of IPM technologies. Separate and combined groups of men (302) and women (330) bean producers have been trained during the past three years in over twenty villages. Eleven peasant trainers (including two women) were used and several of those trained this past year will be used as trainers in the coming year. FFS assessment has shown high adoption of IPM technologies in green bean production areas.

**h.** **Projected Outputs**: Based on the FFS survey, we are finding high levels of adoption among participants and growing adoption among other (non-participant) villagers. We expect increasing numbers of growers will adopt this system of IPM techniques as a package that will result in greater yields, higher quality, less pesticide use, and greater returns.

**i.** **Projected Impacts**: Higher yields, lower pesticide costs and residues, reduced pest losses, more stable supply, and improved exportability of green beans.

**j.** **Start:** November 2000

**k.** **Projected Completion**: September 2004

**l.** **Projected person-months of scientist time per year**: 9-10 person-months.

**m.** **Budget**: $4,180 – IER-Sotuba; $2,200 - OHVN.

## V. Assessing the Impact of IPM Packages on Green Bean Production

**a.** **Scientists:** *Sub-activity leaders*: A. Yeboah - North Carolina A&T State University; P. Sow - IER *Collaborating scientists:* K. Gamby, M. Nousourou, A. Traore, H. Sissoko - IER; R. Foster - Purdue; K. Moore - Virginia Tech; I. Sidibe - OHVN.

**b.** **Objective(s):** To determine the impact and profitability of the various treatments used in the IPM on-farm trials with the aim of making recommendations to producers.

**c.** **Hypothesis:** The adoption of IPM technologies will depend not only on their performance in the field but also on the costs and returns associated with them. More producers will adopt them if the technologies are cost effective and have positive monetary impact on the family.

**d.** **Description of research activities:**

In general, the analytic approach will consist of the following steps:

1. The development of partial budgets for each treatment
2. The identification of "superior" treatments (dominant analysis) in terms of the highest profitability to justify adoption by producers.
3. The calculation of marginal rate of profitability for each "superior" treatment using benefit-cost analysis.
4. Choice of treatment based on farmers' ability to apply them. Sensitivity analysis will also be conducted.

Economic analyses have been conducted on the results from agronomic trials from two cropping seasons. Analysis for the third year is still in progress. Once completed, an overview of the three years' work will be conducted to consolidate reasons for technological choice. Data on the uptake of IPM packages throughout Mali will be included in these analyses. This will form the basis for the formulation of a recommendation policy. Potential for adoption among the farmers will be assessed and intermediate impact indicators developed. Even though the IPM technologies have been shown to be profitable, their adoption will be predetermined by factors such as the initial investment required compared to that of the current technologies being used by the farmers. However, analyses from the previous years show that farmers' current practice requires an average initial investment of 226,000 FCFA or about $329 per hectare compared to 196000 FCFA or $280 per hectare for the IPM technologies. It is safe to assume that if farmers are able to come up with $329 to invest in current practice than the IPM technology will be easily afforded. This analysis will be pursued.

**e.** **Justification:** The on-going emphasis on farming systems research has reinforced the role of on-farm agronomic trials in developing appropriate technologies for farmers' use.

However, statistically significant performance of a particular technology does not always translate into economic benefits to its user. Agronomic efficiency does not always entail economic efficiency. It is therefore necessary to analyze how agronomic benefits translate into socioeconomic benefits, since these ultimately determine the adoptability of the proposed technology.

f. **Relationship to Other CRSP Activities at Site:** This year's technologies are being tested as a "package" rather than in subsets. The economic analysis will take into account the complexity this brings.

g. **Progress to date:** The most progress has been made on economic analysis of insect control trials on green beans. The results of the economic analysis indicates that the use of insect traps yields a net profit of 1,641,532 FCFA or $2,345 per hectare (US$1= 700 FCFA) while the use of insect traps plus the application of neem leaf extract yields 1,640,664 FCFA or $2,344 per hectare. Both figures are slightly higher than the corresponding figures for the farmer's practice of three applications of Decis, plus an application chemical fertilizer and organic manure. This implies that the use IPM technologies can lead to the production of wholesome green beans without sacrificing income to the farmers. The profitability for single and double applications of Decis was not significantly higher than those from the IPM packages: 1,719,462 FCFA ($2,456) and 1,703,642 FCFA ($2,434) per hectare respectively. Hence there is no economic reason for the farmers to use chemical methods of insect control.

h. **Projected Outputs:** This year's work will lead to a consolidation of information about the use of yellow traps in insect control on green beans. The IPM package that includes the use of yellow traps is expected to remain the most cost-effective mode of insect control on green beans. A risk analysis of this IPM technology will provide insight to the variability of performance among farmers. This will involve the calculation and comparison of the variability of added benefit per hectare, marginal rate of return and other economic indicators from the use of yellow traps. This process will allow for the grouping of farmers. The characteristics and unique attributes of each farmer will then be noted.

i. **Projected Impacts:** The potential for adoption by farmers in the research area will be known, and, together with farmers' typology already in existence at OHVN, the overall adoption level by farmers and potential impact on households can be ascertained. Specific intermediate impact indicators will include the number of farmers using the yellow traps, the total crop area of application, quantities of green beans produced and sold and the resulting income generated. It is expected that the increased use of yellow traps will lead to the production of wholesome green beans that will meet the health and nutritional requirements of importing countries.

j. **Start:** October 1998

k. **Projected Completion:** September 2004

**l.** **Projected person-months of scientist time per year:** 3 person-months

**m.** **Budget:** $3,520 – IER-Sotuba; $5,063 - North Carolina A&T.

## VI. Developing a Quality Assurance Program for Peri-urban Horticulture Crops

**a.** **Scientists**: _Subactivity leaders:_ H. Traoré – LCV/Toxicology; J. Cobb, P. Hipkins, D. Mullins – Virginia Tech _Collaborating scientists:_ S. Dem, H. Maïga – LCV/Toxicology; H. McNair – Virginia Tech; K. Gamby – IER; I. Sidibé – OHVN.

**b.** **Objectives**: To provide technical laboratory support to the LCV Toxicology Laboratory and pesticide safety education to village farmers via IER and OHVN trainers in the periurban horticultural crop region of Bamako.

**Objectives for coming year**: (1) Continue to develop, refine, and practice methods for pesticide residue analysis of horticultural crops based on Malian laboratory conditions; (2) Continue training on the use and maintenance of laboratory equipment and instrumentation; (3) Work with a Malian scientist who is an M. S. candidate studying environmental chemistry at Virginia Tech in Fall 2002-Spring 2004; (4) Continue to provide training in pesticide safety education (content and teaching techniques) to IER and OHVN scientists and field technicians, so they may provide training to Malian growers; (5) Hold an in-depth training session at VT with Virginia Cooperative Extension specialists and agents re: development and delivery of VCE pesticide safety education programs for Malian educators involved in technology transfer; (6) Develop additional pesticide safety education lessons and materials; (7) Help to provide sustainable sources of equipment for pesticide application and safe handling for grower use; (8) Evaluate the quality of water used for pesticide applications; and (9) Facilitate a proactive approach towards pesticide residue testing of Malian crop exports destined for the European Union.

**c.** **Hypotheses**: (1) Developing methods for pesticide residue analysis that minimize the use of chemicals/solvents fosters sustainability; (2) Continued training on the use and maintenance of equipment and instrumentation builds professional capabilities and increases the functionality of the laboratory; (3) Training a graduate student in environmental chemistry will extend the capabilities of the LCV Toxicology Laboratory and provide useful information on pesticide residues in the environment; (4) A pesticide safety education program will help to ensure that horticultural crops meet export standards while promoting personal and environmental safety; (5) Training in extension methods and materials will expand the scope of technology transfer in Mali; (6) Additional pesticide safety lessons and program support materials will meet the needs of IER's expanding farmer field school program for vegetable producers, and also be used in production programs for field crop growers; (7) Sustainable sources of safety and application equipment will protect human health; (8) Both application technology and water quality affect pesticide efficacy, and avoiding preventable pesticide failures may prevent misuse and overexposure; and (9) A proactive approach towards pesticide residue testing of crop exports will allow pesticide safety educators to inform farmers before problems occur and will allow the LCV to implement crop testing efficiently in stages.

**d. Description of research activities**:

(1) Develop laboratory methods at Virginia Tech for potential use in Mali and provide written documentation of the results for evaluation at the LCV Toxicology Laboratory. During the annual training session at Virginia Tech, evaluate methods for pesticides in crops not tested under Malian laboratory conditions due to lack of chemicals and glassware.

(2) Continue training on the use and maintenance of equipment and instrumentation both at the LCV Toxicology Laboratory and at Virginia Tech during the annual training session. This year, training will focus on derivitization of acid herbicide samples for gas chromatography and other methods development as needed.

(3) Continue to assist a graduate student who began her studies at Virginia Tech in May of 2002. The student attended both summer sessions at the English as a Second Language Institute in the summer of 2002, and passed the TOEFL exam in August 2002. Continue to mentor the student through the academic year ending in Spring 2004 as she pursues a Master's Degree in environmental chemistry that will involve the study of pesticide residues in soil and water.

(4, 5 and 6) Continue to "fine tune" the initial eight pesticide safety lessons as needed, based on comments from IER trainers and farmers. Write additional lessons to address interests and needs identified by IER and OHVN collaborators during January 2003. Present new lessons to IER and OHVN field agents and other interested parties (export agents, Malian regulators). Include a module specifically designed to explain the capabilities of the EQL lab (residue detections) and its crop quality assurance role. Work with Malian scientists and technicians who transfer technology to farmers to continue to produce useful materials and methods, so pesticide safety education can move from initial training to continuing education. Also, through IER and OHVN, deliver lessons to a wider audience. Produce a pesticide safety 'flip chart' similar to one used to teach farm workers in the U.S.

(7) Continue to work with export agents, their professional organizations (AMELEF, APEFEL), and others to provide appropriate pesticide safety and application equipment to growers.

(8) Conduct water quality tests (pH, turbidity), assess the effects of water quality on pesticide efficacy (bioassay), and evaluate "low tech" remediation methods if experiments do indicate that the water used by Malian periurban crop producers is causing avoidable pesticide failures.

(9) Continue to meet with private organizations and government institutions involved in the export of horticultural crops. Our goal is to facilitate communication and assist in

defining a role for pesticide safety education and laboratory expertise in a quality assurance program for export crops.

**e. Justification**: The LCV Toxicology Laboratory has a comprehensive mandate, which includes pesticide residue analysis of horticultural crops and environmental monitoring. The development of cost effective pesticide residue methods and a thorough familiarity with the use and maintenance of laboratory instrumentation are important components in fulfilling this mandate. In addition, environmental studies by a Malian graduate student will expand the capabilities of the laboratory and has the potential to provide useful data about pesticides in Malian soil and water. Additional training and pesticide safety lessons for IER and OHVN trainers and other cooperators strengthens the information network and helps to improve safety and adoption of IPM technology at the village level. Development of multilingual (French and Bamanan) illustrated "flip charts" provides additional program support material for teachers who work with farmers at the village level. Facilitating a proactive approach to quality assurance of horticultural export crops, through pesticide safety education and pesticide residue testing, promotes higher quality export crops to European and U. S. markets.

**f. Relationship to other CRSP activities at site**: Pesticide safety teaching materials will assist IER and OHVN agents who train growers in farmer field schools and other production programs, and will assist in improving the knowledge base at the village level. Laboratory technical capability in pesticide residue analysis will assist IER field researchers in selecting IPM practices that improve the quality of crops destined for European and U. S. markets.

**g. Progress to date**: Training in pesticide residue analysis (techniques and use of equipment and instrumentation) continues to enhance the capabilities of the LCV Toxicology Laboratory. Pesticide safety lessons were delivered to IER researchers and field staff. Pesticide safety education is now a component of IER's FFS curriculum (which teaches IPM technologies for vegetable production to farmers) as well as part of other IER and OHVN production programs.

**h. Projected outputs**: Pesticide residue analysis conducted at the LCV will assist IER research scientists and others involved in crop quality assurance. Training an M.S. student in environmental chemistry will expand the current capabilities of this laboratory. Pesticide safety education will support Malian efforts to produce crops for export and local markets while protecting human health and the environment.

**i. Projected impacts**: Pesticide residue testing and pesticide safety education will result in front-end quality control of horticultural crops exported to European and U.S. markets. Assistance to the crop export industry will benefit the Malian economy. Adoption of best management practices for pesticides will protect growers, consumers and the environment.

**j. Start:** January 1999

**k.** **Projected completion**: June 2005

**l.** **Projected person-months of scientist time per year**: 36 person-months.

**m.** **Budget (2004-05)**: $21,504 - EQL/LCV; $106,496 - Virginia Tech. (Mission funding)

## VII. Developing Biotechnology-Based Methods to Combat Tomato Yellow Leaf Curl and Similar Viruses

**a.** **Scientist(s):** *Subactivity leaders*: R. L. Gilbertson - UC-Davis; K. Gamby, A. Théra, M. Noussourou - IER; R. Foster – Purdue *Collaborating Scientists:* K. Moore - Virginia Tech; M. N'Diaye, S. Katilé, H. Sissoko, S. Soumaré - IER.

**b.** **Overall Objective(s)**: Identification of the viruses involved in the problem and development of biotech tools for rapid detection of these viruses. The tools developed for the Mali viruses would be used in subsequent years to identify alternate hosts of the virus and possibly develop a PCR test for virus in whiteflies. Screening of germplasm for resistance to the virus complex will entail getting as many different sources of germplasm as possible to study. We will contact AVRDC and private companies (e.g., Seminis Seed [includes Royal Sluis], Novartis, Heinz Seed, and Technisem) as well as the USAID-MERC project. We may have some success with the ones we are studying; however, we are far from having a resistant variety that will work in Mali.

Characterization of the biotype(s) of *B. tabaci* on the basis of host specialization, of host efficacy of virus transmission and molecular markers. Adults and larvae of *B. tabaci* will be collected from various crop and weed plants in the areas of Koulikoro, Ségou. *B. tabaci* colonies would be established and maintained in cages under laboratory conditions. Insects from these colonies will be used to evaluate host preference (e.g., on tomato, eggplant, pepper, common bean, etc.) and their efficiency to transmit TYLCV (from tomato to tomato).

Development and implementation of an IPM plan. Cultural practices will be emphasized because they are inexpensive and can play a significant role in integrated pest management (IPM) systems targeting whiteflies. Here we would establish some pilot IPM programs in a few key locations.

**Objective (s) for coming year**:

1. Characterization of viruses involved in the tomato yellow leaf curl disease.
2. Extensive effort to obtain sources of germplasm for screening for resistance.
3. Implementation of IPM pilot plots at selected locations.
4. Develop strategy for a TYLCV host-free period.

**c.** **Hypotheses**: (1) tomato production in Mali is being attacked by a strain or strains of TYLCV and possibly by other geminiviruses transmitted by *Bemisia tabaci*) or other viruses (e.g., aphid-transmitted viruses), (2) this pest complex can be managed by a combination of reflective mulches, a tomato-free period, insecticides and resistant host cultivars (3) diseases in Mali are caused by at least two different pathogens (*Ralstonia solanacearum* and *Pythium aphanidermatum*).

**d.** **Description of Research Activity**: Characterization of viruses involved in the tomato yellow leaf curl disease. This involves biotechnological tests with the samples collected on the Gilbertson/Foster mission (January 2003), plus analysis of samples to be collected on a second trip (to be conducted in January 2004), which would include additional areas (e.g., Kati, Koulikoro, Baguineda and Cinzana). The tools to be used include DNA probes, PCR and DNA sequencing with a Malian scientist at UC-Davis. This requires a very extensive effort by a dedicated full-time person with experience in these techniques (ideally a postdoctoral researcher). In order to ensure that these skills are developed and transferred to Malian personnel, a period of training an IER specialist under the direction of this individual at UC Davis for a period of 2-3 months and possibly an additional period of training depending on outcome is planned. The output would be the understanding of the virus(es) involved, development of new biotechnological tools for their detection in tomatoes and other crops and whiteflies, and application of these tools to samples collected during the 2004 trip.

Extensive effort to obtain sources of germplasm for screening for resistance. This would involve contacting AVRDC, private companies (e.g., Seminis Seed [includes Royal Sluis], Novartis, Heinz Seed, and Technisem), and USAID-MERC. The person at UC-Davis would be responsible for this and the seeds would be available for 2003-2004 at multiple locations and, depending on the 2003-2004 results, again for 2004-2005.

Implementation of IPM pilot plots at selected locations would involve an extensive effort to test the feasibility of instituting a tomato-free period in a location such as Baguineda or Cinzana. Here we would work on establishing an agreement for a tomato-free period during September-November (this would involve the utmost collaboration between IER and their neighbors) in the general area. This is a nice spot because there is intensive agriculture in a relatively small area. Then we would use some combination of 'resistant' varieties and susceptible varieties grown in isolation or with row covers and/or systemic insecticides (twice-in the seedbed and at transplanting). The same thing would be done at another location but where no tomato-free period was used, for example, Koulikoro. We would then evaluate results from 2003-2004 and plan for 2004-2005.

US Scientists would travel to Mali in the Fall 2003 to help coordinate sample collection, variety trials, and to plan on how to institute a tomato-free period in an area. Sampling evaluation trips are planned for in January 2004.

**e.** **Justification**: Whitefly-transmitted geminivirus diseases have become limiting factors in tomato production in many parts of Africa, as well as the Middle East, southern Europe, Asia, Central America and the Caribbean. Wilt diseases and several aphid-transmitted viruses also can limit tomato production under conducive conditions. Many of these same diseases are either present or a potential threat to tomato production in both Mali and the United States. This complex has been reported to be limiting production of tomato in Mali. The emergence of this pest complex as a serious threat to tomato production is of concern to both Malian and U. S. scientists. Management of the problem is a concern of the USAID/Mali Mission and thus an appropriate focus for IPM CRSP research for periurban horticulture in Mali. USAID/Mali has, as one of its strategic objectives, the promotion of trade in agricultural goods, particularly within the region of West Africa. The other relevant strategic objective targets increased production of irrigated horticultural products. Before the outbreak of the TYLCV, Mali was a tomato exporting nation.

**f.** **Relationship to other CRSP activities at the site**: Results of biological analysis will be used as data for partial budget analysis of treatments and ultimately lead to the development of an integrated package for tomatoes.

**g.** **Progress to date**: An isolate of TYLCV from Mali (TYLCV-Mali) has been characterized on the molecular level and is being used as a DNA probe. Hybridization studies established that tomatoes with virus symptoms from all surveyed locations were infected by geminivirus and most were infected with TYLCV-Mali. Field plots were established for evaluation of the insecticides Admire and Platinum and TYLCV-resistant and tolerant varieties. Insecticide treatments provided protection against whiteflies and a number of varieties provided good yields and had reduced virus infection.

**h.** **Projected Output(s):** Identification of the best combination of practices and varieties to reduce damage due to the insect-transmitted virus disease complex of tomato under local conditions.

**i.** **Projected Impacts**: Reduction of losses due to the insect/virus complex that is currently limiting tomato production in Mali, and increased income to farmers and increased exports for Mali.

**j.** **Projected Start**: October 1998

**k.** **Projected Completion**: September 2004

**l.** **Projected Person-Months of Scientists Time per Year**: 4-5 months

**m.** **Budget:** $17,270 – IER-Sotuba; $5,995 – IER-Cinzana; $9,000 - University of Mali; $59,976 - UC-Davis; $5,720 - Purdue; $5,300 - Virginia Tech.

## VIII. Training of OHVN, OPIB, DNAMR, Exporter and NGO agents in IPM for Technology Transfer

**a.** **Scientists**: *Subactivity leaders*: K. Gamby, H. Sissoko - IER; I. Sidibé - OHVN; C. Harris, P. Hipkins - Virginia Tech; R. Foster – Purdue *Collaborating scientists:* A. Théra, M. N'Diaye, A. Kanté - IER.

**b.** **Objectives**: To increase the number of trained technicians for continued and more efficient training of farmers in IPM technologies for urban green beans.

**Objective for the coming year:** To train field technicians of OHVN, DNAMR, exporters, and NGOs to continue farmer training in IPM technologies for green beans by adapting the Farmer Field School (FFS) methodology to a more efficient model.

**c.** **Hypothesis**: The training of field technicians (future trainers) will permit adapting the FFS approach, which permits the quick introduction, dissemination, and adoption of IPM technologies on the farm to much larger numbers.

**d.** **Description of research activities**: Twelve technicians from OHVN (from ten villages), one DNAMR (Direction Nationale d'Appui au Monde Rurale), six exporter agents, five from OPIB (Office du Périmetre Irrigué de Baguineda) will be trained in IPM technologies, pesticide safety education and information on HIV/AIDS at Baguineda training center for six weeks, two months before the green bean season. Six agents will remain for the additional two weeks to complete the Training Manual.

The program of training will include trials which permit participants to have directed experiences implementing and monitoring crop production using IPM technologies and local farmer practices on a weekly basis, as well as theoretical elements concerning training techniques and general IPM principles. The future trainers will learn to recognize pests, stages of plant development, cultural practices with or without mineral and/or organic fertilizers. An IPM green bean manual will be produced for use in training farmers. At the end of the training each participant will receive a certificate of learning and a copy of the IPM manual.

The methodology of the training will be focused especially on developing trainer skills and approaches suited to illiterate farmers and to women. These approaches will use less oral explanations and greater levels of participant observation in order to maximize comprehension for this group of participants.

**e.** **Justification**: Experimentation with the Farmer Field School approach in years 8 through 10 suggests that this method will improve the production of horticultural crops and speed the introduction and adoption of IPM technologies. For the spreading and the sustainability of IPM technologies learning via FFS we need to deliver training to a wider public of trainers (field technicians).

**f.** **Relationship to Other CRSP Activities at Site**: This activity is the result of the previous and ongoing Farmer Field School program and research conducted on green bean IPM technology.

**h.** **Progress to date**: None

**i.** **Projected Outputs**: We expect that increased numbers of fields technicians trained in improved technology transfer approaches will lead to increased numbers of growers adopting IPM techniques resulting in improved yields, higher quality, less pesticide use, and greater returns.

**j.** **Projected Impacts**: Higher yields, lower pesticide costs and residues, reduced pest losses, more stable supply, and improved exportability of green beans and other horticultural produce.

**k.** **Start:** September 2003

**l.** **Projected Completion**: September 2004

**m.** **Projected person-months of scientist time per year**: 9-10 person-months.

**n.** **Budget**: $24,640 – IER-Sotuba; $1,584 - OHVN; $5,300 - Virginia Tech.

## IX. Survey of the State of Knowledge Concerning Geminiviruses and Whiteflies in the Sahel

**a.** **Scientists:** *Principal investigators*: A. Diarra - CSP/INSAH; K. Gamby - IER; R. Foster - Purdue; R. Gilbertson - UC-Davis; K. Moore - Virginia Tech. *Collaborating scientists*: To be Identified.

**b.** **Status**: New

**c.** **Objectives**: To determine the state of knowledge concerning geminiviruses and whiteflies in West Africa and document the incidence of these pests and the strategies used to combat them.

**d.** **Hypothesis**: It is likely that the experiences of researchers in other countries will provide important information to share concerning incidence and treatment.

**e.** **Description of research activity**: A review of the state of the art (published and grey literature, websites, scientist interviews, etc.) will be conducted by a national researcher in each of the CLISS countries (Niger, Burkina Faso, Senegal, Chad, Mauritania, Gambia, Cape Verde, and Guinea Bissau) and reports forwarded to the CSP offices in Bamako for review and synthesis.

**f**. **Justification:** Scattered reports and anecdotes suggest that geminiviruses and whiteflies are the major pest problem throughout West Africa. Lessons are accumulating about pesticide resistant strains, pest resistant varieties, and methods of treatment. These lessons need to be consolidated in order to develop a region-wide strategy for control.

**g**. **Relationship to other CRSP activities**: This activity supports the experimental research being conducted on resistant varieties and treatment methods.

**h.** **Progress to date**: None.

**i**. **Projected outputs**: A country-by-country report and regional synthesis consolidating geminivirus and whitefly knowledge in the Sahel.

**j.** **Projected impacts:** Improved and better coordinated methods to combat geminiviruses and whiteflies.

**k.** **Project start**: October 2003

**l**. **Project completion**: September 2004.

**m.** **Projected person-month of scientist time**: 4-5 months.

**n.** **Budget**: $6,050 - CSP/INSAH; $2,090 - IER-Sotuba.

## X. Site Coordination

Site coordination will be the responsibility of K. Gamby (Site Coordinator, IER) and K. Moore (Site Chair, Virginia Tech).

**Budget**: $11,220 – IER-Sotuba; $12,706 - Virginia Tech

## Site Activity Summary – West Africa – Year 11

| | Activity | Scientists | Budget |
|---|---|---|---|
| I. | Positioning Stakeholders to Capitalize on Marketing Opportunities | Gamby (IER), Sidibé (OHVN), Moore (VT), Yeboah (NCAT) | $23,019 |
| II. | Transferring Integrated Weed Control Strategies | N'Diaye (IER), Westwood (VT) | $18,242 |
| III. | Promoting Adoption of Innovative Techniques for Striga Management | Dembélé (IER), Westwood (VT) | $2,640 |
| IV. | Disseminating Green Bean IPM Packages Through FFS | Gamby, Théra, N'Diaye (IER), Foster (Purdue) Sidibé (OHVN) | $6,380 |
| V. | Assessing the Impact of IPM Packages | Yeboah (NCAT), Sow (IER) | $8,583 |
| VI. | Developing a Quality Assurance Program (funded by USAID-Mali) | Traoré (LCV), Cobb, Hipkins, Mullins (VT) | $128,000 (USAID-Mali) |
| VII. | Developing Biotechnology Methods to Combat TYLCV and Similar Viruses | Gilbertson (UC-Davis), Gamby, Théra, Noussourou (IER), Foster (Purdue) | $103,261 |
| VIII. | Training of Extension Agents in IPM for Technology Transfer | Gamby, Sissoko (IER), Sidibé (OHVN), Harris, Hipkins (VT) Foster (Purdue) | $31,524 |
| IX. | State of Knowledge Concerning Geminiviruses and Whiteflies in the Sahel | Diarra (CSP/INSAH), Gamby (IER), Foster (Purdue), Gilbertson (UC-Davis), Moore (VT) | $8,140 |
| | Site Management | Moore (VT) | $23,926 |
| | **GRAND TOTAL BUDGET** (excluding Activ #VI) | | **$225,715** |

# YEAR 11 WORKPLAN FOR THE EASTERN AFRICA SITE IN UGANDA

Year 11 IPM CRSP activities at the African Site in Uganda were derived from discussions with USAID/Kampala and USAID contractors over the past year. These discussions focused on activities that would support USAID/Kampala's Strategic Objective 7: Expansion of Sustainable Economic Opportunities for Rural Sector Growth. The rationale behind this objective is that increasing agricultural productivity in Uganda will be the primary strategy for reducing poverty and that this must be realized from a sustainable use of natural resources. The goals and objectives of integrated pest management are well suited to complement and support this rationale. Among the broad-based priority activities suggested were: transfer of improved agricultural technologies to farmers; promotion and improvement of Uganda's capacity to expand production quantity and quality of key commodities; utilization of biotechnology; and impact assessment. The activities described in the Year 11 workplan supplement these suggestions and support SO-7.

Activities proposed in the workplan adhere to previous topical areas with emphases adjusted to incorporate innovative approaches and suggested priorities. Building on the participatory approach to IPM that early in the project's history delineated farmer-driven priorities, research activities to refine and disseminate IPM strategies for cowpea, groundnuts, and sorghum to farmers will be scaled up. Corresponding with this topical area will be activities to promote management of post-harvest pests of cowpea, enhance the activity of natural enemies to provide sustainable management of groundnut and cowpea pests, and a classical biological control effort to manage groundnut leafminer. IPM research activities will be concluded on tomato including grafting tomatoes on wilt resistant indigenous rootstocks, a best-practices package selected by farmers and demonstrated to new farmer groups in Mpigi District. The development of IPM practices for legume and horticultural crops is important because the production of these crops is associated with excessive use of pesticides.

Uganda's Plan for Modernization of Agriculture (PMA) and USAID/Kampala are supporting the production of export and locally marketed crops to enable farmers to move from subsistence to commercial agriculture. Several activities will be undertaken to improve Uganda's capacity in this area. The Ministry of Agriculture and Makerere University, in collaboration with HORTEXA (Horticultural Export Association), will support growers of hot peppers with IPM research and training to improve quality and safety by reducing pesticide use. Pest and disease diagnostic capacity at Makerere University will be strengthened to contribute to pest risk assessments. Demand-driven pesticide use and safety training programs conducted by NARO and Faculty of Agriculture staff for growers and National Agricultural Advisory Service providers will be continued. A PhD research effort nearing completion will be applied to developing and disseminating improved maize quality standards, as established by the Uganda National Bureau of Standards (UNBS), to Uganda Grain Traders' Ltd (UGTL).

In support of USAID/Global Bureau and bi-lateral Mission initiatives to support the application of biotechnology to alleviate hunger and poverty, IPM CRSP Uganda site work that cuts across several areas of emphasis will be continued or implemented. Work on developing simple sequence repeat (SSR) molecular markers to select QTLs conferring resistance to multiple foliar diseases of Quality Protein Maize will be continued by collaborating Ugandan, CIMMYT and OSU scientists, and a Ugandan graduate student at OSU. A seven-month sandwich training program conducted simultaneously with research in Uganda will focus on identifying and characterizing viruses and germplasm of passion fruit (*Passiflora edulis* Sims.), a potentially important export crop, using molecular biotechnology tools. Several biotechnology applications will be applied to support the IPM CRSP Uganda site's emergency response to the integrated management of coffee wilt (*Fusarium xylarioides*). Coffee remains Uganda's most important export crop and the coffee wilt effort has been supported by USAID/Kampala with a match from the IPM CRSP ME.

Finally, Year 11 activities will continue with a series of socioeconomic analyses that address impact assessment, adoption and market analysis. Additional studies on dissemination activities with cowpea, groundnuts and sorghum will compare the impact of two dissemination approaches including farmer field schools and demonstration trials.

Year 11 activities will continue to be conducted by a multi institutional and disciplinary team of US and Ugandan based scientists. In Uganda, the IPM CRSP research team is composed of scientists from each of the major research institutions located in the country, including Makerere University's Faculty of Agriculture, and four research institutes associated with the National Agricultural Research Organization (NARO): Kawanda Agricultural Research Institute (KARI), Namulonge Agricultural Research Institute (NARI), the Serere Agricultural and Animal Research Institute (SAARI), and the Coffee Research Institute (CORI). On-farm research activities are facilitated by extension agents and farmer associations at research sites in Iganga, Kumi, Mpigi and Pallisa districts. Four Ugandan graduate students will be contributing and completing their research efforts.

The eight collaborating research scientists from the USA are drawn from three institutions: Virginia Tech, Ohio State University and Fort Valley State College. This multi-disciplinary and institutional effort is coordinated by the Site Chair located at Ohio State University, the Site Coordinator located at Makerere University and the Deputy Site Coordinator located at NARI. Additional institutions contributing to the IPM CRSP research effort in Uganda are the Rockefeller Research Forum and the International Center for Insect Physiology and Ecology (ICIPE). Four IARCs are participating through germplasm contributions including IITA, CIP, ICRISAT and CIMMYT/Zimbabwe.

## I. Integrated Pest Management for Commercial Legume Crops

### I.1. Dissemination and adoption of cowpea and groundnut IPM technologies

**a.** **Scientists:** E.Adipala, S. Kyamanywa, A.R. Semana, M.Amujal, C.Asekenye – Makerere University; M. Erbaugh – Ohio State University; G. Luther, D. Taylor – Virginia Tech; C. Iceduna, V. Odeke, District Agricultural Officers – Pallisa and Kumi, respectively; graduate and undergraduate students – Makerere University. **Collaborators:** Rockefeller Foundation - cost sharing on graduate students for networking and scaling-out, NAADS - enhancing capacity of service providers' delivery of advisory services related to IPM and technologies generated under IPM CRSP

**b.** **Overall objectives:** (1) To reduce and rationalize pesticide use application on cowpea and groundnut in eastern Uganda, and increase profit margins for the farmers while ensuring environmental sustainability; (2) To scale up dissemination and adoption of IPM menus for increased cowpea and groundnut production. **Objectives for the coming year:** (1) To evaluate farmer adoption of cowpea and groundnut IPM technologies; (2) To assess the influence of extension and farmer-led farmer field schools on knowledge of IPM; (3) To develop effective management options for cowpea yellow blister disease; (4) To search for sources of resistances to diseases and yield among new cowpea germplasm introduced from IITA; (5) To enhance capacity of service providers (extension service) in IPM principles, concepts and dissemination of IPM CRSP-developed technologies.

**c.** **Hypotheses:** (1) Knowledge of cowpea and groundnut IPM technologies leads to adoption; (2) Extension-led farmer field schools perform better than farmer-led farmer field schools; (3) Yellow blister disease management strategies developed are more effective than farmers' management practices; (4) The elite introductions from IITA perform better than the local cowpea genotypes (ebelat and icirikukwai) in terms of disease resistance and yield; (5) Agricultural service providers' (extension) knowledge of IPM and dissemination is better after workshop and field clinics.

**d.** **Description of research activity**.

(1) Assessing adoption: Assessing adoption of cowpea and groundnut IPM technologies and impact on farmers' livelihood will be continued. The project will initiate groundnut adoption studies in Kumi, Pallisa and Iganga districts. This will be done by use of questionnaires. Questions designed to assess adoption will include farmers' practices on use of improved variety, use of 2-3 sprays, date of planting and use of recommended spacing of 45cmx15cm. Farmers' reasons for practicing or rejecting a particular technology will be recorded.

(2) Scaling out cowpea and groundnut IPM technologies: There is a need to scale out cowpea and groundnut IPM technologies in 2 sub-counties in Kumi and in 2 Pallisa districts using extension and farmer-led farmer field school approaches. For each commodity, 2 new farmer field schools will be established: 1 will be extension-led and the other farmer-led. The facilitator for the farmer-led schools will be identified from those farmers trained during the IPM CRSP farmer field schools in years 8 and 9 for the integrated crop management of these crops. In Iganga and Mayuge, only groundnut schools will be established; the farmer-led school will be based in Iganga and extension-led school in Mayuge. The design of the fields will be a split-plot arrangement of a randomized complete block design (RCBD). The two varieties in the case of cowpea (M.U 93 - an improved line being recommended by IPM CRSP, and a local cultivar) will be the main plots while the spray regimes (no spray, 3 sprays, 8 sprays) will be the sub-plots. Each sub-plot will measure 10mx10m with plant spacing of 60cm between rows and 20cm between plants. All the plots will be planted at the onset of rains except for the farmers' plot where activities will be as commonly practiced at the farmers' pace and time. For the spray regimes, no spray will be the control, 3 timed sprays (the IPM recommendation), and 8-10 sprays (farmer's commercial practice) (Karungi et al, 1998). The split plot will facilitate farmers' easy identification and comparison of the different

spray regimes, pest resistance and yield attributes between the improved and local varieties.

(3) Screening of introduced cowpea germplasm: This activity will involve evaluation of the recent cowpea germplasm introduction from IITA, Nigeria. This will be done at MUARIK. The entries (approx 50) will be grown together with 48 advanced selections of year 10 as single row plots (3.5m) of RCBD replicated twice. This will be done for two seasons (second rains of 2003 and first rains of 2004).

Multi-location evaluation of 10 elite cowpea lines. This on-farm trial will be established in yellow blister disease hot spots in 3 sites in Kumi and Pallisa. Ten elite cowpea lines identified in earlier trials will be grown in 5x5m plots, in a RCBD, with each farmer (location) serving as a replicate.

(4) Training of Advisory Service Providers**.** Under the current Uganda government policy of privatizing agricultural extension services, farmers have identified IPM as a key area where they need training. They have also selected groundnuts and horticultural crops as some of the enterprises for which they wish to contract service providers to deliver advisory (extension) services. In collaboration with the National Agricultural Advisory Services (NAADS), training on skill development for IPM, groundnut and horticultural production is proposed. Three trainings will be held in Iganga and the farmer field schools established in Iganga, Pallisa and Kumi will be used as field clinics.

**e.** **Justification:** A key constraint to adoption of IPM packages in Africa is reliance on traditional methods of technology transfer. Increasing farmer participation in the development and implementation of IPM programs is a strategy for overcoming these constraints. The sociological significance of this study rests on the application of diffusion theory to the adoption of IPM in Uganda (Rogers, 1995), which pre-supposes that knowledge is a necessary step in the adoption process. Farmers need to know the presence of cowpea IPM technologies so that they can adopt. Work in years 9 and 10 has shown that knowledge and awareness of cowpea IPM technologies has led to some adoption among the trained farmers. However, the coverage was limited to a few farmers in a few sub-counties of each district (Kumi and Pallisa). For wider adoption and impact, there is need to scale-out of the initial project sites so as to create wider awareness of the technologies and, hence, facilitate wider adoption. Furthermore, in years 9 and 10, traditional extension agents of the Ministry of Agriculture and research scientists were used to facilitate the farmer field school. Experience thus far indicates that the farmers trained in farmer field schools are capable of facilitating farmer field schools. Also there is need to train NAADs service providers (who have replaced the traditional extension staff) on IPM so as to equip them with skills to be able to facilitate IPM training sessions. To further improve cowpea production, the cowpea germplasm base needs to be broadened for production and breeding purposes.

**f.** **Relationship to other CRSP activities at the site:** (1) The proposed studies build on the ongoing work of dissemination of cowpea and groundnut IPM technologies in Kumi, Pallisa, Iganga and Mayuge districts. The proposed work will complement the ongoing studies by identifying strategies for managing crop diseases, specifically yellow blister disease. (2) A curriculum has been developed and is available for application to the wider farming community. (3) Previous work has characterized 200 cowpea germplasm accessions and selected 48 for further evaluation. Ten advanced selections are also available for multi-location testing.

g. **Progress to date:** (1) In years 9 and 10, six farmer field schools were established for cowpea and nine for groundnuts. Pre- and post-test interviews were done on all cowpea and groundnut farmer field school farmers to assess their knowledge of IPM. Adoption and evaluation studies have also been initiated for cowpea farmer field schools but not for groundnuts. Farmer evaluation of M.U.93 and Ebelat (cowpea varieties) were initiated in years 9 and 10. (2) Four papers were published in the African Crop Science Society Conference Proceedings of 2001. (3) Two journal publications (Nabirye et al. in Crop Protection) and three more (2 Amujal et al. and 1 Erbaugh et al.) have been submitted to international journals. (4) One MS student has completed his studies (J Nabirye) and a second (M Amujal) is due to complete in September, 2003

h. **Projected outputs:** (1) About 300 farmers in Kumi, 300 in Pallisa, 100 in Iganga and 100 in Mayuge and 50 service providers will acquire knowledge and skills concerning cowpea and groundnut IPM technologies and 3 graduate and 3 undergraduate students will be trained. (2) Extension materials for disseminating knowledge-intensive technologies and reducing pesticide use will be developed. (3) Germplasm for disease and pest resistance and yield will be identified. (4) Six papers will be presented during the 6$^{th}$ African Crop Science Conference, October 12 – 17, 2003.

i. **Projected Impacts:** (1) Reduced usage of pesticides on cowpea and groundnuts. (2) Reduced cost of production and increased yield of cowpea and groundnuts and thus increased income to farmers. (3) Enhanced farmer decision-making capacity for farm management and incorporation of IPM technologies learned into other farming practices. (4) More access by farmers to advisory services from NAADS since they are already in groups and have selected income-generating crops.

j. **Project start:** October 2003

k. **Projected Completion:** September 2004

l. **Projected Person Months of Scientist Time Per Year:** 3

m. **Budget:** $12,551 – Makerere; $4,410 – OSU; $4,342 – VT

**I.2. Integrated field management of *Callosobruchus maculatus* on cowpea using pheromone baits, cypermethrin and tobacco extracts, and improved insect resistant varieties (Yr 11 Priority: Technology development wrap-up)**

**a. Scientists:** J.A. Agona-NARO, S. Kyamanywa, Adipala Ekwamu – Makerere University; G. Mbata – Fort Valley State University; C.A. Fatokun – IITA

**b. Overall Objective:** To reduce and/or control cowpea losses due to podding pests, including bruchids, in the field. **Objectives for coming year:** To determine the (1) onset of *C. maculatus* infestation on cowpea in the field using pheromone baits, (2) effectiveness of Cypermethrin-Pheromone-Tobacco application regimes in controlling *C. maculatus* field infestation of cowpea, and (3) the effectiveness of selected improved insect pest- and disease-resistant cowpea varieties against bruchids.

**c. Hypotheses:** (1) The integration of pheromone baits will optimize the effectiveness of field management of *C. maculatus* on cowpeas using synthetic insecticides and biorationals, and (2) improved cowpea varieties are less susceptible to bruchid infestation during storage.

**d. Description of Research Activity:** Laboratory bioassay will be conducted with olfactometers to determine the effectiveness of the pheromones on *C. maculatus* males from Uganda. On-station trials will be conducted in two locations (Kawanda and Kabanyolo) to validate the effectiveness of a synthetic pheromone bait (to be supplied by Dr Mbata) in entrapping *C. maculatus* males using suitable dispensers. Different types of dispensers will be evaluated. The information obtained on pheromone baits will be used to determine the onset of *C. maculatus* infestation of cowpeas in the field, and thus necessitating application of bio-pesticides. A synthetic insecticide, Cypermethrin, will be applied at budding, pod formation and filling stage to control thrips, pod suckers and borers. Tobacco extracts will be applied at pod maturity and harvest maturity. The level of *C. maculatus* population reduction on stored cowpea seeds will determine the success of the different treatment methods. Screening for bruchid resistance of 5 selected improved cowpea varieties from IITA will be conducted both in the field and in storage.

**e. Justification:** Previous IPM CRSP work has demonstrated that there is significant reduction in bruchid load when some selected insecticides and biorationals are applied in the field. The methods, however, do not confer 100% reduction in damage levels of stored cowpea seeds. One of the problems encountered in using insecticides or biorational, is the timing of the application schedules. It is therefore important that a versatile method that permits detection of onset and peaks of bruchid infestation is incorporated into the field management package in order to allow for the timely application of environmentally sound and sustainable bruchid control methods.

**f. Relationship to other CRSP activities at the site:** This activity is related to other IPM CRSP research, development and application activities on cowpeas in Uganda.

**g. Progress to date:** Cypermethrin and tobacco extracts have been found to have significant reduction on bruchid damage on stored cowpeas. Sources of sex pheromone and improved cowpea varieties have been identified.

**h.** **Projected Outputs:** Bruchid load carryover from the field into storage will be significantly reduced and, therefore, increase shelf life of stored cowpea seeds; new improved bruchid- esistant cowpea varieties will be identified, multiplied and distributed to farmers.

**i.** **Projected Impacts:** Livelihoods of farmers improved in terms of food security, good nutrition and raised incomes.

**j.** **Project start:** October 2003.

**k.** **Project Completion:** September 2004.

**l.** **Projected Person-Months of Scientist Time per Year:** 3

**m.** **Budget:** $7,110 – NARO/MUK; $6,900 – FVSU

### I.3. Biological control of cowpea pests and groundnut leafminer in Uganda (Yr. 11. Priority: Technology Development wrap-up)

**a.** **Scientists:** S.Kyamanywa, T.M.B.Munyuli – Makerere University; G. Luther – Virginia Polytechnic and State University; R. Hammond – Ohio State University

**b.** **Objectives:** The overall objective is to develop IPM strategies that reduce and rationalize pesticide usage and promote ecologically sustainable production systems on cowpea in eastern Uganda. Specific objectives: (1)Development and evaluation of methods of enhancing native natural enemies of pests of cowpea in Uganda, and (2)Exploration of classical biological control in management of groundnut leafminer.

**c.** **Hypotheses:** (1) Manipulation of traditional and modern farming systems/practices can increase the population density and effectiveness of natural enemies of cowpea pests in Uganda. (2) Leafminer is an exotic pest of groundnut in Uganda that can be managed through classical biological control methods.

**d.** **Description of Research Activity:** This activity is subdivided into two sub-activities. (1) Assessment of different methods for the enhancement of native natural enemies. Two approaches will be used to try and increase natural enemy activity in a cowpea crop. The first approach will include use of a trap crop and intercropping cowpeas with greengram. The treatments will be (a) a Trap-crop (pigeon pea short term varieties) planted around and in the cowpea crop, (b) intercropping of cowpea with greengram, and (c) application of natural enemies' attractant food (envirofeast). These will be evaluated for their capacity to maintain and increase natural enemies (predators and parasitoids) population densities, in a completely randomized block design with four replications. The work will be conducted at MUARIK and Kumi district, eastern Uganda. The second approach will involve varying pesticide application methods to preserve the natural enemies. The treatments will include (a) insecticide application based on the economic injury level for pests, (b) application of insecticide in strips, (c) farmers' dose, and (d) a control where no pesticides will be applied. A randomized complete block design with four replications will be used. The study will be also conducted at MUARIK and in Kumi district. Population densities of beneficial arthropods will be sampled at weekly intervals.

(2) Exploring of classical biological control in management of groundnut leafminer. In collaboration with ICIPE, we will explore use of a classical biological control program to manage groundnut leafminer. ICIPE will assist in identifying the appropriate parasitoids from the country of origin, importing them and rearing them until ready for release. This will be in collaboration with the biological control unit of Namulonge Agricultural Research Institute (NAARI). The effectiveness of these biological control agents will be evaluated under laboratory and field conditions. Parasitism (%) will be evaluated.

**e**. **Justification:** A diversity of predators (*Cheilomenes lunata*, *Syrphus* sp., *Forficulata auricularia*, *Orius* sp., Staphylinidae, *Oxyopes* sp., *Lycosa pseudoannulata and Mantis religiosa* ) and parasitoids (B*raconidae, Tachinidae, Aphidius* spp) have been identified in cowpea fields during year 9 and 10 surveys. *C. lunata*, *Syrphus* sp., *F. auricularia*, *L. pseudoannulata* and *M. religiosa* were observed to be effective in controlling cowpea pests, under cage and laboratory experiments. The presence of predators and parasitoids in fields indicated that they were controlling the pests. The problem, however, is that use of pesticides was found to reduce the population of natural enemies significantly. There is, therefore, a need to protect the natural enemies and augment their population. This study will evaluate methods and practices that can enhance natural enemies in cowpea fields. Leafminer (*Aproarema modicella*) is an exotic pest of groundnut in Uganda, which was first reported in 1997. Control of leafminer using insecticide has been found to be ineffective in eastern Uganda (Epieru, personal communication). Also, high incidence of leafminer has been observed in several parts of the world where insecticides are applied to control it. IPM CRSP studies have indicated that the indigenous generalist predators were not feeding on the leafminer. Classical biological control, therefore, appears to be the appropriate strategy for controlling the leafminer.

**f**. **Relationship to other research activities at the site**: The research components in this activity focus on reducing dependence on insecticides through the development and implementation of an integrated pest management program for cowpea and groundnut. This activity will complement other ongoing IPM CRSP activities on groundnuts and cowpeas.

**g**. **Progress to date:** Two seasons of data (2001-2002) have been collected on the impact of cropping systems and insecticides on the population density and diversity of natural enemies (parasitoids and predators). Data for feeding behavior of different predator species, through laboratory and cage experiments, has been collected for two seasons during years 9 & 10. The work was presented at the international conference on IPM in sub-Saharan Africa in September, 2002.

**h.** **Project output:** (1) Recommendations on rational use of biological control agents for managing leafminer. (2) Strategies for the integration of biological agents into IPM systems for Uganda. (3) Methods/practices for enhancing natural enemies and yield in cowpea agro-ecosystems.

**i.** **Project Impacts:** (1) Reduced usage of pesticides in rural areas of eastern Uganda. (2) Reduction of leafminer incidence in Eastern Uganda. (3) Increased usage of biological control agents in groundnut pests management.

**j.** **Project Start**: October 2003

**k.** **Project Completion**: September 2004

**l.** **Projected Person-Months of Scientist Time per Year**: 3

**m.** **Budget:** $6,600 – Makerere University; $4,214 – Virginia Tech

## II. Integrated Pest Management for Important Cereal Crops Associated with Farming systems in Eastern Uganda

### II.1. Biotechnological approaches to improve disease management strategies in quality protein maize in Uganda (Year 11 Priority: Biotechnology)

**a.** **Scientists:** G. Bigirwa – NARO/NAARI; R. Edema; E. Adipala – Makerere University; R.C. Pratt; P.E. Lipps – OARDC-OSU; R.G. Asea – Graduate Student OARDC-OSU. **Collaborators:** K. Pixley – CIMMYT

**b.** **Overall Objectives:** (1) Enhance sustainability of maize production in mid- and high-altitude agro-ecosystems by improvement of host resistance to the leading foliar diseases: maize streak virus (MSV), northern leaf blight *Exserohilum turcicum* (NLB), and, gray leaf spot (GLS) *Cercospora zeae-maydis*. (2) Improve human nutrition in East Africa by developing a disease-resistant synthetic variety with enhanced nutritional quality; i.e. the quality protein maize (QPM). **Objective for the coming year:** Utilize simple sequence repeat (SSR) molecular markers to select QTL conferring foliar resistance to MSV, NLB and GLS and the QPM trait in maize kernels.

**c.** **Hypotheses:** (1) QTLs for GLS, MSV and NLB resistance can be verified and shown to be heritable in a QPM genetic background. (2) The QPM trait also can be selected using MAS while concomitantly selecting for multiple disease resistance QTL. (3) Molecular markers can be used successfully to integrate multiple disease resistance loci into a synthetic population enriched in the *opaque-2* locus using MAS.

**d.** **Description of Research Activity:** In order to develop multiple disease resistance traits in an efficient and expedient manner, farmers/scientists are often confronted by uncertain disease development at specific sites, high logistical or resource demands, coupled with limited resource availability. Variable disease expression due to environmental variation or complex inheritance due to control of resistance by multiple or recessive genes can make selection difficult or impossible during some seasons. To resolve this dilemma, we propose utilization of a biotechnological approach (marker assisted selection) and experimental designs that address these issues. In addition, we merge selected materials coming from the IPM CRSP special biotechnology grant on maize in Uganda with QPM crosses arising from the same resistance donor (CML202) in the CIMMYT program. Cooperative research at multiple locations also should enable this research to be undertaken in an expedient and cost-efficient manner.

There is a strong need to expand the mid-altitude-adapted QPM germplasm base. CIMMYT has initiated pedigree and backcross projects with elite lines and QPM lines. Partially inbred progenies ($S_3$) are now available from CIMMYT/Zimbabwe. We propose conducting MAS for the opaque-*2* locus, msv1 (confers MSV resistance) and NLB resistance QTL in CIMMYT population CML202 x CML176. CML176 is a white flint inbred adapted to sub-tropical regions that displays a particularly high level of tryptophan, an essential and limiting amino acid for human nutrition. CML202 (NLB and MSV resistance donor) has previously been used at OARDC in crosses with a GLS resistant line selected from our earlier research with the South African inbred VO613Y.

In separate IPM-sponsored biotechnology research, we will confirm molecular markers to resistance loci for NLB and MSV that have been reported in CML202 (Welz et al, 1998), and in VO613Y for GLS (Gordon et al, 2001), by mapping loci in a population derived from the cross between VP31 (GLS resistant, MSV and NLB susceptible) with CML202 (MSV and NLB resistant). SSR molecular markers will be used to select resistance loci and opaque-2 markers developed at CIMMYT to select these traits in the CML202 x CML176 progenies. It is estimated that it will be necessary to select for the following number of loci (MSV: 1 minimum; GLS, 2 minimum; NLB, 3 minimum; and rust: unknown - 1 minimum) in addition to selection for the opaque 2 locus. In total, the development of the desired breeding material will necessitate the selection of 8 loci. In order to have a reasonable chance of securing lines with a high frequency of the favorable loci, it would be necessary to have large population sizes. Because the heritability of these traits is moderate, it is also necessary to replicate across environments to assure accurate phenotypic classification. The requirements for population sizes and replication make the scale of the proposed work rather daunting, and for that reason we feel it is critical to develop the MAS strategy and a collaborative approach to optimize field-testing.

It is our intention to combine multiple disease resistant breeding lines obtained from the cross of VP31 x CML202 (Special Biotech project) with superior breeding lines containing QPM traits and disease resistance from the CML202 x CML176. All of the lines will be selected using MAS. The breeding lines arising from each population will also be pre-selected for CML202 background in the VP31 x CML202 cross and for the CML176 background in the CML202 x CML176 to ensure that sufficient diversity will be manifested following re-synthesis of an open-pollinated population by inter-crossing them. The breeding lines, following additional testing, will constitute highly desirable candidates for inclusion in the parentage of synthetic QPM varieties for production in the mid- and high-altitude production regions in Africa.

The plan is to determine disease resistance phenotypic values for approximately 500 segregating $S_3$ progenies at 3 locations using an augmented design. The locations will include Ohio, CIMMYT-Zimbabwe or Kenya, and Uganda.

To further build capacity for biotechnology research in eastern Africa, it is proposed to hold a 3-day workshop in Uganda to share experiences, give hands-on training, and develop a forum for future collaborative research and networking.

**e.** **Justification:** The development of QPM maize started with the discovery of a gene called *opaque2* that resulted in maize kernels with elevated levels of two essential amino acids, lysine and tryptophan. Early varieties of maize with the *opaque2* mutation suffered from numerous problems, including lower yields and soft endosperm that was associated with increased susceptibility to pests and diseases. Following considerable research and breeding efforts, CIMMYT researchers were able to find modifier genes that restored the desirable hard endosperm phenotype in *opaque2* genotypes. Selected lines with improved agronomic and nutritional characteristics came to be known as Quality Protein Maize (QPM). Recently, CIMMYT scientists were awarded the prestigious World Food Prize for their efforts to create this new kind of maize that could improve nutrition for millions of people worldwide (www.cimmyt.org).

The best QPM genotypes make possible improved human and food animal nutrition, but they are susceptible to economically important diseases and poorly adapted to the mid- and high-altitude maize producing regions of Sub-Saharan Africa. Turcicum leaf blight (TLB) incited by *Exserohilum turcicum* and gray leaf spot (GLS), incited by *Cercospora zeae maydis*, occur throughout maize producing regions of the U.S. and Africa. Maize streak virus (MSV) is a devastating disease of maize in Africa, and QPM materials are highly susceptible (BOSTID, 1988).

Gray leaf spot, maize streak virus, and Northern leaf blight are the three major foliar maize diseases in Uganda. Considerable efforts are being made by the National Research Programs (NARO and Makerere) in collaboration with scientists from other institutions like OARDC-USA and CIMMYT to address these diseases. Several control and management options have been tried, but host resistance is the most cost effective for the majority of farmers in the country. Conventional breeding takes a long period of time and is not as precise as new biotech tools, which are readily available in advanced laboratories. These new tools will be employed to help in the selection and identification of sources of resistance for use in improving the elite materials in Uganda.

**f.** **Relationship to other activities:** The proposed work will create synergy with the ongoing studies of identifying multiple disease resistance in the special biotechnology project wherein multiple disease resistant lines are being selected in a non-QPM background. This project will allow us to utilize those lines in crosses with the lines selected from this project and generate parental lines that are candidates for inclusion in an open-pollinated synthetic variety. It will also support the training of one Ugandan PhD student currently at Ohio State University, and provide a forum for future collaborative research and networking.

**g.** **Progress to date:** The graduate student (S. Gordon) completed the research and analysis on the initial QTL mapping effort using selective genotyping. Two resistance QTLs appear to be different than those reported in the US. A manuscript describing the above results has been submitted to the Crop Science journal. Another graduate student (Asea Godfrey) has successfully completed his first year of study at OSU. Segregating lines have been planted from the cross VP31 x CML 202. Parental genotyping has yielded 78 polymorphic loci thus far. The manuscript on epidemiology of GLS in a tropical environment has been published in the *Annals of Applied Biology* (Asea, G., G. Bigirwa, E. Adipala, S.A.P. Owera, R.C. Pratt and P.E. Lipps. 2002: Effect of *Cercospora zeae-maydis* infested maize residue on progress and spread of grey leaf spot of maize in Central Uganda. *Annals of Applied Biology* 140:177-185.)

**h.** **Projected Outputs:** (1) resistance factors and their association with components of resistance identified in QPM material; (2) SSR molecular markers for MAS selection identified; (3) breeding lines suitable for intermating to form a synthetic variety will be identified; (4) one Ph.D. student trained in molecular breeding; (5) fifteen people to receive hands-on training in biotechnology research.

**i.** **Projected Impacts:** (1) reduction in maize losses and increased production; (2) a shortened process for identifying sources of resistance, selection and testing; (3) enhanced maize resistance to many diseases; (4) improved nutritional status of Ugandan and other sub-Saharan farmers; (5) increased capacity for biotechnology research in Uganda.

**j.** **Projected Start Date:** October 2003

**k.** **Project Completion:** September 2004

**l.** **Projected Person-Month of Scientist Time**: 6

**m.** **Budget:** $8,635 – Makerere/NARO; $13,215 – OSU

### II.2. Dissemination of integrated *Striga* management technologies in sorghum among small-scale rural farmers in Eastern Uganda (Year 11 Priority: Technology Dissemination)

**a.** **Scientists:** J. R. Olupot – SAARI; J. Oryokot – NAADS; Herman Warren, Jim Westwood – Virginia Tech

**b.** **Overall objective:** To disseminate the IPM CRSP-developed integrated *Striga* management technologies to a wider community of small-scale sorghum farmers in eastern Uganda. **Specific objectives for coming year:** (1) To disseminate the idea of inter-cropping sorghum with *Striga* Chaser' (*Celosia argentia*) and leguminous crops for the management of *Striga*; (2) To disseminate the use of cotton / Cowpea / Sorghum rotation system for the management of *Striga*; (3) To disseminate the approach of integrating the use of a tolerant sorghum variety, nitrogen fertilizer and weeding for the control of *Striga* in sorghum; and (4) To disseminate the approach of integrating inter-cropping and fertilizer application for the management of *Striga*.

**c.** **Hypotheses:** (1) Inter-cropping sorghum with *Celosia argentia* and legumes has no effect on *Striga*; (2) There is no difference in *Striga* infestation under continuous sorghum cropping and the proposed rotation system; (3) Integrating the use of a tolerant sorghum variety, nitrogen fertilizer and weeding does not minimize *Striga* attack on sorghum; (4) Integrating inter-cropping and nitrogen fertilizer use has no effect on *Striga*.

**d.** **Description of research/diffusion activities:** Dissemination of the IPM CRSP-developed *Striga* management technologies will be carried out in three sub-counties of the Kumi district of eastern Uganda that are heavily infested with *Striga*. In each sub-county, one village will be chosen and an active farmer group of 40 full-time farmers will implement the demonstration trial. The dissemination activities will be carried out in 2 seasons. The extension workers, NGO representatives and the researchers will gather data during the course of each season. Data will be taken on *Striga* emergence, sorghum growth parameters (plant height and flowering dates) and sorghum yield. Towards the end of each season the stakeholders will hold an open day in each village to evaluate and assess demonstration trials. The following technologies will be demonstrated: (1) Intercropping sorghum with *Celosia argenta*; (2) Intercropping sorghum with *Desmodium*; (3) Application of fertilizer; (4) Use of tolerant variety (Seredo); (5) Use of tolerant variety and fertilizer; and, (6) Control consisting of farmer practices. Each treatment will be 10 meters X 10 meters. Best practices will be further disseminated through the print and radio media. Before the end of the project, a simplified farmers' *Striga* control handbook will be produced and distributed to farmers, extension workers and NGOs operating in Eastern Uganda.

**e.** **Justification:** A number of novel integrated *Striga* management technologies in Uganda have been developed and evaluated by the IPM CRSP from 1998 to date. These technologies, most of them cultural practices, have been proven to be effective in controlling *Striga* and applicable under Ugandan conditions. The technologies were developed taking into consideration the low price of sorghum and the cost of fertilizer. The proven technologies now need to be disseminated to the resource poor rural sorghum farmers who are affected by the *Striga* problem. The farmers themselves, local leaders, extension workers and NGOs will be used in the dissemination. Formal communications between the IPM CRSP site in eastern Africa and the INTSORMIL CRSP occurred through the former IPM CRSP program director and Ugandan team member, Dr. B. Gebrekidan. Additionally, the former director of the Serere Agricultural Research Institute, Dr. Peter Esele, a long-time co-PI with the INTSORMIL CRSP, contributed to early workplan development.

**f. Relation to other CRSP activities:** This work is related to the CRSP activities that have been conducted under controlled conditions at Virginia Tech to develop novel approaches for *Striga* management. It is also related to the *Striga* management studies being carried out in Mali, West Africa. All of these studies are aimed at developing management options for *Striga* that are suitable for small-scale farmers. The work also is now related to the previous IPM CRSP activities on dissemination of cowpea and groundnut IPM menus in Uganda using the farmer field school approach.

**g. Progress to date:**

**Publications:**

(1) J.R.Olupot, D.S.O.Osiru, J.Oryokot, B.Gebrekidan. 2003. "The effectiveness of *Celosia argentia* (*Striga* "chaser") to control striga on sorghum in Uganda", *Crop Protection* 22(2003)463-468.

(2) J.R.Olupot, D.S.O.Osiru, J.Oryokot, and B.Gebrekidan. 1999. "Development of an integrated *Striga* management strategy for Ugandan conditions" in: Chivinge,O.A., Tusiime,G., Nampala,P. and Adipala,E. (eds), *Proceedings of the 17$^{th}$ Biennial Weed Science Society Conference for Eastern Africa.* Harare: WSSEA.

(3) J.R.Olupot, D.S.O.Osiru, J.Oryokot, and B.Gebrekidan. "Evaluation of novel options for the management of *Striga* on sorghum in Uganda", submitted to the *African Crop Science Journal* in December 2002).

(4) J.R.Olupot, D.S.O.Osiru, J.Oryokot, and B.Gebrekidan. "The effectiveness of Silver leaf desmodium (*Desmodium uncinutum*) to control *Striga* on sorghum in Uganda", paper presented at the international conference on IPM in sub-Saharan Africa, September 2002, Kampala, Uganda).

**Other:**

(1) MS student, Mr. John Robert Olupot, graduated from Makerere University in January, 2003.

(2) Studies on intercropping, crop rotation, herbicide seed coating and fertilizer use are still ongoing at the site.

**h. Projected output:** Effective and applicable integrated *Striga* management options in sorghum disseminated to farmers in Uganda.

**i. Projected impacts:** (1) Knowledge of effective and applicable *Striga* management options available to farmers; (2) Reduced incidence of *Striga;* (3) High sorghum yield; (4) Depleted *Striga* seed bank; (5) Increased food security and income for small-scale sorghum growers.

**j. Projected start:** October 2003

**k. Projected completion:** September 2004

**l. Projected person-months of Scientist Time per Year:** 4

**m.** **Budget:** $6,820 – SAARI/ Makerere; $1,000 – Virginia Tech

## III. Integrated Pest Management Strategies for High Value Horticultural Crops

### III.1. Development of IPM technologies for tomato production in central Uganda (Yr. 11 priority: Technology dissemination)

**a.** **Scientists:** M.C. Akemo, J.J. Hakiza – KARI; S. Kyamanywa, Adipala Ekwamu, V. Kasenge, M. Magambo, – Makerere University; M. Erbaugh, R. Hammond, P. Grewal – Ohio State University; A. Baudoin – Virginia Tech; A. Alumai – Graduate Research Assistant funded by OSU

**b.** **Overall Objectives**: To reduce the use of pesticides on tomatoes. **Specific objectives:** (1) To develop alternative interventions for controlling priority diseases and pests of tomatoes. (2) To develop an IPM package for the control of priority diseases and insect pests of tomatoes. (3) To promote grafting tomatoes on wilt-resistant indigenous solanacearum root stocks. (4) To determine acceptability of grafting as a technique to control wilt by farmers.

**c.** **Hypotheses**: (1a) Improved tomato varieties and cultural practices will reduce incidence and severity of bacterial wilt (*Ralstonia solanacearum*), late blight (*Phytophthora infestans*), and insect pests (*Thrips tabaci, Myzus persicae, Helicovepa armigera, Bemisia tabaci*). (1b) The frequency of pesticide application can be reduced without yield loss. (2) There are high levels of pesticides residues on tomatoes sold in Ugandan markets. (3) Grafting on rootstock resistant to soil borne disease will reduce bacterial wilt disease. (4) If trained in grafting, farmers will adopt use of resistant rootstocks to manage bacterial wilt.

**d.** **Description of Research Activity (approach):** Validation and dissemination of selected tomato lines and management practices on incidence of *Phytophthora infestans, Ralstonia solanacearum,* and insect pests on tomatoes. (Akemo M.C, J.J. Hakiza, S. Kyamanywa, A. Ekwamu, H. Warren, M. Olanya). (1) In the 2003b season the on-farm trials will be run one more time at Matugga and Namulonge to validate the findings from the 2002b and 2003a seasons. In one trial, each farmer will grow the varieties CLN2123A, CLN2116B, CLN2037B, Redlander, and MT56 to gauge their disease resistance, especially to bacterial wilt, and their yield potential. In the second trial, each farmer will get either MT56 or Redlander varieties and plant them under management practices including mulching, staking, trellising, and clean weeding laid out in a RCBD. At biweekly intervals, data will be collected on diseases and insect pest incidence and severity. The trials will also serve as demonstration sites from which the farmers will discuss and select best options. (2) In the 2003b and 2004a seasons, the 2 best performing lines, 2 cultural practices, and 1 insecticide spraying regime which provided the best disease and insect pest control with economic yields will be tested on-farm. This will be done with 12 farmers, 6 each at Namulonge and at a major tomato-producing area identified in Mpigi District. There will be two IPM packages, each consisting of one variety, one cultural practice, and the same insecticide spray regime for both. Three farmers at each site will test one package while the other three will test the second package. The control will be the farmers' preferred varieties grown under their own management practices. There will be 2 replicates at each farm. Data will be collected on disease (*Phytophthora infestans, Ralstonia solanacearum*) and insect pest (*Thrips tabaci, Myzus persicae, Helicoverpa armigera, Bemisia tabaci*) incidence and severity at biweekly intervals. Economic evaluation will be carried out to determine the most cost-effective combination of technologies. The trials will also serve as demonstration sites from which the farmers will select the best option. Extension agents will participate in the open days and this will increase the dissemination capacity. The performance of grafting the 3 rootstocks (*Solanum indicum*, *S. macrocarpon* and *S. camphylocanthum*) and 2 wilt resistant tomato varieties will be demonstrated to farmers in a participatory way. Five farmers groups in Wakiso district will be taught how to carry out grafting. In addition tomatoes grafted on the 3 species of rootstock will be planted in a farmer field from each group. Each root stock species will be planted at a spacing of 60cm x 45cm in plot 1.5 x 2.5m and will be replicated two times on each field. Data will be corrected on disease incidence and yield.

e. **Justification:** Tomato blights and bacterial wilt have been ranked both by NARO and farmers as priority diseases on tomatoes in Uganda. There is also extensive damage caused by insect pests such as thrips, African bollworm, and vectors of tomato viruses. To control these problems farmers rely on extensive use of pesticides. Farmers, however, do not use pesticides correctly, resulting in undesirable residues on the harvested tomato fruits. There is need to reduce pesticide use on tomato disease and insect pest control. Studying the effect of different cultural methods on late blight will help reduce pesticide applications against this disease and reduce crop losses. Similarly, resistant varieties are one method that can be employed to avoid crop loss from the soil-borne bacterial wilt. Previous on-station and on-farm trials have demonstrated that rootstocks of *Solanum indicum, S. macrocarpon* and *S. camphylocanthum* are resistant to bacterial wilt and that tomatoes grafted very well on these rootstocks with over 80% success rate. Furthermore, the grafted tomatoes do not suffer from bacterial wilt. It is, therefore, important to pass on this technology to the farmers. There is also a need to develop an economically viable IPM package which can be presented to farmers that combines the best varietal, cultural, and pest control technologies.

f. **Relationship to other CRSP activities at the site:** The proposed research builds upon on-station studies at KARI and on-farm studies which have been examining alternative cultural, varietal, and pesticide methods of controlling tomato diseases and insect pests.

g. **Progress to date:** The tomato varietal and management trials are on-farm now for the second season, with mulching and staking proving to be the best practice so far. Redlander and MT56 are performing best out of the 5 varieties taken on-farm. An insecticide spray interval of 7 days (but based on EILS) was identified as the most economically viable option for thrips control. Eric Lerner Kagezi has presented the final draft of his thesis on the study of IPM for thrips and other insects on tomato. Rootstocks of different solanaceous plants have been screened against bacterial wilt and three have been selected to be resistant and suitable for tomato grafting.

**h.** **Projected outputs**: (1) Bacterial wilt resistant/tolerant tomato cultivars identified. (2) Alternative disease and insect pest management practices developed. (3) An economically viable IPM package for the control of priority pests on tomatoes developed. (4) Appropriate rootstocks for grafting selected by farmers. (5) At least 20 farmers trained in the grafting technique

**i.** **Projected impact**: (1) Losses due to tomato diseases and pests reduced. (2) Farmers' incomes increased. (3) Reduction in pesticide use.

**j.** **Project start**: October 2003

**k.** **Project end**: September 2004

**l.** **Projected Person-months of Scientists' Time per year:** 6 months

**m.** **Budget:** $9,790 – Makerere/NARO; $2,520 – OSU; $2,937 – Virginia Tech

### III.2. Identification and characterization of passion fruit (*Passiflora edulis* Sims.) viruses and germplasm from Uganda using molecular biotechnology tools. (Yr 11 priority: Biotechnology)

**a.** **Scientists**: E. Adipala, R. Edema, M. Ochwo-Ssemakula – Makerere University; J.J. Hakiza, T. Sengooba – National Agricultural Research Organization; S. Nameth, P. Redinbaugh – Ohio State University/USDA. **Collaboration:** Funds for the collection of passion fruit virus and germplasm samples will be provided by the Faculty of Agriculture, Makerere University through SIDA/SAREC and NORAD grants.

**b.** **Overall objective**: To contribute towards the development of the export horticultural industry in Uganda by alleviating hindrances to the productivity of passion fruit, considered one of the most promising crops for export. **Objectives for the coming year**: (1) To characterize passion fruit viruses and germplasm using molecular markers; and (2) to build capacity in horticultural virology.

**c.** **Hypotheses**: (1) There are different viruses/strains affecting passion fruit in Uganda; and (2) Different passion fruit cultivars show varied genetic response to virus infection.

**d.** **Description of activity**: The activity will involve short-term training for a period of 7 months at Ohio State University. The course work will build skills in virology and horticulture. While at OSU, molecular techniques will be used to characterize passion fruit clones on samples from Uganda. Upon return to Uganda, viruses will be characterized and the interaction between viruses and clones will be established. The tools to be used include DNA extraction qualitatively analyzed by gel electrophoresis and quantified by spectrophotometry, use of PCR, and sequencing. Significant viruses will be characterized by amplification of specific portions of the genome and sequence alignment alongside similar viruses from geographically diverse regions. These sequences are available in the gene banks of the European Molecular Biology Laboratory (EBML) and the National Centre for Biotechnology Information (NCBI). Screening will utilize artificial inoculation with virus isolates considered significant.

**e. Justification:** This study will specifically target passion fruit, one of eight fruits identified for export promotion. The fruit has been propagated in Uganda on a small scale for more than a century but only gained prominence in the 90's as a means of uplifting the livelihood of rural farmers. However, production is still constrained by a number of biological factors. Among the biotic constraints, viruses are considered the most significant limitation to passion fruit production. It is, therefore, essential that the identity of viruses affecting passion fruit clones in Uganda be established. Currently, passion fruit genotypes in Uganda are not properly characterized and the yield potential of available cultivars has not been ascertained. The program is assembling a germplasm collection. However, extensive seed propagation has resulted in deviant trait expression among these collections. As a result, characterization of this germplasm is essential before any meaningful attempts can be made at breeding for disease resistance. This study will contribute basic knowledge towards the development of a disease management strategy for viruses of passion fruit in Uganda through an integrated approach of pathogen and germplasm characterisation and screening for disease resistance.

**f. Relationship to other IPM CRSP activities at the site:** This activity relates to the IPM CRSP work on tomatoes which is oriented towards developing IPM strategies for horticultural crops in Uganda. The activity will also relate to building the capacity of Makerere University Faculty of Agriculture in the area of horticultural virology.

**g. Progress to date**: N/A

**h. Projected outputs**: (1) Type and nature of viral pathogens and other diseases affecting passion fruit in Uganda identified and quantified for development of an appropriate management strategy by the National Horticultural Program. (2) Ugandan passion fruit species characterized, genetic diversity documented and tolerance to passion fruit woodiness disease (PWD) quantified. (3) Graduate student trained as a horticultural scientist.

**i. Projected impacts**: The output from this project will contribute to the initiation of a breeding program by the National Horticultural Program of the National Agricultural Research Organization (NARO) for development of passion fruit varieties resistant to PWD. There will also be enhanced capacity for horticultural research. The anticipated long-term benefit is a potential increase in foreign exchange earnings from the current amount of $5.2m to up to $10m annually in the next 5-10 years.

**j. Projected start date**: September 2003

**k. Projected completion**: September 2004

**l.** **Projected Person-months of Scientist Time per Year**: Seven (7) in the US and 4 in Uganda.

**m.** **Budget**: $10,670 – Makerere (Biotech); $30,681 – OSU

## III.3. Promotion of export horticulture: Development of IPM options to improve quality and increase quantity of hot pepper exports

**a.** **Scientists:** J.J. Hakiza, C. Akemo, T. Sengooba – NARO, Uganda; Adipala Ekwamu, S. Kyamanywa, Mildred O. Semakula, A. Kaaya – Makerere University; M. Erbaugh, R.B. Hammond – Ohio State University, A. Baudoin – Virginia Tech; MAAIF and HORTEXA.

**b.** **Objectives:** The overall objective is to improve the quality of Ugandan hot pepper production for increased export volume and value. **Specific objectives**: (1) To assess the status of the major pests and diseases of hot pepper and the control measures being employed; (2) To introduce and evaluate hot pepper germplasm with different levels of resistance to the existing pests and diseases; (3) To carry out pesticide residue analysis pre- and post-harvest to comply with the EUREP GAP requirements; (4) To introduce and train hot pepper producers and supervisors on HACCP code of practice to satisfy the export market; and (5) To identify possible IPM options for management of pests and diseases on hot pepper.

**c.** **Hypotheses:** (1) Diseases and pests are important constraints to hot pepper production in Uganda; (2) There are alternatives to pesticides for managing pests and diseases on Scotch Bonnet hot peppers in Uganda; (3) Through backward linkages with producer groups, pesticide residue analysis will increase compliance of hot pepper exports with the EUREP GAP regulations.

**d.** **Description of Research Activity (approach):**

(1) Biological and production baseline survey of hot pepper production in 4 districts of central Uganda. Using a semi-structured questionnaire of about 160 farmers in 4 districts (Mpigi, Mukono, Luwero, and Mubende) growing hot peppers will be surveyed. Specimens of insect pests and diseases will be taken to a laboratory for identification and confirmation. The current pest and disease control measures will be recorded. A survey will be conducted to assess enterprise characteristics including farm size, number of employees, volume of production, sales, and operational constraints and the current application level of the code of practices.

(2) Introduction and evaluation of hot pepper germplasm for export market attributes. Improved varieties will be introduced from the USDA, Charleston South Carolina, and screened at Kawanda Agricultural Research Institute. It is proposed that new improved varieties which might have good market attributes and resistance to viruses be introduced

from Jamaica where IPM CRSP has evaluated hot pepper and then be evaluated under Ugandan conditions. Other sources of hot pepper germplasm will also be sought.

(3) Pesticide residue analyses on farm produce and consignments being exported to Europe to comply with the EUREP GAP requirements. Levels of pesticide residues for different fungicides and insecticides on hot pepper will be assessed for compliance to EUREP GAP. Information on pesticides being applied to control various pests and diseases will be collected. Samples of hot pepper fruits will be taken and analyzed for pesticide residue either within or outside the country.

(4) Introduction and training of hot pepper producers and supervisors on code of practice to satisfy the export market. Farmers and supervisors in hot pepper production villages will be introduced to the code of practice to conform to the good agricultural practices for the European retail market (EUREP GAP) in particular, and other markets in general.

**e.** **Justification:** Hot pepper is one of the major crops produced in Uganda and exported to Europe and the Middle East. The monthly export volumes are 25 metric tons valued at US $72,500. The major varieties are Scotch Bonnet and Madame Janet. In the Plan for Modernization of Agriculture (PMA), production of export crops is being encouraged to enable farmers move from subsistence to commercial agriculture. However, pests and diseases like aphids, mites, fruit flies, viruses, etc., have grossly affected not only the quality of fruits but also the overall yield of hot pepper. Chemicals like Milraz, Antracol, Dithane M45, Dimethoate and Fenikil, have been used to control a variety of pests and diseases. However, pesticide use and residue levels are issues of great concern to the consumers of hot pepper and yet very little information is available regarding the situation in Uganda. Effective April 1, 2003, some exporters have had their consignments destroyed because of high pesticide residues, especially Fenvalerate, on their produce. Consequently, surveys related to prevalent pests and diseases and their distribution should be conducted. Farmers should be exposed to the code of practice for export of hot pepper. Thus, training of hot pepper farmers and quality controllers, analysis of residue levels, and production of brochures and leaflets should be done. Since the Caribbean site has been working on hot pepper IPM for a number of years, the Uganda site chair and site coordinator met briefly with the Caribbean site chair at the IPM CRSP annual meetings in April, 2003. Additional communication and suggestions were made to the activity in subsequent communications among site chairs. Additional communication with the Caribbean site chair and other team members is anticipated following the outcome of pest and disease assessments of hot peppers in Uganda.

**f.** **Relationship to other CRSP activities at the site:** This activity relates to the IPM CRSP work on tomatoes which is oriented towards developing IPM strategies for horticultural crops in Uganda.

**g.** **Progress to date:** Positioning effort

**h.** **Projected Output(s):** (1) Identification of hot pepper varieties resistant to pests and diseases as a component of IPM. (2) Documentation of the distribution of the major hot pepper pests and diseases in the 4 districts surveyed. (3) Identification of strategies for the IPM approach to control the major hot pepper pests and diseases. (4) Creation of awareness about the code of practice related to quality standards to suit consumer requirements. (5) Production of fact sheets and brochures on IPM strategies for hot pepper.

**i.** **Projected Impacts:** (1) Increased awareness of the code of practice related to hot pepper production and marketing by farmers. (2) Reduction in losses attributed to pests and diseases in hot pepper. (3) Increased quality of produce both in local and external markets. (4) Increased foreign exchange earnings through high quality exports.

**j.** **Projected Start:** October 2003

**k.** **Projected Completion:** September 2004.

**l.** **Projected Person-Months of Scientist Time:** 4

**m.** **Budget:** $8,877 – Makerere University; $2,520 – Ohio State University; $2,937 – Virginia Tech.

### III.4. Development of insect pest and plant disease diagnostic services for exporters, farmers and scientists

**a.** **Scientists**: S. Kyamanywa, E. Adipala, G. Kyeyune – Makerere University; R. Karyeija – MAAIF/Plant Quarantine and Phyto-sanitary Services; S. Nameth, R. Hammond – Ohio State University; and A. Baudoin – Virginia Tech.

**b.** **Objectives**: The overall objectives are to promote integrated pest management through provision of sustainable insect and disease diagnostic services to scientists, extension service providers, farmers and exporters; and to enhance international trade through provision of pest risk assessments. **Specific objectives**: (1) establish insect and disease diagnostic clinic at Makerere University, (2) provide information on integrated management of identified insect pests and diseases, (3) develop a catalogue of insect pests and diseases on different crops in Uganda which may help in pest risk assessment required for export crops, (4) provide training material for both under- and post- graduate students for insect pest and disease identification.

**c.** **Hypotheses**: (1) Proper insect and disease identification will help in promoting appropriate phyto-sanitary measures; (2) Availability of pest diagnostic services will facilitate detecting insect pest and disease outbreaks quickly; (3) Pest diagnostic services will facilitate compilation of pest risk assessment lists required for exporting different crops.

**d.** **Description of research activity**: An insect pest and disease diagnostic clinic will be established at Makerere University in the Faculty of Agriculture. Once established, the clinic will integrate expertise in plant pathology, entomology, nematology, agronomy, and soil science into a comprehensive program of plant disease and pest identification. This activity will involve: (1) acquisition of modest equipment for a laboratory to serve as the diagnostic clinic; (2) identification of experts to identify different pests and diseases; expertise will be sought from within Makerere University, NARO and the private sector; (3) develop a fact sheet on submitting insect, mite and diseased plant specimens for identification; (4) develop specimen submission form; (5) develop protocol for handling specimens at the clinic; (6) establish specimen collection centers in various districts; (7) advertise the service to the public through various mass media; (8) initiate specimen identification; (9) establish specimen identification fees.

**e.** **Justification**: Agricultural production in Uganda is constrained by damage due to insect pests, mites, nematodes and plant diseases. Nevertheless, many farmers are not able to identify pests and diseases. Most of the time, they rely on the services of extension agents, who are not provided with proper identification facilities. Unfortunately, experience over the last 8 years of IPM CRSP interacting with extension agents, indicates that most extension agents cannot identify most of the pest/disease specimens, and usually advise the farmers to send their samples to Makerere University or one of the NARO institutes, who also are not well equipped to handle pest identification. Furthermore, horticultural exporters have lost tremendously, when their produce has been rejected at ports of entry because of lack of information on the PRA of the country of origin. This potentially jeopardizes the AGOA framework of export diversification. The proposed diagnostic clinic, therefore, would support both integrated pest management and export agriculture. It will also strengthen training in pest identification and management. Finally, this activity will be sustainable, as identification fees will be charged.

**f.** **Relationship to other IPM CRSP activities**: This activity will complement the current activities on pest identification and management by the farmer IPM schools and studies on bio-control agents. It will also support the USAID bilateral mission objectives of promoting export agriculture in Uganda.

**g.** **Progress to date**: None

**h.** **Projected Outputs:** (1) Fact sheets and brochures on the pest and disease diagnostic services produced; (2) Specimen submission forms; (3) Catalogue of pests and diseases on various crops in Uganda; (4) List of potential pests and diseases available to exporters.

**i.** **Projected impacts:** (1) Reduced export rejection rates and thus increased foreign exchange earning for Uganda; (2) Reduced yield losses as pests and diseases will be identified early and appropriate action taken; (3) Reduced foreign exchange spent on identifying pests outside Uganda; (4) Improved training in pest identification, for both post- and under-graduate students.

**j.** **Projected start:** October 2003

**k.** **Projected completion:** September 2004

**l.** **Projected Person-Months of Scientist Time per Year**: 4

**m.** **Budget:** $9,194 – Makerere/NARO; $2,646 – Ohio State University; $4,789 – Virginia Tech

**III.5. Pesticide application and safety training course for producers, pesticide dealers and exporters**

**a.** **Scientists:** S. Kyamanywa – Makerere University; A. Agona-Kawanda – Agricultural Research Institute; J. Komayombi Bulegeya – MAAIF; R. Hammond – Ohio State University

**b.** **Objectives:** The overall objective of this study is to reduce and rationalize pesticide use and safety in Uganda. The specific objectives are: (1) To create awareness and train the farmers, pesticide dealers and applicators in safe use of pesticides; (2) To introduce the participants to the principles of integrated pest management; (3) To reduce pesticide residue on both export and local market produce; (4) To gain current knowledge on status from pesticide usage in the country from course participants.

**c.** **Hypotheses:** (1) Lack of knowledge on the dangers associated with pesticide use encourages pesticide misuse; (2) Adopting IPM reduces the use of pesticide and the associated dangers; (3) Training producers on safe pesticide use will reduce pesticide residues on produce in both local and international markets.

**d.** **Description of the activity:** Three training sessions in safe pesticide use will be conducted in year 11. The course will target flower and vegetable producers who are the heavy users of pesticide. It will also target pesticide dealers, service providers and applicators who are the main people who advise farmers on pesticide use in the country. Prior to the training, information will be sought from course participants on the status of pesticide usage and safety using a structured questionnaire, and thereafter a post evaluation will be conducted. Two five-day training courses will be conducted for vegetable and flower producers in the main producing districts around Kampala and one three-day training session will be organized for service providers, farmers and pesticide dealers in Eastern Uganda where the rate of pesticide use is very high. Each training session will consist of at least 40 participants. Pre- and post-tests will be administered to course participants to assess knowledge accrual. Each participant will pay a registration fee to cater for meals. The training modules, already developed by Drs. S. Kyamanywa and A. Agona, will be used with some modification. Nevertheless, simple fact sheets on IPM and pesticide use will be produced.

**e.** **Justification:** The problems of pesticide misuse in Uganda are on the increase. A recent study conducted with assistance from the Rockefeller Forum indicated that the pesticide dealers, applicators and even policy makers in the districts were not aware of the dangers associated with pesticide application. Furthermore, there was tremendous misuse of pesticides by farmers, especially the small to medium commercially oriented ones. And finally, a number of vegetable and grain exporters have had their shipments rejected because of violating acceptable pesticide residue levels; therefore the need for the training course. Previous experience has indicated that pesticide dealers and commercial farmers are willing to pay for the training. This will, therefore, be a cost sharing activity.

**f.** **Relationship to other IPM CRSP Activities**: This activity will support other activities aimed at promoting IPM, particularly for tomatoes, cowpeas and groundnuts. It will also give support to the bilateral USAID mission objective of promoting exports from Uganda and protecting and conserving the environment.

**g.** **Progress to date**: Although this activity has never been conducted under IPM CRSP, Drs. Kyamanywa and Agona have conducted successfully one such course in which 65 pesticide dealers and applicators participated. There are, therefore, course modules already developed. Farmer training on pesticide usage and safety was initiated in Kumi. A partnership with the Rockefeller Forum has been forged.

**h.** **Project Impact**: There will be: (1) Reduced misuse of pesticide; (2) Reduced pesticide residue in foods; (3) Reduced pesticide poisoning.

**i.** **Projected Outputs:** (1) Over 160 pesticide dealers and farmers trained; (2) Safe pesticide use brochures produced; (3) Paper on the status of pesticide usage within the country published

**j.** **Projected start:** October 2003

**k.** **Projected end:** September 2004

**l.** **Projected person month:** 2 months

**m.** **Budget:** $6,710 – Makerere/NARO; $2,646 – Ohio State University

## IV. Post-Harvest

### IV.1. Improvement of maize grain quality and marketing through adoption of appropriate post-harvest technologies in Uganda

**a.** **Scientist(s)**: A.N. Kaaya, E. Adipala, S. Kyamanywa – Makerere University; H. Warren – Virginia Tech; A. Agona – KARI; G. Bigirwa – NAARI

**b.** **Objectives:** The overall objective is to improve the quality and marketability of maize grains from farmers, traders and exporters through adoption of appropriate post-harvest handling and storage technologies. **Specific objectives**: (1) Determine the quality of maize grain in the marketing chain; (2) Establish the factors that negatively affect the grain quality; (3) Identify and validate grain quality mitigating post-harvest handling and storage technologies; (4) Recommend and promote dissemination of appropriate technologies that improve maize quality according to standards established by the Uganda National Bureau of Standards (UNBS); (5) Build capacity in grain quality analysis.

c. **Hypotheses:** (1) Poor quality standards affect grain marketing in Uganda; (2) Adoption of appropriate post-harvest handling and storage technologies by producers, processors and traders will result in high quality and improved grain marketing.

d. **Description of Research Activity (approach):** Sampling surveys in major maize growing districts in Eastern Uganda and major maize suppliers to Uganda Grain Traders' Ltd (UGTL) will be conducted. The quality status of sampled grains in terms of physical appearance, insect damage, moisture content, moulds and aflatoxins will be determined in the Department of Food Science and Technology at Makerere University. The established UNBS quality standards will be used as the check. Different post-harvest handling and storage technologies (e.g. drying, shelling, and pest management) will be evaluated for grain quality enhancement. Quality enhancement technologies will be channeled through appropriate dissemination pathways for promotion. Training of a graduate student at the PhD level at Makerere University will be supported.

e. **Justification (relation to IPM-CRSP objectives and priorities):** Low grain quality, especially due to insect damage, mould infection and aflatoxin contamination is a big problem in the marketing chain in Uganda. The majority of farmers, traders and processors are unaware and thus incapable of maintaining grain quality according to the established UNBS standards. This is attributed to poor access to improved grain handling and storage technologies. There is, therefore, a need to assess the quality of grains in the market chain to identify quality status, factors contributing to poor quality and to validate some post-harvest handling and storage technologies that impact positively on quality. This will help improve the quality of maize for both local and export markets. Drying, shelling and pest management technologies exist but need to be validated and recommended for improved maize grain quality. These shall be disseminated to end users using appropriate channels for improved grain quality for both local and export markets. The PhD student has finished coursework at Virginia Tech and needs to be supported further at Makerere University to conduct research and write a dissertation.

f. **Relationship to other IPM CRSP Activities:** This work is related to the on-going activities of moulds and aflatoxin isolation and identification in maize and groundnuts. The IPM CRSP has been working on issues surrounding aflatoxin and mycotoxin contol with stored grain for five years. Communication with the Peanut CRSP has been through co-PIs who are part of both CRSPs.

g. **Progress to date:** (1) Inadequate drying and storage practices have been reported to be the major promoters of moulds and aflatoxin contamination of maize and groundnuts at both farm and market levels. Different drying technologies are yet to be validated. (2) Moulds and aflatoxin contamination of maize was more at market than farm level, but factors promoting their development are yet to be identified. (3) Solarization technique was proven effective against the insect pests of stored maize. The method remains to be investigated against moulds and mycotoxin contamination. (4) The PhD student has successfully accomplished coursework at Virginia Tech and has returned to Uganda to continue with research and write a dissertation. (5) A review paper on the status of aflatoxin contamination of food in Uganda and the related factors has been submitted to *The Journal of Food Additives and Contaminants* and is currently under review. (6) Two papers have been published, one in *African Crop Science*, the other in MUARIK Bulletin. (7) A paper was presented during the IPM conference in sub-Saharan Africa, September 2002.

**h.** **Projected Output(s):** (1) Maize grain quality in the marketing chain improved; and (2) Appropriate postharvest technologies that improve maize grain quality accessed by target clientele.

**i.** **Projected Impacts:** (1) Control of moulds and mycotoxin contamination of maize in Uganda. (2) Increased export potential of maize grains. (3) Improved consumer safety of grains.

**j.** **Projected Start:** October 2003

**k.** **Projected Completion:** September 2004

**l.** **Projected Person-Months of Scientist Time per Year:** 6

**m.** **Budget:** $8,370 – Makerere University; $3,470 – Virginia Tech

## V. Socioeconomic Assessment of IPM CRSP Technology Development, IPM Dissemination and IPM Conference Proceedings Support

### V.1. Socioeconomic Assessment of IPM CRSP Technology Development Activities in Uganda

**a.** **Scientist(s) Names and Institutional Affiliations:** V. Kasenge, W. Ekere, J. Bonabana-Wabbi, B. Mugonola, P. Kibwika, M. Amujal – Makerere University; V. Odeke, E. Mwanja – Uganda Extension Crop Protection Specialists; Daniel B. Taylor – Virginia Tech; J.M. Erbaugh – Ohio State. **Collaborating Scientists**: S. Kyamanywa, A. Kaaya, E. Adipala – Makerere University; G. Bigirwa, J. Olupot, A. Agona, C. Akemo - NARO; G. Luther – Virginia Tech.

**b.** **Overall Objective(s):** The overall purpose of this research is to assess the economic impacts of IPM CRSP activities in Uganda at: the level of the individual production activity, farm, region, and beyond as appropriate. Resource limitations prevent comprehensive evaluation of all technologies at all levels. We will attempt to evaluate all promising technologies at the individual production activity level, while only a few technologies will be subjected to a more comprehensive analysis. **Objectives for the coming year:** (1) To evaluate the study area level economic impacts of IPM packages on sorghum, groundnuts, cowpeas, tomatoes and maize projected to agro-ecologically similar regions of Uganda (2) To assess factors influencing the adoption of IPM CRSP packages.

c. **Hypotheses:** Uganda will realize substantial economic benefits from IPM CRSP technology adoption. Adoption is directly related to per capita farm size, income, education level and awareness of technologies. Women are less likely to adopt IPM technologies than men. IPM CRSP technologies are profitable.

d. **Description of Research Activity:** New Activity: Impact assessment of IPM CRSP interventions (objective 1) will be undertaken with two approaches. In the first approach, for those IPM CRSP interventions that have had the assessment of their farm level economic impacts completed, projections of those economic impacts to similar agro-ecological areas in Uganda will be made. The land area to project these impacts will be determined from agricultural statistics, expert opinion, and GIS. The second baseline survey, the M.S. work of J. Bonabana-Wabbi and M. Amujal will provide guidance on adoption rates for some of the interventions. Impacts will be assessed at current levels of adoption and full adoption, with the final impact falling somewhere in between. (J. Bonabana-Wabbi, D.B. Taylor, V. Kasenge, J.M. Erbaugh & others) The second approach involves an inter-CRSPing activity with the Peanut CRSP. National level economic impacts of rosette resistant groundnut varieties introduced by the Peanut CRSP whose adoption has been promoted by the Peanut and IPM CRSPs will be assessed. Changes in consumer, producer, and total economic surplus due to resistant variety adoption will be computed for Uganda. Much of the data for these projections will be obtained as expert opinion from researchers and extension personnel, supplemented with information from IPM CRSP baseline surveys and M.S. theses. **Continuing Activities:** (1) Market acceptability of split cowpeas (J. Bonabana-Wabbi, B. Mugonola, A. Agona, E. Adipala). (2) An economic assessment of the use of fish bones to control predatory ants on Maize (W. Ekere, B. Mugonola, B. Sekamatte, S. Kyamanywa). (3) Social acceptance of visible pesticide residue on tomatoes (V. Kasenge, B. Mugonola, A. Kaaya). (4) Assessing the influence of farmer field schools on adoption of IPM technologies on cowpea (M.S. thesis research (Magdalena Amujal, objective 2). (5) Economic assessment of striga management options on sorghum in Uganda (W. Ekere, V.Kasenge, P.Ahabwe, B. Mugonola, R. Olupot, M. Erbaugh and D. B.Taylor). (6) Marketing of Fresh Tomatoes in Kampala City (V. Kasenge, B. Mugonola).

e. **Justification:** IPM CRSP interventions must be evaluated from both a biological science and an economic perspective. It is possible that interventions viewed favorably from a biological perspective will not be economically viable. Conversely, it may be the case that interventions that do not appear to be superior from a biological perspective, are profitable from an economic perspective if they sufficiently reduce production costs and/or the risks of production (as was demonstrated in our post-harvest storage work). Socioeconomic research is essential to assess profitability of technologies and impacts on food security, poverty reduction and sustainable resources use. The basic economic analyses are crucial components in the assessment of the economy-wide impacts of IPM CRSP activities as well as their potential spillover effects. Given the complexity of factors influencing agricultural production and marketing, substantial empirical research is still needed to investigate the feasibility and social acceptance of IPM CRSP technologies in Uganda.

To date, impact assessments of IPM CRSP interventions have been limited to a pest management package on beans, and one disease resistant variety of maize. Farm level economic analyses on a number of crops and IPM interventions have been or will soon be completed. Several studies have collected information on adoption of IPM interventions. Using this information, farm level impacts of economically viable IPM interventions will be projected to the relevant agro-ecological regions in Uganda in order to project the national level impacts of these interventions.

**f.** **Relationship to Other IPM CRSP Activities:** As indicated in the discussion of new and continuing activities above, interaction will take place with many of the biological scientists involved in some aspect of IPM CRSP research. While resource limitations preclude an economic assessment of every aspect of the project, the majority of the project's activities will undergo some form of economic evaluation.

**g.** **Progress to Date:** (1) Jackline Bonabana-Wabbi completed her M.S. degree at Virginia Tech and Basil Mugonola is about to complete his M.S. degree at Makerere University. (2) Magdalena Amujal has collected her data for her M.S. thesis and is currently analyzing the data. (3) The folowing presentations were made at the international IPM conference in Kampala Uganda by members of the Uganda IPM CRSP research team: "Factors affecting IPM technology adoption in Uganda: A preliminary analysis," by J. Bonabana-Wabbi, D.B. Taylor, V. Kasenge & V. Odeke; "An economic assessment of novel striga management options on sorghum in Uganda," by W. Ekere, V. Kasenge, T. Habwe, B. Mugonola, M Erbaugh & D.B. Taylor; "An economic analysis of IPM technologies used in the control of cowpea pests and diseases in Kumi and Pallisa Districts of Uganda," by B. Mugonola, V. Kasenge, W. Ekere, S. Kyamanywa, E. Adipala, J. Nabirye, D.B. Taylor & M. Erbaugh; "Assessing the economic impact of IPM CRSP strategies on groundnut diseases in Kumi, Uganda," by J. Bonabana-Wabbi, V. Kasenge, D.B. Taylor, V. Odeke, C. Mukankusi, E. Adipala, S. Kyamanywa & M. Erbaugh; " Economics of fresh market tomato production by peri-urban farmers in Wakiso District," by V. Kasenge, M.C. Akemo, D.B. Taylor, S. Kyamanywa, E. Adipala & B. Mugonola; "The IPM CRSP experience with implementing participatory integrated pest management research in Uganda," by J.M. Erbaugh, D.B. Taylor, S. Kyamanywa & E. Adipala; "An economic assessment of integration of plant resistance and minimum fungicide use for management of potato late blight in southern Uganda," by G.P. Turiho-Ahabwe, V. Kasenge, W. Ekere, E. Adipala, J.J. Hakiza & S. Namanda; "Adoption of IPM technologies in groundnut production in eastern Uganda," by R.O. Ogwal, J. Mugisha, W. Ekere & V. Ekiyar. (4) The following presentation was made in July at an organized symposium at the joint American Agricultural Economics Association, the Rural Sociological Society and the Canadian Agricultural Economics Society: "Assessing Factors Affecting Adoption of Agricultural Technologies: The Case of Integrated Pest Management in Kumi District, Eastern Uganda" by J. Bonabana-Wabbi, D.B. Taylor, V. Kasenge, V. Odeke, B. Bashaasha, S. Kyamanywa, and M. Erbaugh.

**h.** **Projected Outputs:** (1) Two Ugandans will receive their M.S. degrees from Makerere University, completing studies on the influence of risk on optimal input use in maize production and the influence of farmer field schools on adoption of IPM on cowpea. (2) Papers will continue to be presented at professional meetings and submitted for publication as the opportunities arise.

**i.** **Projected Impacts:** Estimates of area level economic impacts of IPM CRSP interventions will be developed as well as the spillover effects. Multi-disciplinary collaboration between social scientists and biological scientists will be enhanced. The analyses will provide information on socially acceptable and economically viable technologies.

**j.** **Projected Start:** September 2003

**k.** **Projected Completion:** October, 2004

**l.** **Projected Person-Months of Scientist Time per Year:** 7

**m.** **Budget:** $13,700 – Makerere/NARO, $9,765 – Ohio State University; $18,772 – Virginia Tech

## VI. Integrated Pest Management for Coffee

### VI.1. Etiology and epidemiology of coffee wilt disease (*Fusarium xylarioides* (teleomorph = *Gibberella xylarioides*) and integrated pest management of robusta coffee (*C. canephora* Pierre)

**a**. **Scientist(s)**: G. J. Hakiza, A. Kangire, D. Kyetere, P Aluka, P. Musoli, P. Kucel, S. Olal – CORI; R. Edema – MU; M. Erbaugh, S. Miller, M. Ivey, B. McFadden – OSU; D. Geiser, PSU; A. Baudoin – Virginia Tech. **Other collaborators:** J. Orozco-Hoyos – CENICAFE; R. Day – CABI-ARC

**b.** **Objective(s):** The broad objective is to develop an integrated pest and disease management program for robusta coffee in Uganda. **Specific objectives**: (1) To continue using molecular techniques and pathogenicity tests to examine isolates of *Fusarium xylarioides* from the major robusta coffee growing zones of Uganda for differences; (2) To assess the potential of soil inhabiting *Pseudomonas* (*Ralstonia)* spp for biocontrol of coffee wilt disease.

Coffee wilt is caused by *Fusarium xylarioides* (teleomorph = *Gibberella xylarioides*). Preliminary DNA typing done by the International Mycological Institute (U.K) in 1996 indicates that the strain, which attacks arabica coffee (*Coffea arabica* L.) in Ethiopia, is different from the strain, which attacks robusta coffee (*C. canephora* Pierre) in Uganda.

This research will provide information on the differences in *F. xylarioides* strains found in Uganda as well.

c. **Hypotheses**: (1), There are different strains of *F. xylarioides* that vary in aggressiveness to different robusta genotypes in the different robusta growing districts of Uganda. (2) Agricultural soils in Uganda harbor beneficial populations of microbial biological control agents capable of reducing the incidence and severity of coffee wilt disease.

d. **Description of Research:** Tissue and soil from coffee trees showing vascular wilt symptoms will be obtained from the nine districts previously sampled in Year 10 and from the remaining coffee growing districts in Uganda. *Fusarium* spp. will be isolated from the symptomatic tissue and soil, purified and DNA extracted. Isolates will be characterized based on morphology and pathogencity confirmed in Uganda. Isolates and/or DNA will be sent to Ohio State University, Penn State University and/or Virginia Tech to be identified using molecular tools (PCR, sequencing and phylogenetic analysis). These isolates will be compared with isolates collected in Uganda in Year 10 and isolates from other countries. Scientists from the United States will conduct training in Uganda on current methods used for species level identification.

The presence, abundance, and diversity of biocontrol *Pseudomonas* spp. in Ugandan soils will be determined using a well-established PCR-based assay to detect biocontrol agents (McSpadden *et al.*, 2001). The assay will target gene clusters responsible for the biosynthesis of broad-spectrum antibiotics associated with biological control of root pathogens (i.e., *phl, plt* and *prn*). This study will involve sampling coffee roots grown at 4 distinct sites. Eight plants per site will be sampled and studied. If detected, genotypes of the biocontrol strains will be determined by using RFLP analysis of the amplified gene sequences.

e. **Justification**: Coffee wilt disease continues to present a serious obstacle to increased coffee production and productivity in Uganda. Sequence data from Year 10 suggests that new outbreaks of vascular wilt in nine districts in Uganda may have been caused by a new pathogen of *Fusarium* in the African clade of the *Gibberella fujikuroi* species complex (GFC). However, this data is based on a small number of isolates. Previously vascular wilt was thought to be caused by *Fusarium xylarioides*. In order to better understand the epidemiology of the pathogen and to determine if multiple species are causing the vascular wilt, a larger isolate collection needs to be obtained. This isolate collection needs to encompass all the districts within Uganda that have vascular wilt. Data on the genetic variability of the various species causing the vascular wilt will assist breeders in developing resistant lines of coffee. In addition, training in the area of species identification is needed. Bacteria like the fluorescent *Pseudomonas spp*. have been successfully used for biological control of diseases in wheat and other crops. These bacteria occur naturally in all soils, and could easily be harnessed for biological control. However, the presence of these beneficial bacteria in Ugandan soils and their ability to control *F. Xylaroides* needs first to be established if they are to be used for routine control of the coffee wilt disease.

**f.** **Relationship to other CRSP activities:** The proposed work will complement ongoing activities as well as providing more information for a comprehensive integrated pest and disease management program for robusta coffee.

**g.** **Progress to date**: (1) Characterization of 16 isolates of *F. xylarioides* from 9 robusta districts using molecular techniques, and pathogenicity tests which show some variation in the isolates. (2) Perithecia (sexual spores) and macroconidia collected from infected plants in the field were able to cause infection to robusta seedlings 5 – 6 months old, which indicates that both types of spores cause infection under field conditions. (3) Sources of inoculum for the disease were found to be forest coffee farms adjacent to forests, soil, leaves and coffee husks. This requires sterilization of soil for all nursery work, and avoiding use of husks for mulching coffee and using volunteer seedlings collected from forests. (4) No evidence of seed transmission has been found yet. More samples to be tested and plants from infected trees to be tested for the presence of the pathogen.

Insect transmission studies have been conducted in which coffee berry borer, berry moth, ladybird beetle, attendant ants, stem borers, termites, thrips, fruit flies and leafminers have been investigated. Only saprophytic fungi like *Fusarium semitectum*, *Curvularia spp* and other unidentified fungi were observed. To date the insects tested negative for *F. xylarioides*. These were collected from Mayuge, Iganga, Jinja and Mukono districts. These studies will continue and beneficial insects like bees will be included.

Possible alternate hosts for the wilt pathogen were also studied. Over 270 suspected plant species were checked from six districts but *F. xylarioides* was recovered in all of them.

Studies of spatial and temporal spread of CWD revealed that the disease could be spread by run off and down hill on slopes.

Host parasite relationship studies in which mode of entry into the host and further development within the host tissues have been conducted. These reveal that the pathogen can enter the plants through intact or wounded roots and wounded stems.

Two graduate students attached to the project are completing their studies by the end of June 2003. Three papers were presented at the IPM Conference last September 2002 from the work of this project. Three papers will be presented in the Crop Science Conference in Nairobi in October 2003.

**h.** **Projected Output(s)**: (1) Strains available and their distribution established and information availed to breeders for resistance breeding.

**i.** **Projected Impacts:** (1 and 2) More effective wilt resistant breeding program in place (i.e. identification of sources of resistance made rapid and utilized to develop cultivars for areas where various strains are found); (3) Biocontrol agents available and being utilized for control of coffee wilt disease; (4) Parasitoids of the berry borer tested and in use for control of the berry borer.

j. **Projected Start:** September 2003

k. **Projected Completion:** September 2004

l. **Person-Months of Scientist Time per Year:** 5

m. **Budget**:
Objective 1: $7,480 (Biotech) – Makerere/NARO; $8,064 – OSU
Objective 2: $6,848 – Makerere/NARO; $8,064 – OSU

## Site Activity Summary – Uganda – Year 11

| ACTIVITY | | SCIENTISTS | BUDGET ($) |
|---|---|---|---|
| **I.** | **Integrated Pest Management for Commercial Legume Crops** | | |
| I.1. | Dissemination and adoption of cowpea and groundnut IPM technologies | E.Adipala, S. Kyamanywa, A.R. Semana, M.Amujal, C.Asekenye – Makerere University; M. Erbaugh – Ohio State University; C. Iceduna, V. Odeke, District Agricultural Officers – Pallisa and Kumi, respectively; graduate and undergraduate students – Makerere University. **Collaborators:** Rockefeller Foundation - cost sharing on graduate students for networking and scaling-out, NAADS - enhancing capacity of service providers' delivery of advisory services related to IPM and technologies generated under IPM CRSP | $12,551 – Makerere; $4,410 – OSU; $4,342 – VT |
| I.2. | Integrated field management of *Callosobruchus maculatus* on cowpea using pheromone baits, cypermethrin and tobacco extracts, and improved insect pests resistant varieties (Yr 11 Priority: Technology development wrap-up) | J.A. Agona-NARO, S. Kyamanywa, Adipala Ekwamu – Makerere University; G. Mbata – Fort Valley State University; C.A. Fatokun – IITA | $7,110 – NARO/MUK; $6,900 – FVSU |
| I.3. | Biological control of cowpea pests and groundnut leafminer in Uganda (Yr. 11. Priority: Technology Development wrap-up) | S.Kyamanywa, T.M.B.Munyuli – Makerere University; G. Luther – Virginia Polytechnic and State University; R. Hammond – Ohio State University | $6,600 – Makerere University; $4,214 – Virginia Tech |
| **II.** | **Integrated Pest Management for Important Cereal Crops Associated with Farming systems in Eastern Uganda** | | |
| II.1. | Biotechnological approaches to improve disease management strategies in quality protein maize in Uganda (Year 11 Priority: Biotechnology) | G. Bigirwa – NARO/NAARI; R. Edema; E. Adipala – Makerere University; R.C. Pratt; P.E. Lipps – OARDC-OSU; R.G. Asea – Graduate Student OARDC-OSU. **Collaborators:** K. Pixley – CIMMYT | $8,635 – Makerere/NARO; $13,215 – OSU |

| | | |
|---|---|---|
| II.2. Dissemination of integrated *Striga* management technologies in sorghum among small-scale rural farmers in Eastern Uganda (Year 11 Priority: Technology Dissemination) | J. R. Olupot – SAARI; J. Oryokot – NAADS; Herman Warren, Jim Westwood – Virginia Tech | $6,820 – SAARI/ Makerere; $1,000 – Virginia Tech |
| **III. Integrated Pest Management Strategies for High Value Horticultural Crops** | | |
| III.1. Development of IPM technologies for tomato production in central Uganda (Yr. 11 priority: Technology dissemination) | M.C. Akemo, J.J. Hakiza – KARI; S. Kyamanywa, Adipala Ekwamu, V. Kasenge, M. Magambo, – Makerere University; M. Erbaugh, R. Hammond, P. Grewal – Ohio State University; A. Baudoin – Virginia Tech; A. Alumai – Graduate Research Assistant funded by OSU | $9,790 – Makerere/NARO; $2,520 – OSU; $2,937 – Virginia Tech |
| III.2. Identification and characterization of passion fruit (*Passiflora edulis* Sims.) viruses and germplasm from Uganda using molecular biotechnology tools. (Yr 11 priority: Biotechnology) | E. Adipala, R. Edema, M. Ochwo-Ssemakula – Makerere University; J.J. Hakiza, T. Sengooba – National Agricultural Research Organization; Pegg Redinbaugh – Ohio State University/USDA. **Collaboration:** Funds for the collection of passion fruit virus and germplasm samples will be provided by the Faculty of Agriculture, Makerere University through SIDA/SAREC and NORAD grants. | $10,670 – Makerere (Biotech); $30,681 – OSU |
| III.3. Promotion of export horticulture: Development of IPM options to improve quality and increase quantity of hot pepper exports | J.J. Hakiza, C. Akemo, T. Sengooba – NARO, Uganda; Adipala Ekwamu, Samuel Kyamanywa, Mildred O. Semakula, A. Kaaya – Makerere University; Mark Erbaugh; R.B. Hammond – Ohio State University, MAAIF and HORTEXA. | $8,877 – Makerere University; $2,520 – Ohio State University; $2,937 – Virginia Tech |
| III.4. Development of insect pest and plant disease diagnostic services for exporters, farmers and scientists | S. Kyamanywa, E. Adipala, G. Kyeyune – Makerere University; R. Karyeija – MAAIF/Plant Quarantine and Phyto-sanitary Services; S. Nameth, R. Hammond – Ohio State University; and A. Baudoin – Virginia Tech | $9,194 – Makerere/NARO; $2,646 – Ohio State University; $4,789– Virginia Tech |

| | | |
|---|---|---|
| III.5. Pesticide application and safety training course for producers, pesticide dealers and exporters | S. Kyamanywa – Makerere University; A. Agona-Kawanda – Agricultural Research Institute; J. Komayombi Bulegeya – MAAIF; R. Hammond – Ohio State University | $6,710 – Makerere/NARO; $2,646 – Ohio State University |
| **IV. Post-Harvest** | | |
| IV.1. Improvement of maize grain quality and marketing through adoption of appropriate post-harvest technologies in Uganda | A.N. Kaaya, E. Adipala, S. Kyamanywa – Makerere University; H. Warren – Virginia Tech; A. Agona – KARI; G. Bigirwa – NAARI | $8,370 – Makerere University; $3,470 – Virginia Tech |
| **V. Socio-Economic Assessment of IPM CRSP Technology Development, IPM Dissemination and IPM Conference Proceedings Support** | | |
| V.1. Socioeconomic assessment of IPM CRSP technology development activities in Uganda | V. Kasenge, W. Ekere, J. Bonabana-Wabbi, B. Mugonola, P. Kibwika, M. Amujal – Makerere University; V. Odeke, E. Mwanja – Uganda Extension Crop Protection Specialists; Daniel B. Taylor – Virginia Tech; J.M. Erbaugh – Ohio State. **Collaborating Scientists**: S. Kyamanywa, A. Kaaya, E. Adipala – Makerere University; G. Bigirwa, B. Sekamatte, J. Olupot, A. Agona, C. Akemo - NARO; H. Warren, G. Luther – Virginia Tech. | $13,700 – Makerere/NARO, $9,765 – Ohio State University; $18,772 – Virginia Tech |
| **VI. Integrated Pest Management for Coffee** | | |
| VI.1. Etiology and epidemiology of coffee wilt disease (*Fusarium xylarioides* (teleomorph = *Gibberella xylarioides*) and integrated pest management of rosbusta coffee (*C. canephora* Pierre) | G. J. Hakiza, A. Kangire, D. Kyetere, P Aluka, P. Musoli, P. Kucel, S. Olal, R. Edema, M. Erbaugh, I. Deep, S. Miller, M. Ivey, A. Baudoin – Virginia Tech. **Other collaborators:** J. Orozco-Hoyos – CENICAFE; R. Day – CABI-ARC | Objective 1: $7,480 – Makerere/NARO (Biotech); $8,064 – OSU. Objective 2: $6,848 – Makerere/NARO; $8,064 – OSU |

# YEAR 11 WORKPLAN FOR THE CENTAL AMERICAN SITES IN GUATEMALA AND HONDURAS

The Central American site of the IPM CRSP has been successful in addressing the overall IPM CRSP objectives that include: (1) Identify and describe the technical factors affecting pest management; (2) Identify and describe the social, economic, political, and institutional factors affecting pest management; (3) Work with participating groups to design, test, and evaluate appropriate participatory IPM strategies; (4) Work with participating groups to promote training and information exchange on IPM; and (5) Work with participating groups to foster policy and institutional changes. Proactive research has been conducted to attain these objectives primarily in Guatemala and Honduras. The success of our program is based on the simple concept of collaboration between interested and goal-driven individuals, industrial and private organizations, and government agencies (Central American and US) with support from US-based scientists. This has resulted in a coalescing of the goals of the IPM CRSP, the Government of Guatemala, the USAID Mission, FAS, APHIS and many Guatemalan participants to allow improvement in NTAE integrated crop production practices, post-harvest handling and marketing which help sustain and enlarge NTAE markets. The final goal of these programs is to more quickly move the industry towards attaining consistently high quality produce the meets SPS and HACCP standards, leading to stability and growth of the NTAE sector and improvement in the socio-economic level of Central American NTAE producers. The programs established with the help of the IPM CRSP have lead to an increase in crop production diversity, more stable cropping systems and supply availability of high quality safe food that meets the exacting standards of the modern consumer in local, regional, and US markets; resulting industry's desire to institutionalize these practices.

Our year 11 activities are the culmination of 10 years of research in IPM technology with NTAE crops, based on market analysis and targeted to developing holistic ICM production systems (all aspects of culture, including pest management), that will be transferred to growers and result in improved market performance. An example is the development of pest management programs for snow peas that has resulted in reductions in pesticide use, improvement in grower returns and increased socio-economic status for farmer families. These studies are being summarized and written into a production manual that describes production practices that, when monitored by inspections, will lead to a pre-inspection program that will ensure quality in the snow pea production arena. The pre-inspection/production manual was prepared based on IPM CRSP research results and collaborations between ICADA, ICTA, APHIS and PIPA. Technology transfers to producers will ensure that growers are trained in proper production and handling procedures. As a result of this success, the Government of Guatemala and FAS has supported the establishment of regional distribution centers to serve as gathering points for produce which will be properly handled and shipped to commercial outlets. These centers will also serve as educational centers for technology transfer and for production research projects. The first center (FRUTAGRU) was opened November of 2002 in San Cristobal, Totonicapan in collaboration with the "Associacion de Fruticultores Agrupados", FRUTAGRU.

Throughout the 10 years of the IPM CRSP support has been provided to assist our programs through FAS and the Government of Guatemala involvement (PL 480 Funds), continual contact with and support of the USAID Mission and its agricultural objectives, and collaborations with

AGEXPRONT, APHIS, ICTA, MAGA and many individual grower coops and exporters. The pre-inspection manual for snow peas will serve as a model for similar programs in other NTAE crops (tomatoes, broccoli, cucurbits and fruits) that are based on discovery-driven research to solve pest and crop management problems and develop stable post-harvest handling and marketing systems.

Also in year 11, we will develop additional collaborations in Honduras and El Salvador with their Ministries of Agriculture, NGO's, and grower groups, and support the common interests of the in-country USAID Mission. Our program already includes visits to Honduras and El Salvador to discuss projects of mutual interest in the NTAE area. Possible collaborations include pest management research, socio-economic studies relating to farm development opportunities and investigations relating to the Central America Free Trade Agreement and its impact on agricultural development.

As we proceed into year 11, the Central American IPM CRSP site is well poised to continue our productive programs that have resulted in NTAE market expansion and increased opportunity. The year 11 IPM CRSP program activities in the Guatemala/Honduras sites will include research, technical assistance, institutional strengthening, and oversight and program leadership in four major workplan areas: (1) socioeconomic, marketing, and policy analysis, (2) assessment of alternative cropping systems including biorational and organic approaches, (3) strategically targeted disease and insect control, and (4) transfer and adoption of IPM/ICM technologies.

**Site Chair Oversight.** Program leadership, coordination, management and oversight for the Central American Site will be handled by Dr. Stephen Weller (new site Chair) and Lonni Kucik, administrative assistant for the IPM CRSP. Since the Site management responsibility will cut across all the research activities, a separate oversight budget has been included.

**Budget:** $26,345 – Purdue University

### I.1. Economic and socioeconomic impact assessment of IPM and nontraditional crop production strategies on small farm households in Guatemala

**a.** **Scientists:** S. Hamilton – Virginia Tech; L. Asturias de Barrios – Estudio 1360; G. Sánchez, L. Calderón – ICADA

**b.** **Overall Objectives:** (1) To increase economic and social benefits of IPM for all members of farm families; (2) To measure the economic and social impacts of IPM adoption by gender; and (3) To measure economic and social constraints of IPM adoption by gender. **Objectives for Year 11**: (1) To measure levels of current adoption of IPM and evaluate adoption trajectory since socio-economic baseline study in 1998 and first follow-up survey in 2000. (2) To assess changes in adoption constraints since 1998. (3) To assess changes in economic and social well-being of IPM adopters and non-adopters who produce targeted crops since 1998. (4) To assess changes in gender (intra-household) constraints to adoption and results of adoption since 1998. (5) To provide social science information that will strengthen IPM dissemination efforts of collaborating institutions.

**c.** **Hypotheses:** (1) Rates of IPM adoption across 10 categories of implementation have continued to rise since 1998 (observed: there was a demonstrable increase between 1998-99 and 2000-2001. (2) Farmers with most sustained access to technology transfer are likely to adopt IPM across a wider range of implementation categories. (3) Farmers who belong to membership-based production organizations that transfer IPM are more likely to have sustained access to IPM technology transfer. (4) Controlling for market and other production variables, IPM has contributed to improved incomes and social outcomes for adopting farm families in highland Guatemala. (5) Benefits of IPM and targeted crop adoption are shared among all family members. (6) Gender-based constraints to adoption have changed little since 1998.

**d.** **Description of Research Activity:** Research will involve (1) a socio-economic impact assessment survey of households in three communities that were included in baseline surveys in 1998; (2) final data collection from, and reports to, collaborating institutions regarding dissemination of IPM. All research will be disaggregated by gender.

The follow-up household socio-economic surveys will be administered to a probabilistic sample of some 300 householders in three communities that reflect variation in access to IPM transfer across similar markets for targeted crops. Both male and female household heads will be interviewed in each household. Households included in the original sample will be included in the survey, together with additional randomly-selected households to compensate for population changes over time. Survey instruments will be adapted from those used in 1998-99 and 2001-2003. All original questions will be asked, including those on household and individual economic and social assets; production and marketing of all crops during the previous year's production cycles; IPM adoption across a range of practices; labor of all household members; intra-household decision-making concerning land use, production finance, agrochemical use, family labor, and control of agricultural and other incomes; family health and nutrition as related to production of targeted crops and IPM; and perceived production constraints. The original survey instrument included questions concerning farmers' memberships in production coops, access to production contracts, and access to IPM technology transfer. In the follow-up survey, additional questions will be fielded concerning IPM dissemination methods and channels. The intermediate follow-up survey included questions concerning the role of targeted crop production in changing household economic and social asset bases over time. The proposed ultimate follow-up survey may include refined questions concerning these trajectories. The proposed survey will include refined questions concerning women's roles in IPM and target crop production, marketing, and income management (in order to elucidate statistical associations between women's marketing, land ownership, and household production decisions that emerged from the earlier surveys). (2) To bring to closure a study of the implications of production finance options for IPM adoption and target crop economic impacts (2001-3), final information collection will be conducted among administrators and members of at least one agricultural export cooperative and a report will be provided to the institution and to the CRSP. Institutional interviews will concern methods and pathways of disseminating IPM and other crop management information.

e. **Justification:** Impact assessment is a critically important component of IPM CRSP research. For this reason, we have constructed all of our research activities for the last five years around the objective of providing sound information that will enable economic and social impact assessment. We began with cross-sectional analysis of baseline data across levels of adoption of targeted crops and we followed up with mid-term longitudinal assessment of IPM adoption and targeted crop adoption impacts. Because adoption levels of targeted crops and their economic impacts change rapidly in the volatile nontraditional export sector, it is important to provide short-term and longer-term impact assessments on a regular basis to understand the market dynamics and other constraints that affect producer adoption and outcomes of IPM. The ultimate follow-up survey proposed for 2003-2004 will make a strong contribution to this process.

All of our work is disaggregated by gender. Our publications have contributed to an international understanding of the roles of women in agricultural decision-making and IPM, as well as to the effects of targeted crop and IPM adoption on the well-being of women and children in farm families. The proposed research will further strengthen our understanding of the intra-household dynamics of IPM adoption and benefits.

Both activities (1) and (2) will contribute further to identifying organizational constraints to adoption and effective practice of IPM and to the economically sustainable production of targeted nontraditional export crops. Past work on this project has demonstrated that most farmers are willing to adopt some, but not all, of the recommended IPM practices, and that the most difficult practices to transfer require sustained producer contact. Providing incentives for producers to seek out knowledge and to practice IPM appears to be related to organizations' input supply and credit supply channels. The proposed research will enable the CRSP to produce recommendations for both collaborating scientists and production organizations regarding producer perceptions of IPM costs and benefits and effective information dissemination channels.

f. **Relationship to other CRSP activities at the site:** In household surveys during 1998-2001, farmers indicated (1) high level of self and family involvement in NTAE labor; (2) their continuing need for production credit, (3) high-level adoption of technology-based IPM but low-level adoption of scouting and other labor- and information-intensive practices; and (4) that they received better prices if they sold nontraditional export crops through production cooperatives and contracts with exporters than if they marketed independently. Access to membership in cooperatives and to contracts varied greatly among Kaqchikel communities in Chimaltenango and Sacatepéquez. Yet voiced need for credit and low adoption of information-intensive IPM were present in all communities. In 2001-3, studies of production finance and social capital were undertaken to help sort out the sources of informal and formal production credit available to farmers; associated risks and the role of social capital in mitigating those risks; farmer preferences among these sources; and associations between credit, input supply, and IPM within organizations. This research uncovered a disarticulation between organizations' informational bases and producer perceptions of credit and input supply channels and of IPM. This information can help in organizational recruitment and communication and can provide useful knowledge of diffusion mechanisms for IPM CRSP stakeholders throughout the research, extension, and marketing chains.

**g.** **Progress to date:** Probabilistic household surveys were conducted in three Maya communities in 1998-1999 and in 2000-2001. These dealt with social and economic effects of nontraditional export production in small farm households, adoption of IPM by these households, and perception of long-term economic and social impacts of NTAEs at the household and community level. All of these results were disaggregated by gender. Results of this research have been published in international journals (e.g., Goldin and Asturias de Barrios 2001; Hamilton, Asturias de Barrios, and Tevalán 2001; Hamilton and Fischer 2003) as well as three IPM CRSP working papers, several IPM CRSP annual reports, and annual presentations at international forums. These baseline and intermediate follow-up results have generated considerable interest in the scientific community. We anticipate that the proposed longer-term follow-up survey will enable us to build on this publication record as well as providing useful programming information.

**h.** **Projected Outputs:** Minimum of one working paper and one article presenting research results; report to collaborating institutions providing socio-economic context for IPM dissemination; presentation of policy recommendations for IPM information and technology transfer mechanisms to IPM CRSP site committee.

**i.** **Projected Impacts:** Increased IPM adoption, production income, and social well-being among small-holding farmers and their families in the Central Guatemalan highlands.

**j.** **Projected Start:** October 2003

**k.** **Projected Completion:** September 2004

**l.** **Projected Person-Months of Scientists Time per Year:** 3

**m.** **Budget:** $13,200 – ICADA/Estudio 1360; $17,878 – Virginia Tech

### I.2. Survey on sanitary and phytosanitary (SPS) issues faced by the Central American Common Market (CACM) and impact of the Central America Free Trade Agreement (CAFTA)

**a.** **Scientists:** D. Orden, T. J. Yamagiwa, (Ph.D. student from El Salvador) – Virginia Tech; A. Angel – Ministry of Agriculture, El Salvador.

**b.** **Overall Objectives:** The principal objective of this research is to lay the groundwork for future expansion of the IPM program on nontraditional agricultural export (NTAE) crops in Central America by systematically assessing the state of sanitary and phyto-sanitary (SPS) barriers that affect NTAE crops from the Central America Common Market

(CACM, consisting of Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua). This objective will be pursued through an initial comprehensive literature review, followed by surveys and interviews within the countries involved. Despite existing analysis treating some aspects of SPS issues in the CACM, a concise survey that serves as a reference point for further progress to reduce these trade impediments is absent. As more than 80% of total CACM exports are directed either to the United States, within the CACM, or to the European Union (40%, 28% and 13% of total exports, respectively), the survey will concentrate on SPS measures imposed in those markets. All aspects of this project will be coordinated with and designed to compliment USAID Missions objectives in each of the countries under study.

The CACM countries are presumed to be incurring significant costs to their trade due to SPS measures that 1) are required by their export destinations, and 2) CACM countries impose on intra-market trade. Characterization of SPS requirements will be made by destination of CACM exports. Identification of traits related to SPS barriers applied by the United States will be evaluated due to 1) the preliminary indication that SPS measures impose significant costs (the CACM suffered from 51 import rejections per $1 billion of exports to the U.S. in 2002, which contrasts to comparable figures of 6 and 17 for Canada and Mexico, respectively), and 2) changes in the nature of trade relations that may result from the implementation of the Central America Free Trade Agreement (CAFTA) between the United States and the CACM countries, negotiations for which are planned to be completed by December 2003 (to illustrate, Mexico's SPS regulatory process and SPS authorities' collaboration with U.S. counterparts improved after implementation of the North American Free Trade Agreement (NAFTA)). A thorough survey of SPS issues affecting intra-CACM trade is also crucial (preliminary assessment by the Secretary of Central American Economic Integration finds that 22% of intra-trade barriers were due to SPS measures), as these could also be affected by creation of the CAFTA. Institutional capacity to handle SPS issues will be analyzed, and specific SPS barriers that could be the subject of further research will be identified.

c. **Hypotheses:** (1) Costs due to SPS measures represent a significant impediment to the region's trade; (2) Characteristics of SPS barriers differ according to markets of export destination; (3) The CACM and its member countries require additional institutional, technical, and financial capacity to effectively manage SPS issues; (4) Establishment of the CAFTA will improve quality of the SPS regulatory process in the CACM countries, and collaboration among SPS authorities in the countries involved; (5) Incidence of SPS barriers forcing intra- and extra-CACM trade can be decreased with the implementation of the CAFTA.

d. **Description of Research Activity:** Extensive literature review, data collection, and telephone and personal interviews with government officials (both at the national level and Central American regional institutions), producers, exporters, and researchers will be the primary means of conducting the survey, but particularly, USAID missions will first be visited to obtain an initial on-site orientation for the research. It is expected that these activities will require one trip by the principal scientist and two trips by the graduate student to Central American countries.

Costs of SPS measures in CACM trade will be evaluated by variables such as number of detentions of CACM exports at the border and the value of those exports. SPS barriers will be characterized by: inter alia, the product SPS barriers apply to, the period of application of the barrier, and the negotiating opportunities of the sector that grows the product. Comparison of the SPS institutional, technical, and financial capacity in the CACM and in the U.S. may be one of the means to evaluate the SPS infrastructure in the CACM. Finally, ongoing CAFTA negotiations will be analyzed with special attention to the treatment of SPS issues in an attempt to foresee outcomes when the agreement is implemented. Implications from the NAFTA experience will be drawn for comparison purposes.

**e.** **Justification:** The overall IPM-CRSP objective in Central America is to attain "economically sustainable nontraditional agricultural export (NTAE) crop trade expansion in Central America, with less dependency on chemical pest control methods" (IPM CRSP Eighth Annual Report 2000-2001). The proposed research will provide a more comprehensive understanding of the institutional environment in which this objective is to be achieved. Furthermore, the intended geographical reach of this research is in accord with the regionalization of the Central America IPM CRSP program in the next phase, and the aim of this research parallels USAID mission objectives.

**f.** **Relationship to other CRSP activities at the site:** As the present research activity does not initiate a new program, its support of other CRSP activities and objectives of USAID missions in the site is crucial. It is expected that the present research will deepen understanding derived from the IPM CRSP project "An Assessment of Production, Post-harvest Handling, and Regulatory Compliance (including food safety) Factors Critical to Sustainable NTAE Program Development" conducted in Guatemala.

The present survey is strongly related to USAID mission objectives at Central American IPM CRSP sites. One of the El Salvador mission objectives is to expand trade and attain greater competitiveness, issues on which the survey will give guidance. Similarly, the Honduras mission recently provided an analysis of the export incentive framework, which is in line with the objective of the present survey. Finally, one of the Central American mission programs based in Guatemala is entitled "Increased Participation in Global Markets."

**g.** **Progress to date:** New activity; not applicable.

**h.** **Projected Output:** A report systematically documenting the literature survey, collected data, interview summaries, and a list of references will be elaborated. Analysis of the survey results will be provided. These reports will be presented to, and discussed with, relevant USAID missions and agriculture ministries to help in defining mutually beneficial IPM programs.

**i.** **Projected Impacts:** The survey will provide personnel working for IPM CRSP projects or for USAID agricultural export promotion programs a more thorough appreciation of the institutional framework and incidence of SPS issues. Given that this research project will systematically characterize the extent to which SPS barriers are an impediment to the objectives for the CACM, the survey will enable scientists to take on constructive opportunities for research to lessen this constraint.

**j.** **Projected Start:** September 2003

**k.** **Projected Completion:** September 2004

**l.** **Projected Person-Months of Scientists Time per Year:** 14 person-months

**m.** **Budget:** $30,000 - Virginia Tech (an additional $7,386 is allocated from existing Global Themes making total budget for this project $37,386)

### II.1. Evaluation of transgenic papayas (*solo* and native) with resistance to papaya ringspot potyvirus, using kanamicyn as selection marker in greenhouse conditions (Biotechnology project)

**a.** **Scientists**: M. Palmieri, J.M. Seijas, L. López – Universidad del Valle/Guatemala; G. Sánchez, ICADA; W. Parrott, M. Deom – U. of Georgia

**b.** **Overall Objectives:** To identify papayas which are resistant to papaya ringspot virus (via the coat protein gene) and to evaluate their agricultural and organoleptic characteristics under greenhouse and field conditions. **Objectives for Year 11:** (1) Evaluate through PCR the presence of the coat protein gene in the transgenic plants. (2) Test, through mechanical transmission, the presence of the coat protein gene in the transgenic plants. (3) Micropropagate the PRSV-resistant plants. (4) Evaluation of first generation (F1) transgenic papayas for PRSV resistance expression. (5) Transfer of PRSV-resistant papaya plants to field conditions.

**c.** **Hypotheses:** Papayas expressing the coat protein gene for ring-spot virus resistance are not susceptible (are resistant) to papaya ringspot virus (PRSV-p). Transformed plants will: be true to type, have gene expression that is stable over generations, be resistant to ring-spot virus; and produce papayas accepted not only for domestic commercialization but also for export in the NTAE markets.

**d.** **Description of Research Activity:** During this period, papayas produced by tissue culture will be taken to the greenhouse and evaluated for the presence of coat protein gene. Lateral meristems and some apical meristems will then be propagated in tissue culture. Papayas will be mechanically inoculated with the virus and evaluated visually for viral symptoms and by DAS-ELISA for the presence of the virus. Grafts from infected not-transformed papaya to transgenic papaya will be made to determine if such treatments result in disease resistance. If no symptoms are detected, the grafted plants will be pollinated and compared with resistant papayas. The existence of papaya ring spot virus resistant varieties in Hawaii will be used for comparison with the varieties developed in Guatemala for determination of resistance levels obtained. See web site: http://www.alohaseed.com/papaya.html for information concerning Hawaiian papaya.

Data to be collected includes plant phenological characterization, as well as fruit quality and plant yield. Fruit quality will be assessed according to market quality and consumer preference, including size, color, shape and other consumer-preference characteristics. Time permitting, seeds from the fruits will be planted and will be evaluated for the presence of the coat protein gene by PCR. Southern blots will be run to confirm the existence of the coat protein gene in the transgenic plants and compared to the genetic makeup of control, non-transformed plants. These tests will be conducted in collaboration with researchers from the University of Georgia. By the end of this study we expect to have identified and propagated enough PRSV-resistant papaya plants to start field assessment of PRSV-resistance under natural field conditions. These studies will be funded through the Guatemalan Agricultural Science and Technology Council (AGROCYT).

**e.** **Justification:** Papaya is a very nutritious fruit, highly consumed in many countries. In Guatemala papaya is a preferred fruit among the local population, and given this demand, represents a profitable product for small and medium growers. In addition the potential of papaya as an export crop makes it an even more attractive option for growers as previous IPM CRSP studies suggest an increasing demand for solo-type papaya in the US for at least a decade in the future. The production of papaya in Guatemala and the rest of Central America is limited severely by viral infection caused by the Papaya Ringspot potyvirus (PRSV). The development of PRSV-p resistant papayas will help to solve one of the most important problems and will also bring some other contributions. One of them is the reduction of high quantities of pesticides for control of aphids, resulting in a decrease in costs of production for the growers but it also will help promote safer ways to produce papaya for growers and the environment.

**f.** **Relationship to other CRSP activities at the site:** This study is of interest to many collaborators. These activities have been and will continue to be developed with the help of institutions like ICTA, AGEXPRONT, CONCYT, PROFRUTA and especially with the help of papaya growers.

**g.** **Progress to date:** A regeneration and transformation system has been developed for Guatemalan type papaya. Papaya embryos have been transformed with the gene for ring-spot virus resistance and papaya plantlets have been regenerated from the transformed embryos. Techniques for shoot elongation and rooting have been developed, and plantlets with roots have been obtained and are being transferred to the greenhouse for further testing under greenhouse and field conditions during year 10 and 11.

**h.** **Projected Outputs:** Papaya plants with effective coat protein mediated PRSV resistance will be obtained and tested for stability of gene expression and growth characteristics. In the future, these plants will be developed for commercial production of papaya for domestic and export markets.

**i.** **Projected Impacts:** The main impacts of this project will be the generation of papayas with resistance to PRSV-p, decreased usage of pesticides during papaya production, and an expansion of papaya growing in Guatemala for many small farmers, thus increasing farmer income and improving potential for papaya in the NTAE markets.

**j.** **Projected Start:** October 2003

**k.** **Projected Completion:** October 2004.

**l.** **Projected person-months of scientific time per year:** 7 person-months.

**m.** **Budget:** $2,800 – ICADA; $2,200 – UVG.

### II.2. Validation of the technology generated by the IPM CRSP to control the Mediterranean fruit fly in guava (Thailand's variety) and giant star fruit

**a.** **Scientists:** O. Sierra, D. Dardón – ICTA; L. Calderón, G. Sánchez – ICADA; S. Weller - Purdue University

**b.** **Objectives:** (1) To validate the results of the IPM CRSP technology to farmers that produce guava and star fruit; and (2) To determine the acceptance of the technology that will be promoted.

**c.** **Hypothesis:** Non-chemical treatments involving the covering of fruit are effective in eliminating fly ovipositioning on guava and star fruit.

**d.** **Description of Research Activity:** The fruits will be protected with paraffin bags in order to avoid Mediterranean fruit fly oviposition. This will be compared with the traditional management that farmers use to avoid oviposition. The activity will include 2 sites: Cuyuta, Escuintla and Zacapa. Researchers will contact IPM CRSP collaborators in the Philippines to consult about their research involving the use of pheromones to control the fruit flies as an additional approach to designing integrated programs of insect control.

**e.** **Justification:** Guatemala has problems in exporting guava and star fruit due to the damage that med fly and other fruit flies cause. The IPM CRSP has generated technology which is effective in controlling these insects, using covers that eliminate the flies' damage and the use of insecticides. Therefore, it is necessary to promote this technology.

**f.** **Relationship to other CRSP activities at the site:** ICTA, in conjunction with the IPM CRSP, has conducted some activities related to this research and the results have been successful, so it is necessary to validate this technology.

**g.** **Progress to date:** Several protective fruit coverings were effective in protecting guava and star fruit from med fly larvae. The most effective were paraffin bags, white nylon bags and polyurethane fabric.

**h.** **Projected Outputs:** It is expected that farmers will adopt this technology since it does not require the use of pesticides to reduce the fruit flies attack and will be more attractive to farmers. The successful transfer of this technology will allow better access to local and international markets.

**i.** **Projected Impacts:** Farmers who adopt this technology will reduce the presence of insect larvae in the production system. Technology of this type will provide increased potential in fruit area, thus creating more jobs and potential for increased economic development in the fruit sector.

**j.** **Projected Start:** October 2003

**k.** **Projected Completion:** August 2004

**l.** **Projected person month of scientist's time per year:** 3 person-month

**m.** **Budget:** $5,830 – ICTA

## II.3. Molecular identification of viruses of solanaceous and cucurbit crops in Honduras and transgenic resistance to control *Tomato mosaic* and *Pepper Golden Mosaic* viruses in tomato (Biotechnology project)

**a.** **Scientists:** A. Rueda, M.M. Roca de Doyle – Zamorano; D. Krigsvold, M. Rivera, J.C. Melgar – FHIA; R. Martyn – Purdue University; J. Brown – U. of Arizona; M. Deom – U. of Georgia

**b.** **Objectives:** Due to limited amounts of funding available, the project will focus on the *Begomovirus* characterization and causal nature and transgenic tomato strategies (Objectives 2-6) and although described, Objective 1 – Virus identification and distribution will be delayed until additional funds are available.

(1) To conduct a three-year virus survey of pepper, tomato, and watermelon crops in Honduras to identify viruses that should be targeted and prioritized for management programs; (2) To clone and obtain the nucleotide sequence for the CP gene of the ToMV isolate from Honduras; (3) To obtain full-length, infectious clones for PepGMV, and one other tomato-infecting begomovirus that is widespread in Honduras (and other Central American countries, including Nicaragua and Guatemala); (4) To develop constructs for ToMV and PepGMV for tomato transformation; (5) To generate R0 and R1 transgenic tomato plants expressing ToMV coat protein or a PepGMV REP fragment, and anti-sense and sense control constructs for PepGMV REP; and (6) To analyze transgenic tomato

lines, to determine copy number, evidence for transgene expression and/or protein expression (ToMV CP), and challenge inoculation data.

**c.** **Hypothesis:** Aphid- and whitefly-transmitted, and other plant viruses are important limiting factors in vegetable cropping systems in Honduras. Little, if any, information is available to farmers regarding the specific plant viruses that limit vegetable crop production. As a result, disease control practices are often misguided, leading to application of chemicals that have no affect on virus pathogens. Virus disease resistance is essential to alleviating the reliance on harsh chemicals and can be achieved through the application of agro-biotechnology, including plant breeding and transgenic strategies.

**d.** **Description of Research Activity:** (1) **Begomovirus characterization and causal nature**. The genomic sequence for two previously uncharacterized tomato-infecting *Begomovirus* DNA A and DNA B components will be cloned and the sequence determined for each. A 1.5 mer DNA A and DNA B component (viral chromosomes) will be constructed and used to demonstrate infectivity (to demonstrate causality). Clones will serve as the source of sequences for constructing transgenes in the next phase of the project and for challenging transgenic plants containing PepGMV transgenes.

(2) **Transgenic tomato strategies.** (a) Clone and sequence of viral REP (Replication-associated protein) and CP (coat protein) genes from Honduran PepGMV, and the CP gene from the Honduran ToMV isolate to guide the construction of transgenes. (b) Clone viral genes into transgene cassettes and transform into disarmed *Agrobacterium*. (c) Transform tomato independently with PepGMV Rep and ToMV CP transgenes. (d) Screen R0/R1 lines in AZ and GA for extent of homologous virus protection, respectively.

(3) **Virus identification and distribution**. FHIA will make collections and carry out ELISA and PCR tests for samples collected during 2003-4 in Honduras. (a) Target area, sampling pressure and sample numbers. Leaf tissue samples will be collected in three geographical areas in Honduras during the two consecutive cropping seasons beginning in September 2003 and ending May 2004. About 100 samples total will be collected, with an emphasis on plants that exhibit symptoms not previously documented, or those that are particularly severe. (b) Documentation of cases. All samples collected will be documented in a specially designed format with the symptoms and circumstances of occurrence of the problem (crop history, prevalent weather, distribution and frequency, etc.). Additionally, each case will be photographed in the field using a digital camera for the development of photographic archives and preparation of a field guide. (c) Processing of samples. Each sample will be tested by ELISA using a battery of 10 different viruses and by PCR for begomoviruses using universal PCR primers (~550 bp) (Brown et al., 2000; Wyatt and Brown, 1996). *Begomovirus* isolates from Honduras will be sent to the AZ lab where they will be identified using PCR, DNA sequencing, and comparison with sequences available at the Gemini Detect*ive* database at URL http://gemini.biosci.arizona.edu.

Our approach to developing pathogen-derived resistance (PDR) for begomoviruses will focus on introducing virus gene sequences into tomato to induce an RNA-mediated PDR, or post-transcriptional gene silencing (PTGS). PTGS results in the co-suppression of a transgene and the homologous cellular gene. Similarly, in transgenic plants expressing viral transgenes, PTGS suppresses expression of the transgene and accumulating viral RNA, which shares sequence homology with the transgene. PTGS is induced by dsRNA (dsRNA) and requires host gene products. Initially, dsRNA is generated to a specific target RNA and the dsRNA is processed into small interfering RNAs (siRNAs) of 21 to 25 nucleotides. The siRNAs associate with a protein complex, referred to as the RNA-induced silencing complex (RISC), and direct the selection of target RNA for degradation. Evidence suggests that RNA silencing is a natural defense mechanism against foreign nucleic acids, such as from viruses, and/or overexpressed nucleic acids. Begomoviral replication requires expression of REP and down-regulation of its expression would interfere with, and possibly eliminate completely, the synthesis of Rep protein, thereby blocking viral replication, an early activity in the disease cycle. Transgene constructs will be inserted into tomato by standard *Agrobacterium*-mediated transformation techniques that are available for dicot plants. For tobamoviruses and potyviruses, coat protein-mediated protection (pioneered by Dr. Deom), which is widely used for these groups of plant viruses, will be implemented. While the introduction of nontranslatable ToMV genomic sequences into transgenic plants routinely induce PTGS, constructs of the PePGMV replicase gene sequences will be designed that produce double-stranded RNA molecules following transcription. Double-stranded RNA has been commonly used to induce RNA interference (RNAi) in a number of organisms (Di Serio, *et al*, 2001) and it has been shown to function similarly for begomoviral sequences when inserted into the plant chromosome (Peele *et al.*, 2001) What makes this approach attractive, is that RNAi and PTGS share a highly conserved functional mechanism for inducing gene silencing (Di Serio, *et al*, 2001).

Because PTGS (and RNAi) require a high degree of sequence homology between the transgene and the targeted viral sequence, it is important that the viral gene sequences used to generate transgenic plants be obtained from the predominant ToMV and PePGMV isolates present in tomato in Honduras. We will ultimately introgress functional transgenes into tomato varieties that are presently adapted to and cultivated in Honduras and the Central American region. These cultivars have been developed for specific agronomic traits (resistance to nonviral pathogens, fruit quality, and heat tolerance) and will be preferred by farmers (Commercial: Peto 25, Maya, Butte, Sheriff, Manzano; Fresh market: Miramar) and local consumers. However, because the majority of cultivars are hybrids, transformation will be conducted in the generic variety, 'Moneymaker', and subsequently crossed into a local variety. Challenge inoculations for ToMV and PePGMV will initially be done in greenhouses in GA or AZ, respectively, which are approved for transgenic plant research. Resistant lines will be assessed for transgene copy number, viral mRNA expression, and ssRNA, ss/dsDNA, and northern/Southern analysis prior to field-testing in Honduras (in collaboration with FHIA); in accordance with national regulations governing genetic modified organisms.

**e.** **Justification:** Whitefly-transmitted geminiviruses (genus: *Begomovirus*), potyviruses, (aphid vectored), and tobamoviruses are economic deterrents to solanaceous (tomato, pepper and oriental vegetables) and cucurbit (watermelon, melon, cucumber and oriental vegetables) crops in Honduras, with yield losses estimated at 50-90%. The largest tomato processor in Honduras now imports paste from outside the country for packaging in Honduras because viral diseases have made it unprofitable to produce processing tomatoes in Honduras. Before rational management strategies can be implemented, it is necessary to determine the causes of the diseases and to identify the sources of inocula. Under year-round irrigated agricultural conditions, viral diseases and insect pests become a much more important problem since there is not an interruption of their biological cycles. Accurate virus identification and knowledge of the biological characteristics of each virus will permit, for the first time, the implementation of rational control approaches that can be integrated in the context of a cropping system. Directed control through implementation of appropriate cultural practices and management of insect vector and direct pest populations will result in reduced application of hard insecticidal chemicals, thereby encouraging environmentally safer production practices in Honduras.

A main deterrent to tomato and also to pepper production that has been identified is *Pepper golden mosaic virus* (PepGMV), a *Begomovirus* (See Years 9 & 10 Report, IPM CRSP Project Report). *Tobacco etch virus* (TEV) a widespread, aphid borne *Potyvirus* and the *Tobamovirus*, *Tomato mosaic virus* significantly reduce yield (up to 80%) in solanaceous crops in Honduras (Years 9/10, IPM CRSP Project Report). Tomato samples analyzed in years 9 /10 revealed that frequently ToMV was found together with PepGMV or other begomoviruses, and typically a synergistic effect was notable, suggesting that simultaneous protection against both viruses is essential. A similar situation was found in pepper with begomoviruses and potyviruses, making this virus combination a priority for disease resistance, as well. In this project, we will develop transgenic tomato plants with resistance to PepGMV and ToMV, and ultimately, also to TEV strains that predominate in Honduras and the region, but for which little if any molecular characterization has been accomplished to date. Our aim in tracking the viruses for a third year is to determine if results are consistent for three consecutive years of investigation, and to determine if new or emerging viruses are present this year that were not detected in the previous years. For ToMV and TEV, sequencing of several isolates will provide insights into their coat protein (CP) diversity in Honduras, which is crucial to developing an effective CP-mediated resistance approach. Complete viral genomic sequences are essential for the design of broad spectrum virus-derived resistance, and infectious clones will be used to challenge-inoculate transgenic tomato plants to test them for disease resistance.

In addition, it is important to share information with other IPM CRSPs working in other project sites that share common plant virus problems and the need for disease resistant germplasm. In this spirit, selected pepper (*Capsicum* spp.) samples in which potyviruses are identified will be shared with Dr. Sue Tolin (of VT) and the team in the Caribbean Region to determine the relative extent of virus diversity in the Eastern Caribbean (Greater and Lesser Antilles) /Central American locales, for which certain viral pathogens are shared in common.

Honduras is the first Central American country to develop guidelines for transgenic plant evaluation. FHIA and ZAMORANO are the leading institutions there involved in field testing of transgenic crops, e.g., maize and soybean for Monsanto, among others. We expect that this project will lead to the development of transgenic plants with genetically engineered disease resistance in tomato to two highly damaging viral pathogens. An added advantage to making available a virus-resistant tomato is the elimination of pesticide misapplication aimed at controlling the whitefly vector to reduce virus spread. Transgenic tomato, transformed with RNA-mediated sense, anti-sense, and dsRNA constructs, will provide the first technology of this kind to Honduran farmers to combat two of the most virulent and widespread viral pathogens in tomato crops. Employing the begomovirus-tobamovirus system, we will stack tomato with genes from two different, unrelated plant viruses. In follow-up efforts, resistance can be developed for additional crop species (pepper, melon, watermelon), which are hosts for potyviruses and other begomoviruses that occur commonly in Honduran vegetable crops.

**Past and Related Work**. Three of the most destructive viruses on tomato and pepper in Honduras and throughout Central America are *Tobacco etch virus* (TEV), a single-stranded, positive-sense RNA virus, *Tomato mosaic virus*, and *Pepper golden mosaic virus* (PePGMV), a single-stranded DNA virus having a bipartite genome (Brown, 2001; Years 8,9 IPM CRSP Project). Because tomato and pepper are grown predominantly by smallholding farmers as both subsistence and cash crops, TEV, ToMV, and PeGMV are particularly crippling to the rural economies given 50-90% losses. This project proposes to achieve disease resistant tomato to protect against two of the three viral diseases (initially, and then the third can be added) by generating tomato germplasm with resistance, obtained through genetic engineered approaches. Although the genetic mechanism(s) underlying the proposed strategies is not entirely understood, there are many examples in which the suppression of gene expression has resulted in effective elimination of detectable levels of viral mRNA and proteins crucial to the infection process, resulting in resistance to viral diseases. Examples for which this strategy has been used successfully in plants include anti-sense to slow tomato fruit ripening, and antisense/sense strategies to achieve protection against the Old World, monopartite begomoviruses, TYLCV-IS (Czosnek et al., 1994) and TYLCV-ES (Norris et al., 1996). Gene silencing has been demonstrated for TEV CP and 6kDa/VLg in transgenic tobacco plants. In tomato, an easily transformed dicot, *Alfalfa mosaic virus*, *Cucumber mosaic virus*, *Tobacco mosaic virus*, and *Tomato spotted wilt virus* resistance has been achieved using the respective viral CP gene sequence (Deom, 1999).

**f. Relationship to other CRSP activities at the site:** Information regarding the distribution, identity, and diversity of plant viruses identified in Central America will be shared with the IPM CRSP team in the Caribbean region, through direct interactions with Dr. Sue Tolin at VT. Because different labs specialize in different virus groups, it will be beneficial to exchange isolates for examination in greater detail by individual laboratories that specialize in specific virus pathogens, together with interested cooperating team members. For example Dr. Tolin is interested in pursuing potyvirus diversity, Dr. Brown, begomoviruses, and Dr. Deom, tobamoviruses, and in respective training and technology transfer to regional scientists, sharing (1) diagnostic and biotechnology methods, (2) information regarding genetic variability of plant viruses that are common to both regions, and (3) successful management practices. This approach will strengthen inter-regional collaboration and also reduce the need to duplicate efforts in research and training in biotechnology for the region. Examples include standardizing and sharing virus detection and identification methods, and sharing knowledge of disease incidence, genetic variation of viral pathogens, disease management approaches, and transgenic plants technology for controlling plant virus diseases that occur in both regions. Such interactions will enhance cooperative interactions between scientists in both regions, and open the door for future collaborations between inter-regional CRSP participants and those in other CRSPs, particularly those involved in biotechnological solutions to integrated pest and pathogen management. Collectively, participants and activities will be positioned within the context of the project mission in promoting economic development in an integrated management context, thereby leading to more sustainable food production practices for the region.

**g.** **Progress to date:** ELISA and PCR equipment are now available in the laboratories of FHIA. Optimization of ELISA methods (Indirect, DAS-ELISA) and PCR methodologies was accomplished, collaboratively between Arizona, FHIA, and ZAMORANO. A FHIA scientist trained in AZ for several weeks last fall (2002) to learn PCR, cloning, and sequence editing. Dr. Doyle is expected to train in AZ and GA this summer (2003) to learn to clone viral genes and screen transgenic plants for virus resistance. Technicians and students at Zamorano routinely utilize PCR to detect begomovirus DNA in samples collected by that lab. Samples from ZAMORANO and FHIA were forwarded to AZ for cloning and sequencing/virus identification by DNA sequence comparisons. Numerous economically important begomoviruses and RNA-containing plant viruses have been documented in crops in Honduras. The predominant begomovirus, *Pepper golden mosaic virus* (PepGMV), has been selected as the candidate *Begomovirus* for which viral constructs have been made toward genetically engineering tomato (and tobacco to test proof of concept) for disease resistance. *Tomato mosaic virus*, which was identified as widespread and often mixed with PepGMV, has been selected as the candidate virus for coat protein mediated resistance in tomato.

In the AZ laboratory, full-length infectious clones (1.5 mers) for the DNA A and DNA B components of the bipartite virus, PePGMV have been obtained and the entire sequence determined. We have engineered three transgene constructs based on the PepGMV genome sequence (inverted repeat using a fragment of Rep and the corresponding sense and anti-sense constructs, included as experimental controls). Constructs were subcloned into a binary vector system and transformed into *Agrobacterium tumefaciens*, from which they will be mobilized into plants. Constructs are designed as an inverted repeat to capitalize on a gene silencing strategy for *Begomovirus* protection. Tobacco and tomato have been transformed with Rep (and controls, sense and anti-sense) constructs, and RT-PCR, and northern and Southern analysis are presently being standardized using tobacco also transformed with the same constructs as above, which regenerates about 2-3X faster than tomato. Tobacco plants will be ready for assessment in about two weeks. The first transgenic tomato seedlings are expected to be moved from tissue culture into a modified hydroponics system in about 8 weeks.

Plants will be screened by PCR (*Begomovirus* primers) and restriction digestion of total DNA to confirm the presence of the respective transgene integrated into the genome as a single copy. Single copy plants will be challenge-inoculated using biolistic inoculation and infectious clones, and also using an *Agro*inoculation-PepGMV technique if required. Plants will then be assessed for expression of the transgene using RT-PCR and northern analysis and virus replication will be assessed by Southern analysis. Symptoms will be recorded and a disease rating scale will be applied to document phenotype associated with genotype. Plants that are tolerant or resistant to virus infection will be saved and seed will be produced for those plants. Seed will be planted and retested to verify stability of the transgene. Seed will be increased and ultimately used in crosses with resistant transgenic plants analyzed in Georgia (Dr. Deom), which will use the coat-protein-mediated resistant approach to protect against *Tomato mosaic virus.*

In Georgia, ToMV isolates have been made available from the Zamorano PI after field studies in which it was identified as the most important RNA containing plant viruses in pepper and tomato last fall and early spring. The coat protein gene for the Honduran isolate of ToMV is presently being cloned and inserted into the transgene cassette available in the GA lab. Tomato will be transformed with the ToMV transgene in the AZ laboratory *(see budget justification).* Transformants will be provided to the GA laboratory for subsequent screening, which will be carried out similarly to that for *Begomovirus* plants except that relevant procedures for RNA instead of DNA viruses will be implemented. By the end of year three, proof of concept (and additional *Begomovirus* constructs, different lengths, and possibly targeting additional viral ORFs) will have been made, as necessary for transgenic resistance to PepGMV and ToMV in tomato should be in hand. Testing candidate lines for broader spectrum resistance to additional begomoviruses (those for which cloning is in progress) will also then be undertaken in the interim. It is anticipated that crosses between a horticultural desirable parent and transgenic tomato plants will be feasible with the collaboration of a Plant Breeder in phase II of the project (2005-onward). Permits for field testing in Honduras will be applied for as soon as it is apparent that materials are ready to field test. National and International Regulations for transgenic plant trials will be followed

**h.** **Expected Outputs:** (1) Three years of data concerning the most economically important plant viruses in key crops in multiple locations in Honduras, facilitating the prioritization of specific viruses for management programs; (2) Clone and nucleotide sequence for the CP gene of the ToMV isolate from Honduras; (3) Full-length, infectious clones for PepGMV, and two other tomato-infecting begomoviruses that are widespread in Honduras (and other Central American countries, including Nicaragua and Guatemala); (4) Constructs for ToMV and PepGMV for tomato transformation; (5) R0/R1 transgenic tomato plants expressing ToMV coat protein or a PepGMV REP fragment, and anti-sense and sense control constructs for PepGMV REP; and (6) Results of analysis of transgenic tomato lines, including copy number, evidence for transgene expression and/or protein expression (ToMV CP), and challenge inoculation data.

**i.** **Expected Impacts:** (1) Employ ELISA and PCR methodologies for detection and identification of important plant viruses at FHIA and ZAMORANO, independently; (2) Complete a three year study in Honduras to identify and archive predominant DNA- and RNA- viruses of tomato, pepper, watermelon, and various oriental vegetables (year 2003-04), which will be targeted in disease resistance objectives. Knowledge of the extent of *Begomovirus* diversity in Honduran crop species will be available for the first time and can be applied to disease resistance development; (3) Obtain infectious clones and complete Koch's Postulates for two previously uncharacterized begomoviruses of tomato and pepper in the region; (4) Publish joint scientific abstracts, Disease Notes, and/or articles describing results; (5) Clone viral CP and/or REP gene sequences from the Honduran ToMV and PepGMV isolates and determine the sequence; (6) Transform tobacco and tomato with PepGMV *Rep* and ToMV *Cp* transgenes (and appropriate controls: sense and anti-sense for begomovirus *Rep* and truncated CP for tobamovirus constructs); (7) Screen R0 and R1 lines in AZ and GA using homologous viruses; (8) Virus resistant germplasm will be made available for introgression into locally grown cultivars (to be initiated at the end of year 3); and (9) Strengthen collaborative interactions between scientists at FHIA, Zamorano, Purdue, VPI, Georgia and Arizona, participants in the Central American or Caribbean region IPM CRSPs.

**j.** **Projected Start:** October 2003

**k.** **Projected Completion:** September 2004

**l.** **Projected person-months of scientist time per year**: 8 person-months

**m.** **Budget:** $35,000 – U. of AZ. (FHIA and U. of GA have carryover funds from the Year 10 Biotech award to continue work. Those funds are not included in the Year 11 request).

## III.1. Use of faba bean (*Vicia faba*) as an integrated crop management strategy to control thrips (Thysanoptera: Agromyzidae) in snow pea (*Pisum sativum* L.), Xeabaj, Santa Apolonia, Chimaltenango

**a.** **Scientists:** J. Sandoval, G. Sánchez, L. Calderón – ICADA; S. Weller – Purdue University

**b.** **Objective:** Evaluate faba bean (*Vicia faba*) as trap crop to reduce populations of thrips (*Frankliniella occidentalis* and *Thrips tabaci*) in snow pea (<u>*Pisum sativum*</u> L.) in Xeabaj, Santa Apolonia, Chimaltenango.

**c.** **Hypothesis:** Faba bean *Vicia faba* can be an effective trap crop for thrips and leaf miner L. in snow pea production.

**d.** **Description of Research Activity:** This activity will consist of planting faba bean in different densities: 0,2,4,8 and 12 plants per posture. These plants will be produced as seedlings and transplanted to the field at the same time that snow pea is germinating. Each experimental unit will have 6 rows of snow pea (8 meters long) and there will be 8 sampling points. Thrips will be evaluated in 10 apical buds of snow pea and faba bean, and the leaves and pods of each will be examined for leaf miner damage. This experiment will allow an evaluation of the attractive effect of faba bean compared to snow pea for thrips and leaf miner. The research will be conducted in 3 localities: Patzún, Tecpan and Santa Apolonia.

**e.** **Justification:** It is necessary to validate the use of faba bean (*Vicia faba*) as a trap crop, within the integrated crop management system, as a method to reduce populations of leaf miners and thrips in snow pea, and to demonstrate that it is possible to reduce thrip populations without high use of chemical pesticides.

**f.** **Relationship to other CRSP activities at the site:** This research is related to other IPM CRSP activities which showed excellent effectiveness of faba bean trap crops in snow peas for leaf miners (Lamport, MS thesis), and the subsequent reduction in insecticides applications. This technology has been transferred to farmers, technicians and exporters, and hopefully will work for thrips.

**g.** **Progress to date:** Some farms belonging to agro-exporter companies are currently working with the ICM and faba bean as a trap crop, and they will be important in the continued transfer of this technology to additional farmers.

**h.** **Projected Outputs:** Demonstrate the efficiency of faba bean as a trap crop for attracting thrips and reducing its incidence in snow pea.

**i.** **Projected Impacts:** A reduced use of insecticides for thrips control in snow pea, and in turn, improved production principles based on ICM techniques developed by IPM CRSP resulting in enhanced product marketability.

**j.** **Projected Start:** February 2004

**k.** **Projected Completion:** July 2004

**l.** **Projected person-months of scientist time per year:** 4 person-month.

**m.** **Budget**: $9,900 – ICADA

**III.2. Transfer to growers the results of the mathematical models generated by the IPM CRSP in broccoli and snow pea for insect control**

**a.** **Scientists:** F. Solis, D. Dardón – ICTA; L. Calderón – ICADA; S. Weller – Purdue University; E. Rajotte - Penn State

**b.** **Objective:** To transfer to growers the results of the mathematical models developed to control diamond back moth (*Plutella xylostella*) in broccoli and Ascochyta (*Ascochyta pisi*) and leaf miner (*Liriomyza huidobrensis*) in snow pea.

**c.** **Hypothesis:** Mathematical climatic models are effective for targeting pest management practices.

**d.** **Description of Research Activity:** Mathematical models were generated to decide the best time to control diamond back moth in broccoli and Ascochyta and leaf miner in snow pea. These models are now ready to be transferred to growers to allow better timing of pest management techniques. This activity will be conducted at Chimaltenango and Sacatepequez in Guatemala. The Asociación Gremial de Exportadores de Productos No Tradicionales (AGEXPRONT) and the IPM CRSP are currently working in both sites, which will facilitate the efficient transfer of the results to producers of broccoli and snow pea. The transfer of technology will be done with the companies' technicians, who will transfer the telemetric results to their farmers. Collaborations will involve assistance from Dr. Rajotte at Penn State University to obtain world-wide weather information for testing of models.

**e.** **Justification:** Producers of broccoli have had problems with the use of chemicals to control diamond back moth as have the producers of snow pea in controlling Ascochyta and leaf miner. Over and misuse of pesticides can result in rejection of imported vegetables by authorities in the United States, where about 90% of broccoli and 95% of snow pea produced in Guatemala are exported. In addition to unacceptable residues on the produce, the pesticides are a risk to the environment and the consumers' and farmers' health. In previous years, the IPM CRSP generated mathematical models based on climatic conditions that have demonstrated how to efficiently target pesticide timing to control pests in both crops and reduce the use of chemicals. Therefore, it is necessary to promote the IPM CRSP technology among the producers of broccoli and snow pea to more efficiently produce crops.

**f.** **Relationship to other CRSP activities at the site:** Since the IPM CRSP started working in Guatemala, mathematical models have been generated based on telemetry technology, which will facilitate the use of IPM technologies in broccoli and snow pea and, once integrated in usable form, can be transferred to producers of broccoli and snow pea.

**g.** **Progress to date:** Data to date show a clear correlation of model predictions of pest outbreaks and actual outbreaks, which allows more precise timing of pesticide application, better control and reduced pesticide use.

**h.** **Projected Outputs:** Farmers can be educated in use of model results for their crop management systems in conjunction with cooperatives and exporting companies. This will reduce the use of pesticides and it will be possible to obtain safer products for domestic and export markets.

**i.** **Projected Impacts:** Farmers once educated in the use of the telemetric information will use fewer pesticides more efficiently to control diamond back moth in broccoli and Ascochyta and leaf miner in snow pea. Such adoption of IPM-based pest management protocols will lead to reduced pesticide use, more acceptable export produce, reduced contamination of the environment and improved stability of NTAE production and export markets.

**j.** **Projected Start**: October 2003

**k.** **Projected Completion:** September 2004

**l.** **Projected person month of scientist time per year:** 3 person-month

**m.** **Budget:** $3,080 – ICTA

### III.3. Identification and management of factors responsible for limiting melon production in southern Honduras

**a.** **Scientists:** D.T. Krigsvold, J.M. Rivera, J.C. Melgar – FHIA; R. Martyn, S Weller – Purdue University

**b.** **Overall Objective(s):** This activity is envisioned as a three-year project to be carried out in the melon growing areas of the southern Departments of Valle and Choluteca in Honduras, where recurrent, severe losses of melon production due to vine "collapse" have occurred since 1994. Two consecutive production cycles of melons are normally grown in Honduras: November- January and January-March. The objective of the project is to identify/develop crop management practices aimed specifically to prevent the occurrence of the vine "collapse" syndrome of melon plants that occurs, generally at or near time of fruit maturation, particularly during the first production cycle (November-January). **Objectives for Year 11:** During the first year an array of treatments will be evaluated in three different trials set up in collaborator's fields with a history of vine "collapse". Data generated during the first year will be analyzed and used to refine the second year's experimental protocol. Treatments that appear promising for control of vine "collapse" will be tested in collaborator's fields. In the third year an integrated crop management (ICM) package based on project results will be validated under commercial field conditions.

**c.** **Hypotheses:** (1) Production of melon seedlings in multi-cell trays results in transplants with poorly developed root systems that are worsened by the improper field irrigation regimes commonly practiced. These result in severe morphological and functional abnormalities of the root systems that lead to i) stress-induced susceptibility (predisposition) of the plants to an assortment of soilborne fungal diseases, and ii) eventual vine "collapse" and plant death. Thus, changing the manner in which melons are grown might alleviate or reduce the amount of vine collapse late in the season when the plants are under heat and fruit stress. (2) Many years of continuous mono-cropping with melons and the intensive use of plant protection agrichemicals have resulted in changes in the populations of the natural soil microfauna and microflora that contribute in keeping soilborne plant pathogens at low levels. Thus, if these populations could be brought back to their original levels in the soil and the rhizosphere it might alleviate or reduce vine collapse through competition with the weakly pathogenic fungi.

**d. Description of Research Activity: Testing of Hypothesis 1 (Improvement of Roots Function):** A study will be established in two different fields (with a history of "Vine collapse") of collaborating growers. Combinations of the two levels of each of three factors (soil treatment, watering regime, and seedling type) will be evaluated in an appropriate experimental set up, with three replications per site, in order to structure four treatments as follows:

| Soil treatment | | $H_20$ Regime | | Seedling Type |
|---|---|---|---|---|
| 1[1]. Methyl Bromide (MeBr) | + | Traditional watering[2] | + | Tray-germinated plants[3] |
| 2. MeBr | + | Traditional watering | + | Deep-cell-tray germinated |
| 3. MeBr | + | Traditional watering | + | Direct seeded |
| 3. MeBr | + | TR-based watering | + | Deep-cell-tray germinated |
| 4. MeBr | + | TR-based watering | + | Direct seeded |
| 5. No-MeBr | + | TR-based watering | + | Deep-cell-tray germinated |
| 6. No-MeBr | + | TR-based watering | | Direct seeded |

[1] Commercial Control, applying the inputs in the fashion accustomed by local growers.

[2] There is not a criterion common to all growers for watering but, in general, it consists of cycles carried out once a day at usually 1 or 2 day intervals, with duration and frequency determined subjectively based on experience, w/o consideration to objective descriptors of water status in the plant, soil or environment. Root systems under these watering regimes are poor and limited to the upper 2-3 inches of the soil. Comparisons will be made to watering based on tensiometric readings (TR-based watering).

[3] In plants germinated in regular seed trays the rootlet mass adopts the shape of the cell as it develops and twists abnormally, and the taproot disappears. Once in the field these plants have a very superficial, spatially limited and poor root system. Comparisons will be made to plants produced in deep cell trays and plants directly seeded in the field, which are expected to initially develop a normal root system and that also have to go through the stress of the transplanting operation.

In one of the sites an additional factor will be incorporated, consisting of injection of Oxygen to water in the sub-surface drip irrigation lines. Since poor oxygenation of root systems reduces the plant's ability to withstand biotic and/or abiotic stresses, it is also expected that oxygenation of the rhizosphere via irrigation water might also contribute to improve the root condition and the general plant health. This factor will be incorporated in an additional treatment together with the factors of treatment 4.

Data will be taken of the seedlings at transplanting time, including quantitative records of plant and root morphology and mass; data taking will be continued in the field phase of the study, including at this time disease incidence and severity, plant growth and yield, in addition to laboratory characterization of pathogens that might be present in the root systems. This study should ideally be conducted during the "worst case scenario" time of the year (November thru January), although this might not be possible; if so, it could also be conducted in any other time of the year. The best treatments identified during this phase eventually will be incorporated in a trial to be conducted during the normal melon growing season.

**Testing of Hypothesis 2 (Improvement of physical-chemical-biological condition of the soil and the phytosanitary condition of the plants):** Two field experiments will be conducted using different approaches to test this hypothesis. All experiments will be held in the fields of collaborating growers.

**Approach 1.** The purpose of this trial is to contribute to the improvement of the general biological condition of the soils *per se* by means of application of selected treatments and, with this, to assure maintenance of the soil's suitability for sustainable melon production. Some of the treatments described below would have to be established in the field at the initiation of the rainy season in May/2003. The following five treatments will be evaluated:

| | | | | |
|---|---|---|---|---|
| T. 1.- Traditional field cropping practices[1] | | | | |
| T. 2.- Soil solarization | + | Melon crop w/o MeBr[2] | | |
| T. 3.- Green cover crop | + | Melon crop w/o MeBr[3] | | |
| T. 4.- Soil solarization | + | Green cover crop | + | Melon crop w/o MeBr (in that order)[4] |
| T. 5.- Green cover crop | + | Soil solarization | + | Melon crop w/o MeBr (in that order)[5] |

[1] The soil will be cropped according to local standards, including pre-plant MeBr application.
[2] Solarization of the soil will be conducted for 6 weeks immediately prior to planting of the melon crop. No MeBr will be applied.
[3] At the initiation of the rainy season (May) a suitable, fast-growing, high biomass production green cover crop will planted and incorporated into the soil two months before planting the melon crop. No MeBr will be applied.
[4] Solarization of the soil will be performed for 5 weeks prior to initiation of the rainy season, then the green cover crop will be established, allowed to grow for three months, and then incorporated into the soil two months before planting the melon crop. No MeBr will be applied.
[5] Similar to T.4 save for switching the order of application of the cover crop and solarization. Again, no MeBr will be applied.

Some adjustments will have to be made in order to adapt the application of the treatments to the conditions under which melon cropping is normally done. It will also be necessary to pay attention to the nutritional condition of the crop and, if needed, do corrective applications of mineral fertilizers, particularly in those cases in which the time between incorporation of the cover crop and establishment of the melon crop is very short. This study and the one proposed below have to be conducted during the normal melon growing season, in two different sites with a history of "collapse". In both experiments the variables to be assessed will be the same as those recorded to test Hypothesis "a". Approach 2. **This activity is aimed at improving the condition of the plants *per se* as a result of exposing them to promising agents of a biological nature. The following five treatments will be evaluated:**

T.1. Traditional greenhouse and field cropping practices[1].
T.2. Mycorrhizae applied to seedlings in greenhouse trays[2] + traditional field cropping practices with and w/o MeBr.
T.3. *Trichoderma* sp. applied to seedlings in greenhouse trays and field + traditional field cropping practices with and w/o MeBr.
T.4. Mycorrhizae applied to seedlings in greenhouse trays + Harpin protein (Messenger®) applied in greenhouse and field + traditional field cropping practices with and w/o MeBr.
T.5. *Trichoderma* sp. applied to seedlings in greenhouse trays and field + Harpin protein (Messenger®) applied in greenhouse and field + traditional field cropping practices with and w/o MeBr.

[1] Commercial control, with the soil cropped according to local standards, including MeBr application.
[2] In all cases in which Mycorrhiza is used fertilizer will be reduced to half of the recommended rate.

The experiment will be set up in two different fields, in each case using the layout of a split-plot factorial (with and without MeBr as the major plot) with three replications.

Adjustments may have to be made to the proposed treatments trying to fit them as much as possible into the routine logistics of commercial melon cropping.

e. **Justification (relation to IPM-CRSP objectives and priorities):** Melon constitutes the third most economically important export-oriented agricultural crop in Honduras, after coffee and bananas. In addition, the crop is an important source of employment and economic activity in the areas of the Southern region of the country where the crop is concentrated. Unfortunately, over the last 8 years there has been a recurring problem of vine "collapse", generally at or near fruit maturation, which has led to yield losses of up to 50 percent in some years. This generally has been attributed to soilborne fungal pathogens. During this time specialists from different institutions, including FHIA, Zamorano, Chiquita, DOLE, PETOSEED, and Texas A&M University, have been brought in to observe the problem in the field. Numerous potentially pathogenic fungi have been isolated from roots of diseased plants obtained from different fields and different varieties, including species of *Fusarium*, *Pythium*, *Sclerotium* and *Rhizoctonia*. As a result, it has been difficult, if not impossible to attribute the exact cause of the problem. In addition, there is circumstantial evidence (FHIA and Purdue) that suggests the problem may be related to changes in production practices that have occurred in the melon industry over the last decade, particularly the industry's wide use of transplants as compared to direct seeding in the past. In fact, field observations show that the transplants produced locally in trays have malformed root systems and that the watering regimes applied in the field (usually very short and frequent cycles) may also be contributing to the problem. Most fields used for melon production in Southern Honduras have been cropped with melons for the last 12-15 years, usually twice a year, and without proper rotation. Additionally, the intensive use of conventional synthetic chemicals in soils that are naturally poor in organic matter to control pests has had a negative effect on the beneficial soil microflora. This no doubt has led to impoverishment of the soil biota that under normal conditions would also contribute to keeping soilborne pathogens under control. Determination of the precise cause of the "collapse" of melon vines and of the most appropriate measures to prevent it will assure the sustainability of this important crop in the Southern region of Honduras.

f. **Relationship to other CRSP activities at the site:** This is a new activity to be proposed for implementation by FHIA and Purdue University. It is related to another proposed IPM-CRSP year 11 project on virus diseases of melons, tomato, and peppers, to be implemented in the three most important horticultural areas of Honduras and conducted by FHIA and the University of Arizona.

g. **Progress to date:** Due to funding issues, little was accomplished last year.

h. **Projected Outputs:** (1) A determination of the pathological and/or cultural practices important in the manifestation of the vine "collapse" syndrome of melons in Southern Honduras. (2) Recommendations for management of vine "collapse". (3) Scientific papers amenable for publication in refereed scientific journals.

**i.** **Projected Impacts:** (1) Recovery of the melon production industry in Honduras to economically-acceptable production levels. (2) A significant contribution to the recovery of the local and national economy. (3) Introduction into the melon production operations of "clean" integrated cropping practices designed to assure sustainability of the crop as an agricultural activity in the southern region of Honduras.

**j.** **Projected Start:** October 2003

**k.** **Projected Completion:** September 2004 (first year)

**l.** **Projected Person-Months of Scientists Time per Year:** 7 person-months

**m.** **Budget:** $17,705 – FHIA; $5,500 – Purdue

**IV.1. Design a technical manual of: Pre-inspection in peas, Integrated Crop Management in tomato, vegetables grafting in intensive agriculture, biofumigation as an organic technology for soil disinfestations**

**a.** **Scientists:** J. Sandoval, L. Calderón, G. Sánchez – ICADA; M. Del Cid, F. Solís – ICTA; S. Weller – Purdue University

**b**. **Overall Objectives:** Promote the IPM CRSP activities related to development of agricultural technologies using IPM principles and increase farmers' access to and use of the IPM techniques by presenting the information in a simple way. This information will allow farmers to weigh the benefits to be obtained in their cropping systems, and in the environment with less risk to human health by using the research validated IPM technology. Objectives for Year 11: Transfer results of the IPM CRSP research to farmers. Stimulate farmers to increase the use of IPM technologies in their crop systems. Document and illustrate the impact of IPM CRSP research findings on Guatemalan NTAE agriculture.

**c.** **Hypothesis**: The design and distribution of cropping system manuals will promote the adoption of the production technology generated by the IPM CRSP research by collaborating among farmers throughout Guatemala.

**d.** **Description of Research Activity:** All the information generated by the IPM CRSP will be compiled and complemented with additional documents developed in foreign countries. The manual will have a strong bibliographic support of national and international research. In addition, farmers that use the technology will be interviewed. The manual will be written with simple language because it will be directed to farmers and technicians and will include some illustrations and pictures within the text. The completed manual will be distributed among individual farmers and farmers associated to export companies.

**e.** **Justification:** The research included in the manuals has been conducted and validated by the IPM CRSP, however, many farmers have not had ready access to the production techniques or results. The publication and distribution of the production manuals will help to promote the technologies and activities developed by the IPM CRSP and its collaborators in Guatemala and result in greater adoption of IPM-based programs.

**f.** **Relationship to other CRSP activities at the site:** The manuals' contents will be related to all the activities conducted by the IPM CRSP over the past ten years. The research has been validated and shown to result in reduced production cost inputs, higher yields, reduced pest problems and reduced pesticide use. The proposed manuals are the best method to promote IPM practices and will result in greater farmer adoption.

**g.** **Progress to Date**: Completion of IPM/ICM research activities validating production technologies impact. The compilation of the generated IPM technology is in progress. Completion of production manuals will be done using local and international collaborators.

**h.** **Projected Outputs:** The manuals will be distributed to farmers who are potential users of the documented technologies, in the specific area of their interest. The manuals will promote the IPM CRSP research activities and motivate farmers to produce their crops under the basis of integrated pest management.

**i.** **Projected Impacts:** Through the distribution of manuals, it will be possible to promote the activities conducted by the IPM CRSP and its collaborators in Guatemala and stimulate the farmers to use the generated technologies. Adoption of IPM techniques will result in a more sustainable agricultural economy for the region.

**j.** **Projected Start:** September 2003

**k.** **Projected Completion**: August 2004

**l.** **Projected person-months of scientist time per year:** 3

**m.** **Budget:** $18,700 – ICADA

**IV.2. Transfer and diffusion of the technology generated by the IPM CRSP and its collaborators in Guatemala**

**a.** **Scientists:** J. Sandoval, G. Sánchez, L. Calderón – ICADA; D. Dardón, M. Del Cid, F. Solís, M. Morales – ICTA; S. Weller – Purdue University

**b.** **Objectives:** (1) To transfer ICM technology generated by the IPM CRSP and its collaborators, and to demonstrate its implementation in the field. (2) To train leader farmers in the application of these technologies and stimulate their dissemination throughout the farming communities. (3) To convince the farmers about the advantages of the integrated crop management strategies for the sustainability and long-term expansion of the NTAE sector.

**c.** **Hypothesis:** IPM CRSP production technology will result in Guatemalan NTAE crop producers being more competitive.

**d.** **Description of Research Activity:** To transfer IPM CRSP results and technology to farmers and exporters by: (1) organizing groups of producers of snow pea, broccoli, tomato, guava and star fruit in areas of importance, (2) identifying leaders in each crop group and locality, (3) developing production training programs for various production areas and experimental stations, (4) arranging technological interchange between the IPM CRSP researchers, farmers and technicians, and (5) providing a certificate of participation for the training activities. The areas of emphasis will be: Chimaltenango, Sacatepequez, Sololá, Quiche, Quetzaltenango, Cuyuta-Escuintla, Jalapa and Zacapa.

**e.** **Justification:** The integrated pest management technology developed and validated by the IPM CRSP and its collaborators has demonstrated that it is efficient in the control of pests and results in improved product quality, increased yields and reduced production costs while allowing the growth of healthy produce. However, this technology has not been actively promoted in many areas where farmers need this technology to make their production systems more efficient. Therefore, it is necessary to strengthen the transfer and acceptance of this technology among more farmers.

**f.** **Relationship to other CRSP activities at the site:** The IPM/ICM technology to be transferred to Guatemalan farmers was generated from IPM CRSP research results Therefore, this proposal is related with previous production research activities.

**g.** **Progress to Date:** Production research results and suggested technologies have been compiled. Organizational meeting protocols have been outlined for the transfer of technology at each of the designated sites.

**h.** **Projected Outputs:** An increase in the number of farmers, agricultural and community leaders and agricultural technicians who will learn and use integrated pest management technology in their agricultural production, as developed by the IPM CRSP and its collaborators.

**i.** **Projected Impacts:** An increase in the number of farmers and technicians who realize the benefits of using the IPM technology in crop production.

**j.** **Projected Start:** October 2003.

**k.** **Projected Completion:** August 2004.

**l.** **Projected person month of scientist's time per year:** 3 person-month

**m.** **Budget:** $17,160 – ICADA; $6,380 – ICTA

## IV.3. Validation, demonstration and transferal of integrated crop and pest management plots in peas, broccoli and whitefly in tomato

**a.** **Scientists:** J. Sandoval, L. Calderón, G. Sánchez – ICADA; M. Del Cid, M. Morales, D. Dardón – ICTA; S. Weller – Purdue University

**b.** **Objectives:** (1) To demonstrate the effectiveness and efficiency of integrated pest and crop management in peas, broccoli and tomato; (2) To transfer the results of the IPM CRSP technology to farmers that produce peas, broccoli and tomato in Guatemala; and (3) To promote the adoption of IPM and ICM (integrated crop management) technology to rapidly improve its adoption.

**c.** **Hypothesis:** ICM results in improved pest management and crop yields while reducing pesticide use, stabilizing NTAE production and improving export market potential.

**d.** **Description of Research Activity:** Plots of integrated management of peas, broccoli and tomato will be established in order to compare them with the high chemical-based technology that many farmers use. The IPM plots will be produced under the integrated crop management principles developed by IPM CRSP research. Yield, production quality, costs and profitability will be compared with the low IPM technology.

**e.** **Justification:** Several technologies have been developed by the IPM CRSP research. The purpose of this project is to take isolated technologies for pest control and integrate them in the ICM plots. This ICM technology will systematically improve pest control and crop management efficiency, while reducing negative impacts on the environment, improving production quality and reducing production costs.

**f.** **Relationship to other CRSP activities at the site:** All the ICM tactics that were developed by the IPM CRSP and its collaborators will be integrated in the research plots. This research has high relationship with other activities since it will combine previous component research into an integrated approach to production.

**g.** **Progress to date:** ICM programs have been developed through IPM CRSP research in all the target crops listed. Validation of their use in an integrated approach is now required.

**h.** **Expected Outputs:** Research will demonstrate to farmers the benefits that can be obtained by using ICM while producing NTAE crops under IPM principles. Such validation will motivate farmers to use and adopt this technology. The research will promote the activities that the IPM CRSP and its collaborators have conducted in different areas of Guatemala.

**i.** **Expected Impacts**: ICM will reduce the use of pesticides, increase the production, improve the production's quality, reduce the negative impact in the environment and allow farmers to produce snow pea, broccoli and tomato of high quality for export markets.

j. **Projected Start**: October 2003

k. **Projected Completion:** September 2004

l. **Projected person month of scientist's time per year:** 3 person-month

m. **Budget:** $17,322 – ICADA

## Site Activity Summary – Central America – Year 11

| ACTIVITY | | SCIENTISTS | BUDGET ($) |
|---|---|---|---|
| **SITE CHAIR OVERSITE** | | | |
| | Provide oversight for Central American Site. Participation in the various research activities | S. Weller - Purdue | Purdue<br>$26,345 |
| **SOCIOECONOMIC, MARKETING, AND POLICY ANALYSIS** | | | |
| I.1 | Economic and socioeconomic impact assessment of IPM and nontraditional crop production strategies on small farm households in Guatemala | S. Hamilton - Virginia Tech; L. Asturias – Estudio 1360; G. Sánchez, L. Calderón - ICADA | VT/Hamilton<br>$17,878<br>Estudio 1360/ICADA<br>$13,200 |
| I.2 | Survey on sanitary and phytosanitary (SPS) issues faced by the Central American Common Market (CACM) and impact of the Central America Free Trade Agreement (CAFTA) | D. Orden, T. Yamagiwa – Virginia Tech; A. Angel – Ministry of Ag, El Salvador | VT/Orden<br>$30,000<br><br>(Additional $7,386 Existing Global ThemeVPI) |
| **ASSESSMENT OF ALTERNATIVE CROPPING SYSTEMS INCLUDING BIORATIONAL AND ORGANIC APPROACHES** | | | |
| | | | |
| II.1 | Evaluation of transgenic papayas (*solo* and native) with resistance to papaya ringspot potyvirus, using kanamicyn as selection marker in greenhouse conditions | M. Palmieri, J.M. Seijas, L. López – UVG; G. Sánchez – ICADA; W. Parrott, M. Deom – U. of Georgia | ICADA<br>$2,800<br>UVG<br>$2,200 |
| II.2 | Validation of the technology generated by the IPM CRSP to control Mediterranean fruit fly in guava (Thailand's variety) and giant star fruit | O. Sierra, D. Dardón – ICTA; L. Calderón, G. Sánchez – ICADA; S. Weller - Purdue | ICTA<br>$5,830 |
| II.3 | Molecular identification of viruses of solanaceous and cucurbit crops in Honduras and transgenic resistance to control *Tomato mosaic* and *Pepper Golden Mosaic* viruses in tomato. | A. Rueda, M. Mercedes Roca de Doyle – Zamorano; D. Krigsvold, M. Rivera, J. Melgar – FHIA; R. Martyn – Purdue; J. Brown – U. of Arizona; M. Deom – U. of Georgia | U. of AZ<br>$35,000 |

| | | | |
|---|---|---|---|
| **STRATEGICALLY TARGETED DISEASE AND INSECT CONTROL** | | | |
| III.1 | Use of faba bean (Vicia faba) as an integrated crop management strategy to control thrips (Thysanoptera: Agromyzidae) in snow pea (*Pisum sativum* L.), Xeabaj, Santa Apolonia, Chimaltenango | J. Sandoval, G. Sánchez, L. Calderón – ICADA; S. Weller - Purdue | ICADA $9,900 |
| III.2 | Transfer of the mathematical models generated by the IPM CRSP in broccoli and snow pea for the plague control | F. Solis, D. Dardón – ICTA; L. Calderón – ICADA; S. Weller - Purdue | ICTA $3,080 |
| III.3 | Identification and management of factors responsible for limiting melon production in Southern Honduras | D. Krigsvold, M. Rivera, J. Melgar – FHIA; R. Martyn, S. Weller - Purdue | FHIA $17,705 Purdue $5,500 |
| **TRANSFERENCE AND ADOPTION OF IPM/ICM TECHNOLOGIES** | | | |
| IV.1. | Design a technical manual of: Pre-inspection in peas, Integrated Crop Management in tomato, vegetable grafting in intensive agriculture, biofumigation as an organic technology for soil detestation | J. Sandoval, L. Calderón, G. Sánchez – ICADA; M. Del Cid, F. Solis – ICTA; S. Weller - Purdue | ICADA $18,700 |
| IV.2 | Transfer and diffusion of the technology generated by the IPM CRSP and its collaborators in Guatemala | J. Sandoval, G. Sánchez, L. Calderón – ICADA; D. Dardón, M. Del Cid, F. Solis, M. Morales – ICTA; S. Weller - Purdue | ICADA $17,160 ICTA $6,380 |
| IV.3 | Validation, demonstration and transferal of integrated crop and pest management plots in peas, broccoli and whitefly in tomato | J. Sandoval, L. Calderón, G. Sánchez – ICADA; M. Del Cid, M. Morales, D. Dardón – ICTA; S. Weller - Purdue | ICADA $17,322 |

## YEAR 11 WORKPLAN FOR THE SOUTH AMERICAN SITE IN ECUADOR

In year 11, the IPM CRSP will begin its seventh year of research in Ecuador. Activities focus on potato-based systems in the Sierra, plantain-based systems in the coastal region, and mixed coffee-plantain systems and Andean fruits at intermediate elevations. The PIPM approach is being followed in which pest management problems and constraints are being diagnosed through crop/pest monitoring, household surveys, and targeted participatory appraisal activities, and focus group activities are being undertaken aimed at gender issues. Multi-disciplinary on-farm pest management experiments for potatoes are being conducted in the Carchi region as well as farther south, complemented by a limited amount of laboratory, greenhouse, and micro-plot experiments on station at Santa Catalina. Special efforts are being made to validate and diffuse IPM approaches already developed by the CRSP, and to work with the validation and technology transfer units of INIAP, the principal government institution for research and technology transfer. The plantain research has become critically important now that plantain has become an important export crop in Ecuador because the only alternatives up to now have involved heavy pesticide applications for insects, diseases, and nematodes. The Andean fruit experiments focus on non-traditional export crops with strong export potential. Socioeconomic analyses address three primary issues: impact assessment, evaluation of alternative outreach methods, and gender.

Research activities are planned and conducted in a multidisciplinary fashion. Ecuador, CIP, and U.S. scientists review progress and plan future activities in joint meetings with all disciplines contributing to the discussion. Biological scientists assist the social scientists by collecting cost and return data to be used in impact assessment. The Site Coordinator, located at the Pichlingue station near Quevedo on the coast, works with the assistant coordinator for the Sierra, located at the Santa Catalina Experiment Station south of Quito to coordinate the day-to-day research activities. They integrate undergraduate student theses into the research whereever possible to help institutionalize knowledge and interest in IPM. International and U.S. institutions contributing to the IPM CRSP program in Ecuador include CIP/Lima, Ohio State, Georgia, Florida A&M, and Virginia Tech.

During year 11, CRSP researchers will focus on finalizing work started during earlier phases of the project and addressing critical USAID Mission objectives. No new research has been started. In the potato areas, year 11 research will focus on the impacts of IPM technologies on the local regional economy and evaluation of alternative dissemination methods. Both these activities fit into USAID mission priorities to stabilize the socioeconomic situation along the Northern Border Region. Plantain work will produce a finalized “IPM Package”, in addition to evaluating alternative dissemination packages. In Andean fruits, ongoing work will further refine our understanding of the naranjilla pest/disease complex and will establish the economic potential of naranjilla in the northern border region. Naranjilla appears to be an economically viable product that can be produced in fragile agro-ecological conditions along the northern border with Colombia.

**I.1. Developing improved management strategies for disease caused by *Phytophthora infestans* in solanaceous crops using molecular biological tools**

**a. Scientist names and Institutional affiliations**: G. Bernal, J. Ochoa – INIAP; G. A. Forbes, G. Chacon – CIP; G.H. Lacy, C. Hong – Virginia Tech; M. Ellis – Ohio State University. **Collaborative Scientists**: C. Suarez – INIAP

**b. Objectives. General**: To empower the Department of Plant Protection of INIAP to independently carry out studies on plant pathogens using molecular tools. **Specific**: (1) Completely describe genetic similarities and differences of populations of *P. infestans* attacking tree tomato and naranjilla; (2) Associate molecular similarities/differences with pathogenicity of *P. infestans* attacking tree tomato, naranjilla and other important solanaceus crops; (3) Integrate molecular, pathogenetical, biological, plant resistance and fungicide resistance knowledge in order to develop a rational control of *Phytophtora*.

**c. Hypotheses:** (1) Methods for inoculating *P. infestans* for tree tomato and naranjilla are similar; (2) No molecular differences exist among isolates of *P. infestans* affecting tree tomato and naranjilla crops; (3) No differences exist in specificity among isolates of *Phytophthora infestans* in tomato tree and naranjilla crops.

**d. Description of activities:** Collect samples of *P. infestans* from tree tomato and naranjilla in the main tree tomato and naranjilla growing areas. A minimum of 50 isolates will be collected. This will be done in collaboration with the Andean fruit IPM CRSP project being carried out by the Department of Plant Protection of INIAP. A detailed geographical, biological and agronomic description of isolates will be collected.

Isolates will be processed at CIP. Processing will consist of pathogen isolation, DNA extraction, RFLP using probe RG56, Mitochondrial DNA haplotyping, and assessment with micro satellites. Different methods of inoculation will be studied for tree tomato and naranjilla. Inoculations on detached leaves of different ages will be compared with inoculations on plants of different ages. Different incubation temperatures will also be evaluated.

Specificity of isolates of *P. infestans* from tree tomato and naranjilla will be studied by cross inoculations between these isolates with tree tomato, naranjilla and other hosts such as potato and tomato. Inoculations will be carried out as established in the previous experiment. Genetic data will be compared with geographic data. Isolates will be assessed for aggressiveness, virulence and fungicide resistance.

Most of the studies will be conducted at the Department of Plant Protection of INIAP. However, the studies will still be coordinated with CIP. Molecular studies will continue. Studies of specificity will also continue this year as established previously. Studies on fungicide resistance, biological studies and plant resistance will also be conducted. As isolates come from different agro-ecological regions where crops are grown, they might have a different climatic adaptation. Therefore an experiment will be conducted to identify differences in temperature adaptation. Isolates from tree tomato and naranjilla will be tested at 5, 10, 15 and 20ºC. Mycelium growth, sporangium production and pathogenicity will be tested in this experiment.

Fungicide resistance will be conducted *in vitro* with the fungicides frequently used by tree tomato and naranjilla farmers. The methodology will be similar to that developed for potato with a slight difference in the incubation temperatures, if needed, as established in the previous study. A national collection of naranjilla and tree tomato accessions will be evaluated to the most pathogenic isolates of *P. infestans*. Inoculation method and disease evaluations will be similar to those established in pathogenicity tests.

The research associate will spend six to eight weeks at Virginia Tech learning molecular rapid identification techniques with Drs. G.H. Lacy and C. Hong with input from Dr. Sobral. A second set of samples will be collected from the same and additional locations. Isolates will be evaluated using a variety of markers to be determined, but this activity will be conducted in the laboratory of the Plant Protection Department of Santa Catalina, INIAP.

Management strategies for control of *P. infestans* in tree tomato and naranjilla will be developed based on knowledge of pathogen population structure and host/pathogen interaction.

Similar molecular studies will be initiated on *F. oxysporum* causing wilts on naranjilla, caricaceae fruits and tomato in Ecuador. Studies will also be conducted to identify and classify strains of *Mycosphaerella fijiensis* obtained from banana and plantain.

**e.** **Justification:** *P. infestans* is an oomycete pathogen that has gained notoriety for the destructive disease it causes in tomato and potato. This pathogen played a major causal role in the Irish famine of the 1840s. *P. infestans* is also a destructive pathogen of other important solanaceous crops of Ecuador, such as pear melon (*Solanum muricatum*), tree tomato (*Solanum betaceum*) and naranjilla (*Solanum quitoense*), the last two being the subjects of CRSP research in Ecuador.

CIP (Quito) has maintained a research program to analyze populations of *P. infestans* in Ecuador using several molecular markers, including RFLPs, microsatellites, and PCR-RFLP assessment of mitochondrial DNA. These tools have permitted CIP to establish new concepts about populations of *P. infestans* attacking different crops in Ecuador. Association of important characteristics, such as host specificity, virulence, and resistance to fungicides with particular populations of the pathogen has allowed researchers to refine management strategies. INIAP has participated in many of these studies, but primarily in the area of field assessment of disease, collection of samples and validation of management strategies.

Based on these antecedents, the Plant Protection Department of INIAP (DNPV) has as an objective to enhance the capacity of its laboratory to utilize molecular biological techniques to improve management of plant diseases of the main Ecuadorian crops. For several reasons, this is a propitious moment to develop capacity within INIAP to carry out population studies, not only of *P. infestans* but also other pathogens using molecular tools. First, the National Department of Plant Genetic Resources (DENAREF) of INIAP could assist in specific activities since this Department has experience in molecular techniques. Specialized equipment for this kind of work (e.g. PCR thermocycler) can now be purchased for a reasonable price. Also, reagents that were once difficult to acquire can now be purchased locally. Finally, improved internet connections will allow INIAP to hook up to state-of-the-art facilities at Virginia Tech´s Virginia Bioinformatics Institute (VBI).

**f.** **Relationship to other CRSP activities at the site:** This project is related to the activities that, up to this moment, have been implemented on the tree tomato and naranjilla crops within the last phase of the project IPM CRSP. These activities have been conducted in the Ecuadorian inter-Andean valleys and Amazon region. The project is also linked to the projects (diseases on solanaceous) conducted by CIP (Quito), and to the project of management of *Meloidogyne* and *Fusarium solani* in tree tomato, which is being performed within the FONTAGRO project.

The project is also related to the activities of Epidemiology/Biology of *Micosphaerella fijiensis* in banana conducted in the Ecuadorian coast region. Some isolates of this microorganism will be genetically characterized in the Plant Protection Laboratory of INIAP. This research could be considered as a complement to the ones that the Unity of Development of the North (UDENOR) is performing on naranjilla production areas, with the support of USAID in relation to agricultural development.

**g.** **Progress to date:** During the first three months of activities: (1) A workshop on molecular techniques was conducted in CIP and addressed to the Plant Protection staff of INIAP; (2) The research assistant from INIAP has begun training in molecular tools (the training will last for one year); and (3) The genetic similarities of populations of *P. infestans* have been initiated in collaboration with CIP staff. Isolation and inoculation techniques are also being conducted.

**h.** **Projected outputs:** (1) INIAP can independently evaluate populations of important plant pathogens; (2) A detailed genetic description of *P. infestans* and eventually of *F. oxysporum* populations attacking tree tomato, naranjilla and caricaceae crops will be developed; (3) Pathogenic, biological, fungicide resistance and plant resistance knowledge will eventually allow IPM programs to manage *P. infestans* in tree tomato and naranjilla.

**i.** **Projected impacts**: Facilitated development of management recommendations based on knowledge of pathogen populations--host preference and fungicide resistance.

**j.** **Project start**: December 2002.

**k.** **Projected completion**: September 2004

**l.** **Budget:** $12,395 – INIAP

## II. Multidisciplinary On-Farm Pest Management Experiments

### II.1. Development of Biocontrol methods for the two major potato pests in Ecuador: the Andean potato weevil, *Premnotrypes vorax* and the Central American tuber moth, *Tecia solanivora*

**a.** **Scientists:** P. Gallegos, C. Asaquibay, J. Suquillo, V. Barrera – INIAP; J-L. Zeddan – PUCE-Quito; J. Alcázar – CIP; R. Williams – Ohio State University. **Collaborative Scientists:** L. Escudero, F. Merino – INIAP.

**b.** **Objectives (General):** (1) Reduce losses caused by potato weevil and Central American tuber moth; (2) Lower the risk of health deterioration of farmers and consumers through the use of cultural and biological control methods. **Objectives for year 11:** (1) Integrate cultural controls and biological agents to manage *T. solanivora*, and thus, to obtain better quality tubers; (2) Conduct a cost-benefit analysis of an integrated IPM package to control this pest; (3) Finalize and disseminate IPM package.

**c.** **Hypotheses**: (1) The integration of cultural and biological alternatives does not reduce damage caused by *Tecia solanivora* in potato fields; (2) When tubers come from a field where *T. solanivora* has been treated with cultural and biological practices, the use of *Baculovirus* on storaged tubers does not improve control of the insect.

**d.** **Description of activities:** The activities will follow and build upon research from previous years. A field trial will be carried out comparing three levels of technology aimed at management of *T. solanivora* in potato fields and under storage: (1) farmers´ practices for cultivation and storage; (2) farmers' agronomic practices plus insecticides to control the pest; (3) an IPM package developed by the IPM CRSP. This latter package consists of use of certified seed, fertilization (organic and or chemical), *Phytophthora* disease control, *P. vorax* and weed management, ensuring sanitary conditions of the crop, cross tillage at 50 and 70 days from planting, solarization of tubers after harvest and *Baculovirus* treatment prior to storage of tubers for *Tecia* control. In-field treatments will be applied to fairly large plots (250 $m^2$), using a design appropriate to this kind of trial; all tubers harvested from each treatment will be used to test *Tecia* control under storage. Pest incidence in terms of percentage of damaged tubers and intensity of such damage will be the primary evaluating parameters. Cost analysis of all treatments, including the cost of building appropriate seed storage systems and producing the *Baculovirus*, will be compared with yields of different treatments. Activities will be integrated within existing training plots and farmer field schools in the area. A manual of integrated management of *T. solanivora* will be created.

**e.** **Justification:** The potato weevil and the Central American tuber moth are the most important pests of potato in Ecuador in field as well as in storage. Farmers use highly toxic compounds to control these pests. In these experiments we expect to replace these compounds by an integrated management of the crop and a set of clean technologies developed with the IPM CRSP project. So far, different components have been tested independently and it is expected that they complement each other when applied as part of the whole management of the crop. It is necessary, therefore, to test the effect of the whole package over the incidence and intensity of both pests. At the same time, a cost-benefit analysis will allow us to estimate the impact of these practices on farmer incomes. This study will determine the least costly methods of production of *Baculovirus*.

**f.** **Relationship to other IPM CRSP activities at the site:** This project is related to: (1) the project, Validation and Diffusion of Models of IPM of Potato in the province of Carchi, generated by the IPM CRSP project; (2) Project CIP-FAO-INIAP Field Schools, based on IPM programs; (3) INIAP-FORTIPAPA, which requires technology to be transferred to farmers, (4) A project on identification of mortality factors of the Central American tuber moth in crops and storage rooms of potato in Ecuador-project PROMSA 103 (this project is coordinated by the Catholic University of Ecuador in which INIAP participates).

**g.** **Progress to date:** Pest damage diminished with the use of the following cultural practices on the field: (1) use of certified seed; (2) good agronomic practices to ensure development of the natural resistance of the plant; (3) high and cross tillage; and (4) exposure of the harvested seed to sun drying. The use of *Baculovirus* during seed storage, especially when its action is enhanced with chitin inhibitors, may help control the tuber worm.

**h.** **Projected Outputs**: (1) Recommendations for cultural management for the control of *T. solanivora* in the field and in storage; (2) An extension bulletin.

**i.** **Projected Impacts:** Farmers will have low toxicity control technologies that are environmentally benign; the biological control method can be applied for the control of other pests in other crops.

**j.** **Project Start:** October 1998

**k.** **Project Completion:** September 2004

**l.** **Projected Person-Months of Scientist Time per Year:** 6 + support technician 12.

**m.** **Budget:** $ 11,330 – INIAP

## II.2 Agronomical, phytopathological and entomological studies of naranjilla germplasm resistant to *Fusarium oxysporum* causing naranjilla vascular wilt

**a.** **Scientists:** J. Ochoa, P. Gallegos, L. Shiki, M. Insuasti – INIAP; M. Ellis, R. Williams – Ohio State University. **Colaborative Scientists:** J. Fiallos, J. León – INIAP

**b.** **Objectives: General:** (1) Develop pest control methods for the major pests of naranjilla. (2) Integrate control methods into IPM programs for the naranjilla pests. (3) Develop technical and scientific publications from the results obtained in these studies. (4) Disseminate research results and IPM programs through the use of field days, bulletins and other educational forums and materials. **Objectives for year 11:** (1) Evaluate the agronomical, phytopathological and entomological characteristics of common naranjilla grafted on rootstocks resistant to *F. oxysporum*. (2) Evaluate the agronomical, phytopathological and entomological characteristics of accessions and segregating plants of crosses between species of the section lasiocarpa resistant to *F. oxysporum*. (3) Develop technical and scientific publications from results. (4) Disseminate research results and IPM programs through use of field days, bulletins and other educational forums and materials.

**c.** **Hypotheses:** (1) Common naranjilla has different affinity, development, and reaction to pests and yield potential when grafted onto plants (species) of the section lasiocarpa resistant to *F. oxysporum*. (2) Common naranjilla accessions and segregating material of crosses between species of the section lasiocarpa resistant to *F. oxysporum* have different agronomical, phytopathological and entomological traits. (3) We currently have sufficient information to develop technical and scientific publications on naranjilla pests. (4) Research results developed in these studies are sufficient to disseminate through field days, bulletins and other educational forums and materials.

**d.** **Description of research activities:** The agronomical, phytopathological and entomological potential of the common naranjilla varieties Baeza and Dulce grafted on nine species of the section lasiocarpa resistant to *F. oxysporum* are being evaluated. Accessions of *Solanum sessiliflorum*, *Solanum hirtum, Solanum tequilense, Solanum mamosum, Solanum pseudolulo, Solanum candidum, Solanum stramonium, Solanum hyporhodium* and *Solanum robastum* are being evaluated. All accessions used as rootstocks were resistant to *F. oxysporum* in evaluations conducted during CRSP activities in year 10. Treatments will be established in a completely randomized block design with three replications. Plots will consist of four rows separated by 2 m. Each row will contain four plants planted 2 m apart. Late blight and anthracnose will be controlled with applications of fungicides previously evaluated in *in vitro* tests. Naranjilla fruit borer will be controlled using light trap as well as pheromone traps previously evaluated in year 10. Fertilization recommended for naranjilla will be applied. Incidence of anthracnose and late blight and fruit borer will be evaluated, as well as agronomical variables such as size of the plant, number of fruits, the weight and diameter of fruits and fruit yield. An economic analysis will be also conducted. Naranjilla accessions and segregating plants coming from crosses between naranjilla and *Solanum sessiliflorum*, *Solanum hirtum, Solanum pseudolulo, Solanum candidum* and *Solanum hyporhodium* were screened for resistance to *F. oxysporum* during year 10. The accessions of naranjilla and the segregating plants resistant to *F. oxysporum* will be evaluated for agronomical, phytopathological and entomological characteristics. As in the previous study, incidence of anthracnose, late blight and fruit borer, as well as size of the plant, number of fruits, weight, diameter of fruits and fruit yield will be evaluated and an economic analysis will be conducted.

**e.** **Justification:** Surveys of naranjilla diseases conducted during previous IPM CRSP activities showed that naranjilla vascular wilt (NVW) is one of the main constraints to naranjilla production in Ecuador. Epidemics of this disease have resulted in elimination of common naranjilla in traditional production areas. Similar disease epidemics are also occurring in new production areas. Common naranjilla is susceptible to NVW and most farmers currently believe that production of common naranjilla is not profitable despite substantially higher market prices for common naranjilla compared to more disease-resistant varieties. In cases where common naranjilla is grown, quick onset of disease contributes to high rates of deforestation due to shifting cultivation. Sanitation is a good approach to manage NVW in new areas of naranjilla cultivation. However, in places where the pathogen is already present, plant resistance through rootstocks appears to be the unique alternative to cope with this disease in the short term. In the middle and long term, development of cultivars with resistance to NVW is the most appropriate alternative. *F. oxysporum* causing NVW is transmitted by seeds and appears to be the cause of pathogen dissemination in new areas of naranjilla cultivation. Therefore, a bulletin will be produced to warn farmers of *F. oxysporum* seed dissemination and how to avoid it. Naranjilla is widely produced in the northern border region of Ecuador. Development of disease-resistant varieties that produce high returns (as is the case of the common naranjilla) will enable an environmentally sound means of building a sustainable local economic base. This outcome is a high priority of the Ecuador USAID mission.

**f.** **Relationship to other CRSP activities at the site:** During years 9 and 10, germplasm of the lasiocarpa section resistant to *F. oxysporum* was identified. Segregating plants coming from crosses of naranjilla with other species of the lasiocarpa section resistant to *F. oxysporum* were also selected during the IPM CRSP year 10. During year 11, these materials will be evaluated for agronomical and yield potential to identify future clones and varieties of naranjilla. The project is also closely related to the examination of socioeconomic characteristics of farmers in the northern border region.

**g.** **Progress to date:** Surveys of major pests of tree tomato, babaco, blackberry and naranjilla were conducted during previous years of the IPM CRSP project. Pathogenicity, pathogen seed transmission and disease resistance to *F. oxysporum* causing naranjilla vascular wilt have been determined. It is known that the naranjilla fruit borer moth is attracted by a pheromone of *Leucinodes orbonalis*, another borer moth.

**h.** **Projected Outputs:** Technical and scientific publications from the results obtained in these studies will be published. A bulletin of symptoms, seed transmission and measures to prevent *Fusarium oxysporum* in naranjilla will be also published. A field day on naranjilla pests for farmers and professionals will be organized in the Palora Experimental Station of INIAP. Use of *F. oxysporum* resistance rootstocks and validation of fungicides identified as efficient for late blight and anthracnose during year 10 will allow establishment of a rational program to manage these diseases. A control method using pheromone traps will be available for the naranjilla fruit borer. Some materials and segregating plants resistant to *F. oxysporum* identified in year 10 will be potential clones of naranjilla varieties. In addition, the preference of the naranjilla fruit borer on different naranjilla clones will be established.

**i.** **Projected Impacts:** Results from these studies will eventually lead to implementation of IPM programs for naranjilla in Ecuador. In addition to providing cash crops for growers from local sales, increased production of naranjilla could lead to export and increased profitability to growers in Ecuador and neighboring countries such as Colombia. Economic viability of large-scale production of naranjilla along the northern border will be enabled by this study.

**j.** **Project Start:** October 2000

**k.** **Project Completion:** September 2004

**l.** **Projected Person-Months of Scientists Time per Year:** 9 + support technician 12.

**m.** **Budget:** $9,020 – INIAP; $13,070 – OSU

### II.3 Developing IPM programs for viral diseases, anthracnose and *Phyllophaga* sp in tree tomato *(Solanum betaceum)* in Ecuador

**a.** **Scientists:** J. Ochoa, P. Gallegos, W. Viera, M. Insuasti – INIAP; M. Ellis, R. Williams – Ohio State University. **Collaborative Scientists:** A. Martinez, J. Leon – INIAP

**b.** **Objectives (General):** (1) Develop pest control methods for the major pests of tree tomato. (2) Integrate control methods into IPM programs for tree tomato pests. (3) Develop technical and scientific publications from the results obtained in these studies. (4) Disseminate research results and IPM programs through the use of field days bulletins and other educational forums and materials. **Objectives for year 11:** (1) Evaluate the development of aphid populations on the incidence of viral diseases of tree tomato under three crop densities and a crop association; (2)Validate the efficacy of cultural practices (tree crop densities and associations) and fungicide applications for control of anthracnose; (3) Reduce the incidence of *Phyllophaga* sp. with applications of *Beauveria* sp.; (4) Develop a manual of common pests and IPM programs for tree tomato and babaco; (5) Prepare scientific publications associated with these studies.

**c.** **Hypotheses:** (1) Development of aphid populations and incidence of viral diseases of tree tomato are different for different crop densities and crop associations; (2) The efficacy of cultural practices and fungicide applications for control of anthracnose are different for different crop densities and crop associations; (3) The incidence of *Phyllophaga* sp. can be reduced by applications of *Beauveria* sp.

**d.** **Description of activities:** Three tree tomato crop densities and a crop association will be studied in two localities. Crop densities will consist of (1) rows and plants within rows separated by 2 m. (2) rows and plants within rows separated by 2.5 m. (3) rows and plants within rows separated by 3 m. The crop association will consist of alternate rows of tree tomato, babaco and blackberry. In the association rows and within rows, plants are separated by 2 m. Plots will consist of eight rows of 16 m. Each plot will be separated by two rows of passion fruit. Sanitation treatments will consist of pruning and removing old plant debris. Fungicides identified in previous *in vitro* tests will be applied to improve disease management. Applications of *Beauveria* sp. to control *Phyllophaga* sp. will be made as established during year 9. Regular fertilization recommended for tree tomato will be applied. Aphid populations, incidence and severity of viral diseases and incidence of anthracnose will be evaluated. Incidence of *Phyllophaga* sp. will be monitored using a procedure established in year 9. Variables will be evaluated on eight plants located in the middle of each plot. Fruit yield will be evaluated. An economic analysis will be conducted.

**e.** **Justification:** Viral diseases, anthracnose and *Phyllophaga* sp.are serious constraints to tree tomato production in Ecuador. At present, tree tomatoes are being grown in dense monoculture. These two epidemiological aspects have forced farmers to use excessive applications of toxic compounds to control these pests. High density tree tomato plantings might create favorable conditions for these pests. Reduction of plant densities might reduce favorable disease conditions and allow chemical control to be more efficient and rational. Crop associations are expected to give similar advantages. Crop associations are common in the valleys of Ecuador. Therefore, they could be easily implemented. This experiment will allow us evaluate what we have developed so far to implement IPM programs in tree tomato.

**f.** **Relationship to other CRSP activities at the site:** These experiments are a continuation of surveys and research activities on tree tomato, babaco, blackberry and naranjilla conducted in years 8, 9 and 10. Management of viral diseases, anthracnose and *Phyllophaga* sp. will serve as a model to design similar studies in crops such as naranjilla and blackberry in the future.

**g.** **Progress to date:** Surveys of major pests of tree tomato, babaco, blackberry and naranjilla have been conducted during previous years of the IPM CRSP project. Knowledge of fungicide efficacy and plant disease resistance studies are available for anthracnose in tree tomato. Characterization of tree tomato viruses through pathogenicity and ELISA tests were also done. Efficacy of *Beauveria* sp. applications to control *Phyllophaga* sp. has been also established in previous years of the IPM CRSP project.

**h.** **Projected Outputs**: (1) Rational management of tree tomato pests can be obtained by applying knowledge accumulated so far under the IPM/CRSP program; (2) Technologies developed so far can even be more efficient if applied strategically under lower crop densities or crop associations; (3) A manual of common pests of tree tomato and a bulletin on IPM programs for anthracnose of tree tomato will be developed; (4) A bulletin on IPM programs for babaco vascular wilt will be developed together with a bulletin on IPM of babaco mite. Scientific publications associated with these studies will also be published.

**i.** **Projected Impacts:** Results from these studies will eventually lead to the implementation of IPM programs for tree tomato in Ecuador. In addition to providing cash crops for growers from local sales, increased production of tree tomato crop could lead to export markets and increased profitability to growers in Ecuador and neighboring countries such as Colombia. Expanded tree tomato production could assist local economies in the northern border region of Ecuador.

**j.** **Project Start:** October 2000

**k.** **Project Completion:** September 2004

**l.** **Projected Person-Months of Scientists Time per Year:** 9 + support technician 12.

**m.** **Budget:** $4,620 – INIAP; $4,923 – OSU

## II.4. Validation of Integrated Pest Management (IPM) of Plantain throughout the main producing region in Ecuador using innovative diffusion and training tactics

**a.** **Scientists:** C. Suárez-Capello, D. Vera – INIAP; R. Williams, M. Ellis – Ohio State University; C. Harris, J. Alwang, G. Norton – Virginia Tech. **Collaborative scientists:** M. Cabanilla, I. Carranza, J. Cedeño – INIAP; W. Flowers – Florida A & M; Extension Agents

**b.** **Objectives**: (1) To validate and disseminate integrated pest management practices on plantain in the communities of El Carmen, the provinces of Pichincha, Manabí and Los Ríos, Ecuador. (2) To train extension agents and plantain producers throughout the "plantain belt" on IPM components, based on an accurate diagnoses of the problems affecting the crop in the region. (3) To evaluate the impact of validation and training on the strategies developed to transfer IPM technology to farmers and private extension agents. (4) To effect changes in attitudes and practices of plantain producers in these regions.

**c.** **Hypotheses**: (1) IPM practices developed for plantain fit the needs and capacities of farmers in the plantain belt and contribute to the improvement of the productivity, sustainability and competitiveness of plantain production in the region. (2) When farmers and extension agents learn to analyze causes and effects related to pests and diseases, this will facilitate adoption of IPM practices. (3) It is possible to scale up the course so it can be given to several groups at once.

**d.** **Description of activities**: (1) Four validation plots will be implemented in the region, with preference given to farmers organized and being served by private extension agents (PEA). The IPM components (including field sanitation and limited leaf pruning, limited fungicide applications and insect trapping) to be implemented on each plot will be identified and tailored to regional specificities in a participatory workshop with the PEA and farmers. IPM components developed through the experiments conducted by the IPM

CRSP during the last three years will serve as the basic package to be tested. This package will be compared with the actual practices of farmers. Initially, groups of PEA and farmers will be trained in IPM concepts and use of these technologies will be shown on demonstration plots. (2) Two to four pilot groups will receive training courses in the El Carmen region based on materials developed and validated with the farmers and extension workers during year 10 and, in part, on the results of the survey from year 9. The course methodology will be as follows: each group will consist of 20-25 members, who will be provided with a trained facilitator. The courses will be divided into 12-15 lessons, each of which will use a package of text plus photographs, provided by the IPM CRSP. This is an introductory course and will cover general sanitary principles, rational and safe use of agro-chemicals, and basic cost-benefit analyses. Additional training materials will be prepared as necessary to address unforeseen issues during course delivery. Each participant group will be asked to manage demonstration plots following the techniques taught in each lesson. These plots will be monitored by IPM CRSP personnel/extension agents.

e. **Justification**: Studies performed in Ecuador have shown that the main constraints of plantain in the region are: deficient management of the crop through more than 20 years of continuous harvests; diseases like Black Sigatoka (*Mycosphaerella fijiensis*), stem rot (*Erwinia* spp), virus (probably Cucumber Mosaic Virus and Banana Stunt Virus); and an insect pest (*Cosmopolites sordidus*) which has become endemic in the region and produces epidemics and epizooties every year. During the last five years, plantain export demand has increased with some export companies offering special payment to farmers that fulfill their requirements in quantity and increasingly, in quality. This is being achieved with an exaggerated use of chemical pesticides, similar to the banana industry. Due to this situation, during the last three years, INIAP and the IPM CRSP developed IPM activities with the purpose of obtaining an accurate diagnosis of the problems involved and testing IPM strategies to minimize the use of agrochemicals, as well as minimizing the risks to the health of the farmers. In the first instance (years 1 and 2 in Ecuador activities of the CRSP) a whole "package" of technologies was developed and compared with those proposed by companies or farmers. It became evident that more information was needed about these problems, therefore from the second year forward, several activities were carried on to learn more about the plantain pathosystem (diseases), and insect pests. Finally, information about the farmers' system (socioeconomic and gender analysis) was gathered, including level of understanding about crop constraints. The latter analyses led to development of diagnostic and training tools. This whole process is now ready to be validated with a larger group of farmers within the region

f. **Relationship to other CRSP activities at the site**: This activity is related to all other activities in the "plantain belt" under the support of IPM CRSP and will benefit from all the results obtained.

g. **Projected outputs**: (1) Groups of farmers and extension agents using, in a participatory approach, the tools and techniques developed to improve plantain yield in the area. (2) A strategy of training and diffusion of models of integrated pest management. (3) Farmers and extension agents using strategies and instruments involving the new IPM technologies for plantain.

**h.** **Projected impacts**: (1) Increased competitiveness of plantain production in the region; (2) increased PEA and farmers' awareness of constraints and solutions; and (3) sustainable plantain solutions, especially for Black Sigatoka and weevils.

**i.** **Project start**: September 2003

**j.** **Project completion**: September 2004

**k.** **Budget**: $19,470 – INIAP; $5,108 – Virginia Tech

## II.5 Comparative studies on the development of Black Sigatoka on Banana (*Musa* AAA) and Plantain (Musa sp. AAB)

**a.** **Scientists:** D. Vera, C. Suárez-Capello, J. Cedeño – INIAP; M. Ellis – Ohio State University. **Collaborative scientists**: R. Delgado – INIAP; L Maffia – Vicosa University

**b.** **Objectives (Overall):** To determine the biological basis to differentiate the management of Black Sigatoka disease between banana (*Musa* AAA) and plantain (*Musa* AAB); **Year 11:** (1) To determine variability between isolates of *Mycosphaerella fijiensis* obtained from banana and plantain; (2) To determine relative susceptibility of banana and plantain to the disease; and (3) To relate environmental factors to the incidence and severity of the disease.

**c.** **Hypotheses:** (1) Banana and plantain have different responses to *M. fijiensis* attack due to their genetic constitutions, the latter being more resistant to the disease; therefore, it is necessary to use different management practices; (2) Besides the constitution of the plants, weather conditions (environmental factors), mainly rain and relative humidity, influence the intensity of the disease.

**d.** **Description of research activities:** This activity will be carried on in two stages:

Laboratory and shade house. First, monosporic cultures will be obtained both from banana and plantain and their morphological and developmental characteristics on specific media will be described. DNA will be extracted from both types of cultures and analyzed with appropriate molecular biological techniques for a precise characterization of both strains. Spores from these sources will be inoculated on banana (var. Williams) and plantain (var. Barraganete comun) at the $8^{th}$ leaf stage (approximately 2 months old). After inoculation, plants will be covered for 48 hours with plastic bags to form humid chambers. Afterwards, best management practices will be maintained, especially relative humidity, to enable observation of the development of the disease. The experimental design will be a factorial $2^2$ with 6 replicates. Factor 1 is the inoculum's sources and Factor 2 the actual crop species. Three plantlets/plot will be the experimental unit. The variables are: (1) Incubation and latency period, measured as the time between inoculation until symptom and sporulation appearance, respectively; (2) frequency of infection, counting the number of lesions on four 20 $cm^2$ squares on the inoculated leaf, 40 days after inoculation; (3) extent of infection, in this case, the length of 5 streaks taken at random on each selected square will be measured; (4) the infection period, counted as the time that the infected leaf produces spores and (5) severity of the infected leaf using Gould's. 6-point scale.

Field trials. To test the third objective, in the Pichilingue Experimental Station, two experimental plots will be planted with banana (Var. Williams) and plantain (Var. Barraganete). Two-month old plantlets will be taken to the field and planted at distances of 3 X 3 m. The experimental plot will be formed by six experimental units/crop, with three rows of plants as borders and six replicates of each plot. In the middle of the experimental field, a hygrothermograph and a pluviometer will be located to register daily weather conditions. The variables under consideration on this trial will be the disease index (dependent variable) and climatic factors (independent). The established plots of each crop will be managed uniformly with minimal use of chemical pesticides to protect them from weeds, nematodes and insect damage. Fertilization, and choupon selection will be applied according to crop needs (agronomic best management practices-BMPs).

**e.** **Justification**: Research carried on with the CRSP project during three consecutive years has made clear that management practices taken from banana are too intensive and chemical dependent for plantain. However, results have shown as well that there is ample space to improve control measures, either using more intensive cultural practices or including fungicides in the IPM program for plantain. The establishment of IPM programs requires sound knowledge of the biodynamics of the crop and the organisms involved in diseases, something currently lacking in plantain.

**f.** **Relation to other CRSP activities:** Results and research methods from this project will be directly applicable to other activities and projects in Ecuador. Information derived from this activity will be used to reinforce activity I.1. The biotechnology project in INIAP-Santa Catalina will assist the analysis.

**g.** **Progress to date:** Field trials have been set out in Pichilingue and a rain gauge and a hygrothermograph are giving information on daily environmental parameters in addition to data recorded from the met. station. A lab technician and UTEQ student have been trained to do the monosporic isolations of *M. fijiensis* and are ready to assist D. Vera in the shade house and laboratory trial (objectives 1 & 2). The rainy season for 2003 started late, with very little rain in January and very high temperatures; consequently, the disease is just showing on older leaves of the experimental plants.

**h.** **Projected outputs**: Knowledge of the Sigatoka-banana/plantain pathosystem will enable adjustment of recommendations of sanitary and chemical practices to the actual needs of the crop. A comparison between micro (rain, temperature and humidity on the experimental plots) and macro (same data taken from the Met. Station) environment may allow establishing relationships farmers can use for black sigatoka management.

**i.** **Projected impacts**: Availability of parameters of the disease cycle as related to environment and phenology of the crop will allow tailoring of a sustainable IPM strategy to control Black Sigatoka in plantain.

**j.** **Project start:** September 2002

**k.** **Project completion:** September 2004

**l.** **Budget:** $ 7,315 – INIAP

## II.6. Introduction of local strains of entomopathogenic fungi combined with pheromone attractants to control banana weevil in plantain.

**a.** **Scientists:** P. Rodríguez, D. Vera – INIAP; R.Williams – OSU. **Collaborative scientists**: C. Suárez-Capello, K. Solis – INIAP; M. Ellis – OSU

**b.** **Objectives:** (1)To test under on-farm conditions the controlling effect of a combined application of pheromone and the entomopathogen *B. bassiana* to obtain a biological control of the banana weevil (*C. sordidus*) in plantain. (2) Evaluate cost benefit ratio of this practice.

**c.** **Hypothesis:** A combination of pheromones to attract the insects and the invasive application of *B. bassiana* produces an effective way to control weevils in plantain.

**d.** **Description of research activity:** Two one-hectare observation plots will be installed on each of three representative highly infested plantations in the area. In the middle of each plot, the pheromone (Cosmolure+1) set on top of a ramp trap containing soapy water will be installed. One of the plots will be treated with a mixture of cultures of *B. bassiana* collected from the same region (El Carmen) and proven in earlier years of the IPM CRSP to be aggressive against *C. sordidus.* Levels of parasitism/control and population densities of insects will be measured at the beginning and at four intervals during the period when insect activity tends to be at its highest. Measurements will be done both with the ramp trap and five sandwich-type traps made of fresh plantain pseudostem located around each of the ramp traps, for every plot. Level of parasitism at the beginning and end of the experiment will be estimated through the Vilardebo scale applied to the corm of flowering plants. Harvest data and cost profile will establish relative costs.

**e.** **Justification:** Plantain yield is seriously affected by banana weevil attacks on plantain corms, not only because of direct loss due to severe lodging of plants and the subsequent loss of fruit weight, but also, indirectly, because insects provide easy entrance for bacteria. Its debilitating effect on plants renders them more susceptible to diseases.

Although there are no specific figures, it is estimated that half of the 60% yield loss known to occur in plantain is due to banana weevil. There are indications (confirmed by the activities conducted in this project over the last 2 years) of successful parasitism by *B. bassiana* to replace insecticides. However farmers have not adopted their use because the available commercial formulations are expensive and not always effective, perhaps due to the non-uniform virulence of the strains in use. Research conducted under the IPM CRSP project in El Carmen has shown that efforts to reduce black weevil populations have been ineffective and other strategies should be developed to tackle this problem. Experiments carried out during years 9 and 10 have permitted isolation of several strains of *B. bassiana* and methods for mass production are being used in Pichilingue. During the same period, the efficiency of the Cosmolure +1 has been evident with an average of 353 weevils trapped on ramp traps with the pheromone, in contrast to only 6 weevils in traps with no pheromone. The same outcome was observed with pseudostem traps: where Cosmolure+1 was present, an average of 1,015 weevils were captured per trap and only 473 in plots without the pheromone. The combined effects of these two tactics should be tested in order to evaluate its controlling effect on populations of *C. sordidus* and its damage to plantain.

**f.** **Relationship to other CRSP activities**. This activity will provide information and technology to be included in the IPM strategies developed for plantain. This activity is making use of information and technology (traps and attractants) found in previous experiments. Mass production methods developed may be applied to those activities carried on with potato pests.

**g.** **Project impacts**: (1) Reduction of the use of broad-spectrum insecticides and the possible reduction of production costs. (2) Reduction of health risks to farmers and local fauna. (3) Reduction of environmental contamination. (4) If the fungi can be maintained in the soil it could reduce the need for successive annual applications. (5) Extension agents and farmers will become familiar with the use of technology developed by the IPM CRSP.

**h.** **Projected person months**: 6

**i.** **Project starts**: September 2003

**j.** **Project completion**: September 2004

**k.** **Budget**: $9,020 – INIAP; $4,922 – OSU

## II.7. Effects of cultural practices on the three main nematodes affecting plantain

**a.** **Scientists:** R. Rivera, C. Suárez – INIAP. **Collaborative scientists**: M. Ellis, R. Williams - OSU; C. Triviño – INIAP

b. **Objectives**: To establish the effect of certain agricultural practices (mainly soil cover crops, use of agrochemicals and incorporation of organic amendments) on the population of nematodes in plantain.

c. **Hypothesis:** Agricultural practices have a direct influence on threshold levels of nematodes in plantain and an adequate manipulation may keep populations below that level.

d. **Description of research approach**: Experiments were set up on farms with high levels of nematode infestation. Levels of nematode populations present at the onset of the experiment will be measured. Then, four treatments are compared under a completely randomized design with 4 replicates and 20 production units per plot. Treatments are: residue management and soil cover; chemical usage (fertilizer, herbicides and Furadan applications); and soil improvement with organic matter. The cumulative effect of practices will be tested comparing results from three cycles of harvest.

e. **Justification**: Plantain yield in Ecuador is generally low: national averages are 8 metric tons per hectare annually when potential yields are 15 metric tons. Apart from the foliar pathogen causing Sigatoka disease, corm and root damage due to nematode attack contribute to low yields. However, work conducted over the last two years in the CRSP project has shown that (1) *R. similis* and relatively large populations of *Meloidogine* spp. and *Helicotylencus* are unevenly distributed around the area; (2) IPM practices negatively affect the population of root damaging nematodes and increase the beneficial species, particularly *Dorilaimus* and *Rhabditis*; and (3) The use of agrochemicals, in general, affects the type and quantity of nematodes present. No similar studies have been conducted in plantain in Ecuador.

This experiment is a follow-up of the second stage of a year 10 activity established mid-year because activities setting threshold levels took longer than expected due to difficulties in growing nematodes *in vitro* under Pichilingue conditions. Nematode attack is one of the three main biological constraints of the crop; therefore, to be able to demonstrate that they can be controlled by "natural" means, as proposed here, is a key issue to prevent the region from developing into a pesticide culture.

f. **Relationship to other CRSP activities**. This activity will provide key information for determining one of the IPM components (nematode attack) required for IPM in plantain being developed in another CRSP activity within the same area.

g. **Progress to date**: Procedures set up and personnel trained previously in nematode analysis will be used.

h. **Projected outputs**: (1) IPM technology for nematodes in plantain, based on cultural and biological control of nematode populations; (2) An established relationship between nematode incidence and technology level.

**i.** **Projected impacts**: To develop awareness by farmers of the use of cultural practices and IPM management of their crops to avoid serious phytosanitary constraints. The result will allow planning control decisions as part of the integrated management of the crop. It will serve as a baseline for future work on control measures.

**j.** **Project Start**: October 2002

**k.** **Project Completion**: September 2004

**l.** **Person months**: 12

**m.** **Budget:** $3,245 – INIAP

**II.8. IPM for plantain/coffee agro-forestry systems in northwestern Ecuador: a land use alternative to low-quality pasture within a fragile agro ecosystem**

**a.** **Scientists: Principal investigators**: C. Suárez-Capello, D. Vera – INIAP; F. Echeverría; R. Carroll – University of Georgia; R. Williams, M. Ellis – Ohio State University; W. Flowers – Florida A&M University. **Collaborating Scientists:** R. Justicia - Fundación Maquipucuna; C. Triviño – INIAP

**b.** **Objectives: (Overall)** Development of an IPM program for crop management in the fragile subtropical ecosystem of the Andean slopes. **Year 11:** (1) Develop basic information on the incidence of aerial plant pathogens, mainly *M. fijiensis*, the causal agent of black sigatoka disease, in monoculture plantain plantations, and in a polyculture agro-forestry system. (2) Determine incidence, seasonal and relative abundance of pests and diseases within six different crop systems on the Andean north occidental slopes. (3) Determine the effect of bagasse and ash amendments to root-damaging and predator nematode populations. (4) Study the life cycle and ecological requirements of *Castniomera humboldtii* (Castniidae, Lepidoptera), a destructive pest of plantain in northwest Ecuador. (5) Develop basic information about impacts of pest management practices on populations of pests in an agro-forestry system.

**c.** **Hypotheses:** (**Overall**) (1) Integrated pest and disease management are the best alternatives for sustainable production in fragile environments; (2) Identification of major problems in Andean subtropical cropping systems will facilitate development of IPM management strategies for farmers on fragile ecosystems subject to increasing colonization pressure. **Year 11:** (1) Polyculture cropping will show fewer incidences of pests and diseases (especially root-damaging nematodes) than monoculture plantations. (2) Bagasse and ash byproducts from sugarcane, readily available in the area from sugarcane processing, will provide an excellent substrate to facilitate improved biological control of pests and diseases, while, at the same time, providing protection of soil structure and limiting erosion. (3) Determination of environmental effects of Andean subtropical agro-forestry/cropping systems will facilitate development of IPM management strategies for farmers on fragile ecosystems subject to increasing colonization pressure.

**d. Description of research activity:** Plots have been established at Maquipucuna using the following crops: Maqueño plantain, coffee and lemon. Plots consist of single crops or combinations of the three crops. There are three replications of each crop combination. Plots will be monitored in monthly intervals for the presence of insects, mites and symptoms of disease. Tissue samples from apparently diseased plants will be collected and processed on media at Pichilingue laboratories to determine the presence of plant pathogens and vascular wilts. A survey of selected elements of the insect communities, focusing on actual and potential pests as well as parasitoid and predator guilds, has been initiated. Pests are being hand-collected; sweeping crop plants and yellow pan trapping collects parasitoid and predator guilds. Traps are placed to capture possible variation in the insect communities due to the different combinations of crop plantings. Collections of larval and pupae material of *C. humboldti* have been completed, and observations of the tunneling behavior of mature larvae in plantain trunks is underway. In the coming dry season, studies of adult feeding and egg laying behavior will be performed, and we will attempt to use sugarcane bagasse as bait for the adult moths. Studies of egg parasitism will also take place. Based on research on a related species in Peru, we have reason to believe that egg parasitoids will be a method of biological control of this pest.

The established plots of each cropping system will be managed uniformly with minimal use of chemical pesticides. All other agronomic best management practices (BMPs) will be applied. Soil and root sampling and corresponding processing will be conducted to determine nematode type and population within each system. Basic meteorological equipment will be set near the cropping system at Orongo to monitor weather (rain, relative humidity and temperature) conditions throughout the year. Simultaneous data will be collected from a nearby meteorological station for future comparison and analysis. These weather conditions will then be related to pests and diseases present during the same time.

Weeds will be selected in agreement with what local farmers regard as particularly difficult. Grasses and nut sedges will be monitored. They will be preserved, dried and pressed in vouchers for future identification. Another area will be measured for all weeds, and each problem weed will be detected. To determine the relative cover area, a 0.5 square meter PVC sampling frame will be designed. The frame will be divided into a grid of 10X10 cm squares, using string. The sampling frame will be down on randomly chosen locations in different treatments. Then the weeds that occur at each of the 16 intersections on the grids will be recorded. Only one plant in each intersection will be recorded and converted to percentages.

The survey of pests and natural enemies will serve as a baseline to direct subsequent specific studies of the use of individual species in biological control. Subsequent monitoring of pests and their enemies will provide a measure of the impact of both cropping systems and applied practices on the intervened area.

**e.** **Justification:** This highly vulnerable Andean region requires production systems that simultaneously offer an economic activity to farmers and minimize damage to the environment. Sugarcane is a major land use activity in the region, but bagasse and ash byproducts now constitute a source of contamination; few attempts have been made to find alternative uses for them. Farmers do not have many productive alternatives in the area. Farmers now have a mixture of coffee, "banana", citrus and a low-quality pasture, *Setaria*. Coffee, banana and citrus are scattered in farms with high mortality within orchards caused by pest and diseases. The region may produce good quality coffee and citrus. The potential for this agro-forestry system is good, provided farmers can solve their ecological (mainly soil erosion) and phytosanitary constraints. The survey of pests and natural enemies will provide a baseline to direct subsequent specific studies of the use of individual species in biological control. Additionally, it will give managers of conservation areas information on insect interactions in protected forests and neighboring agroscapes. The study of the life cycle of *C. humboldti* in Maquipucuna will be directly applicable to the coastal area of Esmeraldas where this moth is also a serious pest.

**f.** **Relationship to other CRSP activities.** Any information on the type and relative abundance of pests and diseases of this system would be of direct benefit to other CRSP activities both in Ecuador and in other subtropical regions. This research is related to the plantain activity being carried on with this project, especially that concerned with black sigatoka disease and the main insect pests of plantain.

**g.** **Progress to date:** Within the Orongo farm, an area of 5900 $m^2$ has been planted with an ordered system including crops that are common in the region: plantain (Maqueño variety), coffee and citrus. Lemon trees of the Meyer variety were used. Maqueño will be for local market but coffee and lemon are used for export. The agro forestry design consists of 4 blocks each with 6 treatments: (1) single rows plantain + coffee; (2) double rows of plantain + coffee; (3) plantain + citrus; (4) plantain alone; (5) coffee; (6) citrus. Each block has 1,114 $m^2$ with treatments plots of 120 $m^2$. Two Malaise traps have been located in the agro-forestry plots and will be activated four times a year to get periodic snapshots of the general insect fauna of the project area. Initial trials of yellow pan traps have demonstrated the usefulness of this method of trapping. As noted above, specimens and observations on the immature stages of *C. humboldti* have been collected.

**h.** **Projected outputs:** (1) A better understanding of the incidence of root-damaging pest and diseases in polyculture agro forestry. (2) First hand information about incidence, seasonality and severity of phytosanitary constraints for three important crops within an agro-forestry system design suitable for sustainable agricultural usage. This information will serve as a baseline to validate IPM practices on these systems. (3) Knowledge of the effects of using sugarcane bagasse on behavior of *Castniomera*. (4) Knowledge of the occurrence and behavior of predators and parasites of nematodes and insect pests.

**i.** **Projected impacts:** (1) Valuable information about the relative importance of pest and diseases of plantain, coffee and citrus agro forestry, allowing a prioritization of future work in the region. (2) Low-cost strategies to reduce the main plantain pests. Improved incentives for converting low-quality pasture to stable agro forestry in fragile environments like the Andean slopes. (3) A strategy to utilize sugarcane byproducts to improve agro-forestry production.

j. **Project start:** October 2000

k. **Project completion**: September 2004

l. **Projected person-months of scientist time per year**: 6 months

m. **Budget:** $4,510 – INIAP; $5,040 – Florida A& M

## III. Socioeconomics

### III.1. Modeling Impacts of Changes in Pest Management Technologies

a. **Scientists:** V. Barrera, C. Suarez – INIAP; Miriam Cabanilla – University of Quevedo; J. Alwang, G. Norton, C. Baez – Virginia Tech

b. **Status:** Continuing activity

c. **Objectives: (Overall)** (1) To assess the impacts of IPM technologies on land use and management, farmer income, and pesticide use. (2) To assess the aggregate economic impacts of the IPM technologies developed by the IPM CRSP, including spillovers across regional and national boundaries. (3) To understand the distributional and environmental impacts of IPM research. **Year 11:** (1) Finish aggregate impact assessment for IPM in plantain on the coast. (2) Finish assessment of impacts of IPM plantain research by socioeconomic group and among participants in plantain labor markets. (3) Assess distributional impacts of farmer field schools in potato growing regions.

d. **Hypotheses:** (1) Land use and management, farmer income, and pesticide use will not be affected by IPM technologies generated by the IPM CRSP; (2) IPM CRSP technologies do not have economic impacts or spillovers.

e. **Description of research activity:** To address the objective related to aggregate impacts of IPM plantain research, per unit cost reductions measured or projected due to IPM CRSP technologies have been combined with measured or projected information on adoption and included in an economic surplus model to generate aggregate benefits. All changes in input use, outputs, and prices are being measured for each of the CRSP experiments. This information can be used to help generate per unit cost changes. In year 10, the data from the plantain experiments on the coast were gathered; these data will be analyzed in year 11. Impacts of plantain technology across socioeconomic groups will be assessed using discussion groups to identify constraints to adoption of such technologies. This information will be incorporated into a surplus model that is disaggregated by income group and farm size. National data on plantain production by farm size and socioeconomic groups will also be incorporated into this analysis. Finally, labor market spillovers will be measured using an econometric model.

**f.** **Justification:** Knowledge of farm, regional, and aggregate level impacts of IPM is essential for designing IPM programs and pest management recommendations, for justifying programs and research activities, and for designing environmental policies and programs. These impacts often spill over across regions and have differential effects within the household. Application of the models developed at this site may provide a template for subsequent joint research activities in other sites as well. It also provides the first attempt to estimate profitability of plantain IPM.

**g.** **Relation to other research activities at the site:** This project directly complements other research activities underway on the Soils CRSP on bio-economic modeling, at CIP and INIAP in general and the IPM CRSP in particular to control late blight, Andean potato weevil, and potato tuber moth.

**h.** **Progress to date:** In year 9, an aggregate impact assessment was completed for IPM in potato production. In years 9 and 10, a student working under the supervision of Dra. Carmen Suarez collected data to complete the plantain component of the research. An MS student under the supervision of Dr. Jeffrey Alwang and Dr. George Norton completed a review of literature on distributional impacts of agricultural research. She also acquired supplementary data from the World Bank to complete the household-level and distributional analysis.

**i.** **Project start:** October 1999

**j.** **Project completion**: September 2004

**k.** **Projected person-months of scientist time per year**: 6 months

**l.** **Budget:** $5,720 – INIAP; $32,077 – Virginia Tech

## III.2. Diagnosis of socioeconomic conditions and pest management practices in naranjilla-growing regions of Ecuador.

**a.** **Scientists:** V. Barrera - INIAP; J. Alwang, G. Norton - Virginia Tech

**b.** **Objective(s):** (1) To identify social and economic factors influencing pest management practices in the household; (2) to measure social and economic conditions in naranjilla-growing regions; and, (3) to inform researchers about the attributes of pest-control technologies that will be most appropriate given conditions in the region.

**c.** **Hypotheses:** (1) Economic conditions in naranjilla regions are the same as the rest of the country; (2) social and economic conditions affect technology adoption.

d. **Description of Research Activities:** (1) Household socioeconomic surveys will be conducted; (2) Village surveys of key informants and participatory evaluations will complement the household information; (3) Economic information from secondary sources will be compiled. The ideal sample will contain at least 120 families, and will support multivariate statistical analysis of the independent effects of a number of household-level and economic variables on pest management practice.

e. **Justification:** The IPM CRSP has invested substantial resources in identifying pest problems in naranjilla. The project is in the process of developing solutions to these problems, including better seed sanitation, grafting naranjilla onto resistant rootstock, and in-field practices. Despite this progress, very little is known about the socioeconomic conditions in naranjilla-growing regions or about conditions in households in these areas. As demonstrated throughout IPM CRSP research in Ecuador and other sites, knowledge of socioeconomic conditions can contribute to the creation of more effective technologies. This study will provide such information. USAID-Ecuador has shown interest in understanding the underlying economics of regions along the border with Colombia. Such information can help to build a strategy for sustainable economic bases in the region. It is thought that naranjilla can be an effective income-generating strategy for households in the region, but little is known about the importance of naranjilla production for household incomes and whether improvements in naranjilla will have a major impact in the region.

f. **Relationship to other CRSP activities at the site:** This project directly complements work on naranjilla and work in Carchi on the socioeconomics of potato production.

g. **Progress to date:** Investigations of pests and diseases in naranjilla.

h. **Projected Output(s):** (1) Compilation of data and reports presenting descriptive analyses of household income sources and the role of naranjilla in household income generation. (2) General description of socioeconomic conditions in regions. (3) Analysis of social and economic determinants of pest management practices among small-scale producers. (4) Recommendations for naranjilla pest control technologies.

i. **Projected Impacts**: Increased adoption of IPM; more egalitarian destribution of economic and health benefits of IPM among farm family members.

j. **Projected Start**: September 2003

k. **Projected Completion:** September 2004

l. **Projected Person-Months of Scientists Time per Year**: 8

m. **Budget:** $3,410 – INIAP

**III.3. Validation and diffusion of models for integrated pest management (IPM) of potato in Carchi, Ecuador**

**a.** **Scientists:** V. H. Barrera, L. Escudero, J. Suquillo – INIAP-Carchi; G. Norton; J. Alwang; C. Harris; M. Mauceri – Virginia Tech. **Collaborating scientists**: P. Gallegos, G. Heredia – INIAP-E.E. Santa Catalina

**b.** **Objectives:** (1) To extend training and diffusion of IPM practices in potato to include other actors involved in local economic and social development of the northern border areas of Ecuador where potato production forms the base of the economy. (2) To elaborate and test alternative materials for training and diffusion to scale up the use of IPM practices generated by the IPM CRSP. (3) To understand how participation in farmer field schools affects IPM use on farms and how knowledge from field school participants spreads to non-participants**.**

**c.** **Hypothesis:** Farmer field schools are an effective means of promoting the use of IPM production techniques in potato-producing regions of Ecuador.

**d.** **Description of activities:** Farmer field schools have been modified and used to transfer knowledge in three areas of potato growers in Carchi. Training and diffusion for year 11 will expand these activities and scale up technology transfer through a distance learning course and alternative mass dissemination efforts. The distance learning course will use the same method as plantain (see activity II.4). Experiences in plantain and potato will be compared to draw inferences about the optimal technology transfer system given local conditions. Local government actors, including school teachers and economic development officials, will be encouraged to participate with the intent of further multiplying technology transfer and engaging officials in thinking about the role of sustainable agricultural production in building the local economic base.

**e.** **Justification:** The IPM CRSP, in coordination with other INIAP potato projects has conducted research, technology transfer and training in three potato growing locations: San Francisco de Espejo, Santa Martha de Cuba of Tulcán and San Pedro de Piartal of Montúfar. As in all potato areas of Carchi, phytopathological problems of potato have been reported, such as late blight (*Phytophthora infestans*), the Andean weevil (*Premnotrypes vorax*), the Central American tuber moth (*Tecia solanívora*) and the leafminer (*Liriomyza huidobrensis*) (Barrera *et. al.,* 1999). The farmer field schools (FFS) have directly involved more than 250 potato growers, and indirectly impacted more than 1,200 farmers (through field days and other activities), out of a total of 7,000 in Carchi. However, there is some concern that the field schools have not been as cost effective as they might be. This project will exploit knowledge gained through the IPM experiments and field trials and experiences of the field schools to test alternative dissemination efforts. The northern border region, where the work is concentrated, is of primary interest to the USAID mission and has suffered a competitiveness crisis in local potatoes. The CRSP has identified cost-lowering technologies which need to be extended to local producers. Local government officials are struggling to identify activities that will stabilize the population by creating a viable economic base. Given the predominance of potato production in the region, any local strategy will have to involve these producers. This activity will use IPM technologies as a focal point.

**f.** **Relationship to other CRSP activities at the site:** This activity is related to all the activities that have been and are being performed in Carchi, with the support of IPM CRSP as well as with other projects. The activities of the IPM CRSP with which it is related is: "Development of biocontrol methods for two important potato plagues in Ecuador: "the Andean weevil and the Central American tuber moth", "Development of the innovative capability in agricultural production and integrated pest management for the food security of the Ecuadorian highlands INIAP-CIP-FAO", "Identification of the mortality factors of the Guatemalteca moth in potato crops and storage rooms in Ecuador Catholic University -INIAP-PROMSA; "Evaluation and enhancement of a minimum tillage system in potato INIAP-PROMSA"; "Improvement of the productivity and sustainability of the systems of production mixed: crops-livestock, in the Andean ecoregion of Ecuador INIAP-CIP-PROMSA" and "Training in the adequate management of pesticides and integrated pest management INIAP-Croplife".

**g.** **Progress to date:** We selected 16 communities in the counties of Tulcán, Montúfar and Espejo in Carchi. These are representative areas where Andean weevil, late blight, the Central American tuber moth and the leafminer are serious constraints for potato production. In total, 215 training sessions were performed, 265 farmers were trained and 250 potato farmers graduated from the FSs. Courses to train the trainers about methodologies were also held in the northern highlands, graduating 74 participants including technicians, peasant promoters, agricultural school teachers and university students. Six field days were held, with the participation of 1,086 persons.

Regarding implementation of IPM components, 32 plots were evaluated, 16 with IPM and the other 16 with conventional methods. The results showed that IPM components have contributed to a reduction of production costs and the use of high-toxicity pesticides. Analysis indicates that using IPM, farmers can reduce the number of chemical controls up to an average of 45%. Chemical control is lowered from 9 to 5. Costs of pesticide declined by an average of 40%: from $360 per ha with 9 applications, down to $218 per ha with 5 applications.

The FSs have generated the interest of other institutions, national and international. The Sectional Governments of the province and the Mayors of Espejo, Tulcán, Huaca, Julio Andrade and Montufar, and the Provincial Government of Carchi, are motivated to investigate the process of training and diffusion, on behalf of their communities, since the family incomes are derived from the potato crop.

A socioeconomic study of the process of technology transfer and information diffusion patterns is needed. Little is known about how information provided to FFS participants is diffused to non-participants. Such information is needed to measure the full impact of the FFS programs and to design improved diffusion methods. A survey to compile information on knowledge and practices of participant and non-participant farmers on the FFSs will provide this information.

**h.** **Projected Outputs:** 1) IPM practices adapted to agro-socioeconomic conditions of the potato producers in the influence of the Plan Colombia.area; 2) Training and diffusion strategy of IPM practices.

**i.** **Projected Impacts:** (1) Reduction of pesticide use and low production costs. (2) Reduction of health risk to potato producers and consumers. (3) Higher environmental protection from the reduction in the use of pesticides.

**j.** **Project Start:** October 1999

**k.** **Project Completion:** September 2004

**l.** **Projected Person-Months of Scientists Time per Year:** 12

**m.** **Budget:** $14,520 – INIAP; $30,439 – Virginia Tech

## Site Activity Summary – Ecuador – Year 11

| ACTIVITY | | SCIENTISTS | BUDGET ($) |
|---|---|---|---|
| I.1. | Developing improved management strategies for disease caused by *Phytophthora infestans* in solanaceous crops using molecular biological tools | G. Bernal, J. Ochoa – INIAP; G. A. Forbes, G. Chacon – CIP; G.H. Lacy, C. Hong – Virginia Tech; M. Ellis – Ohio State University. Collaborative Scientists: C. Suarez – INIAP | $12,395 – INIAP |
| **II.** | **Multidisciplinary On-Farm Pest Management Experiments** | | |
| II.1. | Development of Biocontrol methods for the two major potato pests in Ecuador: The Andean potato weevil, *Premnotrypes vorax* and the Central American tuber moth, *Tecia solanivora* | P. Gallegos, C. Asaquibay, J. Suquillo, V. Barrera – INIAP; J-L. Zeddan – PUCE-Quito; J. Alcázar – CIP; R. Williams – Ohio State University. Collaborative Scientists: L. Escudero, F. Merino – INIAP. | $ 11,330 – INIAP |
| II.2 | Agronomical, phytopathological and entomological studies of naranjilla germplasm resistant to *Fusarium oxysporum* causing naranjilla vascular wilt | J. Ochoa, P. Gallegos, L. Shiki, M. Insuasti – INIAP; M. Ellis, R. Williams – Ohio State University. Colaborative Scientists: J. Fiallos, J. León – INIAP | $9,020 – INIAP; $13,070 – OSU |
| II.3 | Developing IPM programs for viral diseases, anthracnose and *Phyllophaga* sp. in tree tomato (*Solanum betaceum*) in Ecuador | J. Ochoa, P. Gallegos, W. Viera, M. Insuasti – INIAP; M. Ellis, R. Williams – Ohio State University. Collaborative Scientists: A. Martinez, J. Leon – INIAP | $4,620 – INIAP; $4,923 – OSU |
| II.4. | Validation of Integrated Pest Management (IPM) of plantain throughout the main producing region in Ecuador using innovative diffusion and training tactics | C. Suárez-Capello, D. Vera – INIAP; R. Williams, M. Ellis – Ohio State University; C. Harris, J. Alwang, G. Norton – Virginia Tech. Collaborative scientists**:** M. Cabanilla, I. Carranza, J. Cedeño – INIAP; W. Flowers – Florida A & M; Extension Agents | $19,470 – INIAP; $5,108 – Virginia Tech |

| | | | |
|---|---|---|---|
| II.5 | Comparative studies on the development of black sigatoka on banana (Musa AAA) and plantain (Musa sp. AAB) | D. Vera, C. Suárez-Capello, J. Cedeño – INIAP; M. Ellis – Ohio State University. Collaborative scientists: R. Delgado – INIAP; L Maffia – Vicosa University | $ 7,315 – INIAP |
| II.6. | Introduction of local strains of entomopathogenic fungi combined with pheromone attractants to control banana weevil in plantain. | P. Rodríguez, D. Vera – INIAP; R.Williams – OSU. Collaborative scientists: C. Suárez-Capello, K. Solis – INIAP; M. Ellis – OSU | $9,020 – INIAP; $4,922 – OSU |
| II.7. | Effects of cultural practices over the three main nematodes affecting plantain | R. Rivera, C. Suárez – INIAP. Collaborative scientists: M. Ellis, R. Williams - OSU; C. Triviño – INIAP | $3,245 – INIAP |
| II.8. | IPM for plantain/coffee agro-forestry systems in northwestern Ecuador: a land use alternative to low-quality pasture within a fragile agro ecosystem | C. Suárez-Capello, D. Vera – INIAP; F. Echeverría; R. Carroll – University of Georgia; R. Williams, M. Ellis – Ohio State University; W. Flowers – Florida A&M University. Collaborating Scientists: R. Justicia - Fundación Maquipucuna; C. Triviño – INIAP | $4,510 – INIAP; $5,040 – Florida A&M |
| **III.** | **Socioeconomics** | | |
| III.1. | Modeling impacts of changes in pest management technologies | V. Barrera, C. Suarez – INIAP; Miriam Cabanilla-Univ of Quevedo; J. Alwang, G. Norton – Virginia Tech | $5,720 – INIAP; $32,077 – Virginia Tech |
| III.2. | Diagnosis of socioeconomic conditions and pest management practices in naranjilla-growing regions of Ecuador | V. Barrera - INIAP; J. Alwang, G. Norton - Virginia Tech | $3,410 – INIAP |
| III.3. | Validation and diffusion of models for integrated pest management (IPM) of potato in Carchi, Ecuador | V. H. Barrera, L. Escudero, J. Suquillo – INIAP-Carchi; G. Norton, J. Alwang; C. Harris – Virginia Tech. Collaborating scientists: P. Gallegos, G. Heredia – INIAP-E.E. Santa Catalina | $14,520 – INIAP; $30,439 – Virginia Tech |

# YEAR 11 WORKPLAN FOR THE ALBANIAN SITE

The IPM CRSP project in Eastern Europe has focused on olives grown in Albania. Several multi-disciplinary projects have focused on olive fruit fly, olive moth, Mediterranean black scale, olive knot and leaf spot, and the complexes of weeds and nematodes that attack olive trees. In addition to a baseline survey and biological monitoring of the pest complexes on olives, IPM projects include (i) Effect of harvest timing on olive fruit fly infestation and olive oil yields and quality, (ii) organic methods of vegetation management and olive insect control, (iii) effect of pruning on olive production, infestation by black scale and the incidence of olive knot and timing of copper sprays to control leaf spot and olive knot, and (iv) pheromone-based IPM in olive and effects on non-target species. An evaluation of economic impacts of IPM CRSP-related research for the Albanian olive industry was conducted. The Albanian institutions involved have been the Plant Protection Institute (PPI, Durrës), the Agricultural University of Tirana (AUT) and the Fruit Tree Research Institute (FTRI, Vlore).

Our project has been funded totally by the USAID mission in Tirana. Funding was initially for three years, though we were able to stretch this to four since progress was initially slow due to political troubles associated with the Kosovar/Serbian conflict. However, progress in our trials since has been excellent. We have shown several results: 1) harvest timing has strong potential to eliminate the need to spray for olive fruit fly; 2) attract-and-kill technology can control olive fruit fly injury in most years; 3) timing for disease sprays has been improved; and 4) organic methods of controlling olive moth are effective.

Since the CRSP activity as originally planned is nearing an end, we now must consider directions for expansion of our IPM research into other crops. In the original planning, greenhouse grown tomatoes and cucumbers were considered to be the most likely candidates for such crops. Since that time, vineyards have also been put forward for potential work. We would like to take the opportunity during Year 11 to complete a Participatory Appraisal to allow a basis for decision-making on future directions of the IPM CRSP in Albania.

IPM CRSP research activities in Albania in year eleven will involve three major types of activities: (1) participatory appraisal and baseline survey to position the CRSP and the host country institutions for the next phase of their IPM program, (2) completion of olive field research, and (3) technology transfer for olive IPM.

## I. Participatory Appraisal and Baseline Survey

### I.1. Title: Participatory Appraisal for IPM in Albanian Greenhouse Tomatoes, Cucumbers, and Vineyards, and Associated Baseline Survey.

**a. Scientists:** While specific individuals are yet to be decided, it is anticipated that there will be four each from the Agricultural University of Tirana (AUT) and the Plant Protection Institute (PPI), and two each from Fruit Tree Research Institute (FTRI) and the Vegetable and Potato Institute (VPI). From the American side, three each from University of California and Virginia Tech, and two from Penn State.

**b.** **Objectives:** To determine the main IPM-related issues in greenhouse tomatoes and cucumbers and vineyards in Albania, and constraints to their solutions.

**c.** **Hypotheses:** There is a range of pest problems existing in Albanian greenhouse vegetables and in vineyards. A participatory appraisal will allow prioritization of these problems, and allow the IPM CRSP to best determine the most suitable role in these cropping systems.

**d.** **Description of research activity:** Early in the project period, several U.S. scientists will visit Albania, and meet with colleagues from four Albanian research institutions: Plant Protection Institute (Durrës), Agricultural University of Tirana, Vegetable and Potato Institute, and the Fruit Tree Research Institute (Vlora). PA techniques will be reviewed, followed by farm visits in several relevant agricultural communities. The most likely areas will center in Durrës/Tirana, Lushnja/Divjaka, and Vlora. After the farm visits, Albanian and American scientists will review the results and develop several research proposals for further consideration.

**e.** **Justification:** When the IPM CRSP began work in Albania, the first crop to be considered was olive. It was decided that a future phase should address greenhouse tomatoes and cucumbers. It has since become apparent that grape is another crop important throughout Albania that could serve as a focus of IPM research. This PA will help prioritize the most appropriate crops to be pursued for additional research.

**f.** **Relationship to other research activities at the site:** The proposed work will build on the success of IPM CRSP-supported research on olives. There will be a good blend of researchers familiar with Participatory IPM approaches who can share their knowledge with with new scientists from the Vegetable and Potato Institute.

**g.** **Progress to date:** New Project.

**h.** **Projected outputs:** A set of proposals with relevant background information and a baseline survey.

**i.** **Project impacts:** The research proposals and baseline survey will be available for IPM CRSP-Eastern Europe to pursue new support. This will assist the AID mission and the host country institutions in prioritizing crops and will facilitate decision-making.

**j.** **Project start:** September 2003

**k.** **Projected completion:** September 2004

**l.** **Projected person-months of scientist time per year:**

**m.** **Budget:** Including carryover funds: $18,362 – Albanian institutions; $8,299 – Penn State; $12,033 – University of California; $10,918 – Virginia Tech. **Year 11 only**: $10,396 –

Albanian institutions; $5,089 – Penn State; $5,292 – University of California; $5,363 – Virginia Tech.

**II. Termination of multi-disciplinary projects in olive [Mainly costs associated with harvest, olive oil analysis (Nov-Dec)]**

**II.1. Title: Effect of Harvest Timing on Olive Fruit Fly Infestation and Olive Oil Yields and Quality**

**a.** **Scientists:** D. Pfeiffer – Virginia Tech; F. Thomaj, M. Bregasi, J. Tedeschini, D. Panajoti, B. Ferraj – Albanian institutions; L. Ferguson – University of California; C. Pitts – Penn State.

**b.** **Status:** Finishing fourth year; project completion

**c.** **Objectives:** (1) To determine the optimal time to harvest olives to minimize olive fruit fly infestation and maximize oil yield and quality; (2) To determine the effect of storage time on olive fruit fly infestation and percent olive oil quality; (3) To determine the effect of harvest date on return bloom and yield the subsequent year.

**d.** **Hypothesis:** After temperatures drop below 34C olive fruit fly infestation, which decreases oil quality (by increasing % acidity), increases. At the same time, olives are maturing and accumulating oil content (% oil/kg of fruit), or yield. As these two processes proceed there is an arc of time when oil yields (% oil/kg of fruit) and quality (% acidity) are least affected by olive fruit fly infestations and therefore give maximum return to the grower. There is an optimal harvest time if these two processes can be balanced. Harvest can be timed to maximize increasing yield and minimize increasing olive fruit fly infestation.

**e.** **Description of research activity.** Olives must be harvested in the experimental grove, and olive oil pressed and analyzed.

**f.** **Justification:** If growers can select the optimal time to simultaneously maximize yield and minimize olive fruit fly infestation, possibly chemical control for olive fruit fly can be minimized. Funds are included to pay for chemical oil analysis in Greece. Sampling must be extended into November 2003, the normal harvest period for olives in Albania.

**g.** **Relationship to other research activities at the site:** Effectiveness will be enhanced by lowered crop-bearing canopy developed in the pruning experiment. Prevention of pesticide applications for olive fruit fly will favor biological control of black scale and organic management of olive moth.

**h.** **Progress to date:** Work on this project was initiated in spring, 2000. Orchard blocks have been cultivated and pruned at Shamogjin, a research grove near Vlora operated by the Fruit Tree Research Institute. Positive results have been obtained to date, with olive content reaching nearly maximum levels before the third generation of olive fruit fly. An additional harvest is needed to terminate the project.

**i.** **Projected outputs:** Improved IPM management of olives.

**j.** **Projected impacts:** Increased net returns and decreased use of pesticides.

**k.** **Projected start:** September 1999

**l.** **Projected completion:** September 2004

**m.** **Projected person-months of scientists time per year:** 12

**n.** **Budget:** Including carryover funds: $4,200 – Albanian institutions; $ 0 – Penn State; $ 0 – University of California; $0 – Virginia Tech. **Year 11 only**: $3,000 – Albanian institutions

## II.2. Title: Organic Pest and Vegetation Management

**a.** **Scientists:** J. Tedeschini, B. Stamo, H. Pace, B. Huqi, Sh. Shahini, Dh. Panajoti, H. Ismaili, M. Baçaj – Albanian institutions; M. McGiffen and L. Ferguson - Univ. of California

**b.** **Status:** Finishing fourth year; project completion

**c.** **Objectives:** Determine the effect of vegetation management on pest populations and yield.

**d.** **Hypotheses:** (1) Vegetation management affects pest populations and yields of olive; (2) Organic vegetable production can be profitable for Albanian farmers.

**e.** **Description of research activity**: A randomized complete block experiment has been set up in two fields: an organic production system, and one using synthetic pesticides and fertilizers. Each treatment is replicated five times. The seven conventional treatments include: (1) cover crop – mixed legume and rye for winter growth, (2) untreated control, (3) non-selective herbicide - glyphosate, (4) selective herbicide - diuron, (5) grazing, (6) plowing, (7) straw mulch. Synthetic insecticides and fungicides are used for the conventional production field. The organic field has five of the above treatments, and does not include the two herbicide treatments. Copper sulfate and Bordeaux Mix are used for pathogen control in the organic field; organic insect control uses BT and pheromone disruption.

The following parameters are measured for all field experiments: (1) Weed population density, measured once in January, and again in July; (2) Olive fruit fly population counts; (3) Leaf spot counts; (4) Olive yield and quality, using a once over harvest of all fruit; and (5) Black scale, assessed by counting the number of scales in 10-cm sections of twig, and number of nymphs on foliage. Age structure of scale will be compared across pruning treatments. Scale feeding will be assessed by counting the percent of leaves with sooty mold accumulations.

**f.** **Justification:** Weeds reduce olive yield and quality by competing directly with the plants for light, water, and nutrients. Newly established orchards are especially vulnerable to weed competition, and trees may be killed before they can bear fruit. Weeds also harbor insects and pathogens. Sampling must be extended into November 2003, the normal harvest period for olives in Albania.

There is a rapidly growing market for organic products. Organic products command prices several times higher than for the conventional segment of the market. This would increase competitiveness in the European market. The rules for organic certification require production without the use of synthetic pesticides or fertilizers. Many Albania growers are currently producing crops that would be eligible for organic certification, but the yields are low. Additional research on nitrogen production by cover crops and non-chemical pest management should provide the information needed to boost yields.

**g.** **Relationship to other research activities at the site:** The study, along with the harvest timing and pheromone-based olive fruit fly control experiments, will contribute to developing an organic olive production system.

**h.** **Progress to date:** Work on this project was initiated in spring, 2000. Orchard blocks have been cultivated and pruned at Shamogjin, a research grove near Vlora operated by the Fruit Tree Research Institute (FTRI). Two types of management were evaluated, an organic production system and one using synthetic pesticides and fertilizers (conventional system). Both systems were established in experimental fields of FTRI. Satisfactory results were obtained with the use of mulching straw including increased productivity of olive trees, avoiding weed competition and conserving soil moisture for longer periods of time. Good results were also obtained using the selective herbicide diuron, reducing weed germination and the non-selective herbicide glyphosate. Olive yields in the respective treatments must be obtained; harvest occurs after the beginning of the new fiscal year.

**i.** **Projected outputs:** Refereed publications. Growers will gain new information on vegetation management and organic production.

**j.** **Projected impacts:** New systems for weed management. Reduced disease and insect populations. Development of new products, organic vegetables, for the export market.

**k.** **Project start:** October 1999

**l.** **Projected completion:** September 2004

**m.** **Projected person-months of scientists time per year:** 12 person months

**n.** **Budget:** Including carryover funds: $2,762 – Albanian institutions; $0 – University of California; $0 – Penn State; $0 – Virginia Tech. **Year 11 only**: $2,179 – Albanian institutions

**II.3. Title: Pheromone-Based IPM in Olive and Effects on Non-Target Species.**

**a.** **Scientists**: R. Uka, E. Isufi, J. Tedeschini, M. Baci – Albanian institutions; D. Pfeiffer – Virginia Tech

**b.** **Status:** Finishing fourth year; project completion.

**c.** **Objective:** To develop a selective attractant-based control system for olive fruit fly, *Bactrocera (Dacus) oleae* (Gmelin), and document its compatibility with black scale, *Saisettia oleae* Olivier, biological control.

**d.** **Hypotheses:** (1) Mating disruption can be an effective management tool for olive fruit fly, (2) A minimum block size of 2 ha is required; (3) The pheromone-based program will allow successful biological control of black scale.

**e.** **Description of research activity:** Mating disruption will be used for olive fruit fly (pheromone placed before first flight, traps checked weekly, fruit damage assessed every two weeks). Oil quality will be determined at harvest. There will be three treatments (applied before the beginning of the proposed fiscal year): (1) pheromone-based, (2) insecticide, and (3) untreated control.

**f.** **Justification:** Olive fruit fly is the main key pest of olive in Albania. Sprays for this species disrupt biological control of black scale. The latter is considered a very damaging olive pest. Because sprays have not been widely used for several years, most groves now have viable populations of scale parasites and predators, a resource that should be conserved. If a pheromone based program is successful, fly damage will be minimized without sacrificing biological control of black scale. Sampling must be extended into November 2003, the normal harvest period for olives in Albania.

**g.** **Relationship to other research activities:** Pheromone-based management of olive fruit fly will interact with other experiments in fostering an organic management system for olive.

**h.** **Projected outputs:** A series of recommendations will be made on selective IPM, which will be distributed to growers through the Extension Service and by other standard means. Results will also be published in scientific journals.

**i.** **Projected impacts:** A stable IPM program will allow a nontoxic control for two important olive pests, increasing farmer safety. The improved survival of natural enemies will prevent black scale from exceeding the economic threshold. IPM practices will result in lower costs and higher income for farmers.

**j.** **Progress to date:** Work on this project using attract-and-kill technology was initiated in spring, 2000. Orchard blocks have been cultivated and pruned at Shamogjin, a research grove near Vlora operated by Fruit Tree Research Institute. Results have been excellent, with high degree of control provided. On untreated experimental fields, the levels of fruit infestation were relatively high while the olive fruit fly infestation remained low where eco-traps were used. At the harvest time in November, only 5-6 % of the olive fruits were infested (the difference between treatments was less pronounced in 2002 because of climatic conditions). In the olive groves protected with one insecticide spray, the infestation reached about 20%. An alternative pheromone-based tactic is mating disruption; this has not been tried in Albania.

**k.** **Starting date:** October 1999

**l.** **Ending date**: September 2004

**m.** **Scientist-months per year:** 10

**n.** **Budget:** Including carryover funds: $4,200 – Albanian institutions; $0 – Penn State; $0 – University of California; $0 – Virginia Tech. **Year 11 only**: $3,000 – Albanian institutions

## III. Technology Transfer

### III.1 Olive IPM Symposium

**a.** **Scientists:** J. Tedeschini, H. Pace, B. Stamo, V. Jovani, B. Huqi, Sh. Shahini, R. Uka, M. Hasani, F. Thomaj, M. Bregasi, M. Baci, Dh. Panajoti, H. Ismaili, B. Ferraj, Z. Veshi – Albanian Institutions; C. Pitts – Penn State; D. Pfeiffer – Virginia Tech; L. Ferguson, B. Teviotdale, M. McGiffen – University of California.

**b.** **Objective:** To present the overall results of IPM CRSP-supported activity in Albanian olives to scientists, USAID mission personnel, Ministry of Agriculture and Food, and agricultural representatives.

**c.** **Hypothesis:** Presentation of the results of IPM research will allow a more complete understanding of the benefits to Albanian agriculture resulting from the investment by the USAID mission.

**d.** **Description of research activity:** A full-day session will be arranged in Tirana, in which time will be spent on each of the multi-disciplinary projects. A review of the baseline biological monitoring will be presented, as well as a summary of the baseline survey of olive producers. A summary of the specific IPM research will be presented on the following topics: harvest timing and its effects on olive fruit fly infestation and olive oil yields and quality; organic methods of vegetation management and olive insect control; effects of pruning on olive production; infestation by black scale and the incidence of olive knot and timing of copper sprays to control leaf spot and olive knot; and pheromone-based IPM in olive and effects on non-target species. After the specific projects are related, a summary of the economic aspects will be presented. This will emphasize long-term economic benefits allowed by our projects' results. Appropriate stakeholders in Albania will be invited to attend.

**e.** **Justification:** As we develop the case for further support of IPM CRSP research, it is imperative that we have transmitted a clear understanding of the economic benefit of our IPM research. This symposium will allow the results of all of our projects to be presented together, allowing a more complete context for evaluation of impact.

**f.** **Relationship to other research activities at the site:** This symposium will summarize the results of our several years of research in the several projects.

**g.** **Progress to date:** New project

**h.** **Projected outputs:** Papers and presentations to research community and policy makers

**i.** **Projected impacts:** (1) Improved support of proposed new research activities; (2) Improved knowledge supporting other research and policy considerations.

**j.** **Project start:** September 2003

**k.** **Projected completion:** September 2004

**l.** **Projected person-months of scientists time per year:** 3

**m.** **Budget:** Including carryover funds: $10,162 – Albanian institutions; $10,216 – Virginia Tech. **Year 11 only**: $7,422 – Albanian institutions; $5,785 – Virginia Tech.

## III.2 Farmer schools

**a.** **Scientists:** J. Tedeschini, H. Pace, B. Stamo, V. Jovani, B. Huqi, Sh. Shahini, R. Uka, M. Hasani, F. Thomaj, M. Bregasi, M. Baci, Dh. Panajoti, H. Ismaili, B. Ferraj, Z. Veshi – Albanian Institutions.

**b.** **Status:** Farmer schools have been previously held to present our research. The schools this year will present a broader perspective, and will allow a broader view of our research results. With the perspective of four years' of experience, we can make more well-founded recommendations.

c. **Objectives:** To present appropriate IPM technologies and concepts to Albanian olive growers.

d. **Hypothesis:** Presentation of our projects, emphasizing the successes and presenting the economic benefits will support adoption of our results by growers.

e. **Description of research activity:** Less formal versions of the olive IPM symposium will be presented in several key areas in the Albanian olive-producing region. The same overall framework will be provided; the technical aspects will be adjusted for farmer audiences, rather than the scientist/academic/governmental audience of the symposium.

f. **Justification:** Potential economic benefits of our IPM CRSP research have been projected. In order to accomplish these significant benefits, the degree of control and the economic impacts must be presented to the growers.

g. **Relationship to other research activities at the site:** This project presents information on the profitability of IPM strategies developed by the IPM CRSP scientists.

h. **Progress to date:** There have been several farmer schools supported by our project over the course of our activity. This projected educational series will present our results with a broader perspective.

i. **Projected outputs:** The profitability of IPM components and packages will be estimated and reported in papers and presentations to the research community and policy makers in Albania

j. **Projected impacts:** Better decision making among olive producers regarding appropriate IPM technologies and likely on-farm impacts.

k. **Project start:** September 2003

l. **Projected completion:** September 2004

m. **Projected person-months of scientists time per year:** 3

n. **Budget:** Including carryover funds: $3,000 – Albanian institutions; $0 – Virginia Tech.
**Year 11 only:** $2,474 – Albanian institutions

## Site Activity Summary – Albania – Year 11

| ACTIVITY | SCIENTISTS | BUDGET ($) |
|---|---|---|
| **I. Participatory Appraisal and Baseline Survey** | | |
| I.1. A participatory appraisal for IPM in Albanian greenhouse tomatoes and cucumbers, and vineyards, and associated baseline survey | While specific individuals are yet to be decided, it is anticipated that there will be four each from the Agricultural University of Tirana (AUT) and the Plant Protection Institute (PPI), and two each from Fruit Tree Research Institute (FTRI) and the Vegetable and Potato Institute (VPI). From the American side, three each from University of California and Virginia Tech, and two from Penn State | Including carryover funds: $18,362 – Albanian institutions; $8,299 – Penn State; $12,033 – University of California; $10,918 – Virginia Tech. Year 11 only: $10,396 – Albanian institutions; $5,089 – Penn State; $5,292 – University of California; $5,363 – Virginia Tech |
| **II. Termination of multi-disciplinary projects in olive [Mainly costs associated with harvest, olive oil analysis (Nov-Dec)]** | | |
| II.1. Effect of Harvest Timing on Olive fruit fly Infestation and Olive Oil Yields and Quality | D. Pfeiffer – Virginia Tech; F. Thomaj, M. Bregasi, J. Tedeschini, D. Panajoti, B. Ferraj – Albanian institutions; L. Ferguson – University of California; C. Pitts – Penn State | Including carryover funds: $4,200 – Albanian institutions; $ 0 – Penn State; $ 0 – University of California; $0 – Virginia Tech. Year 11 only: $3,000 – Albanian institutions |
| II.2. Organic Pest and Vegetation Management | J. Tedeschini, B. Stamo, H. Pace, B. Huqi, Sh. Shahini, Dh. Panajoti, H. Ismaili, M. Baçaj – Albanian institutions; M. McGiffen and L. Ferguson - Univ. of California | Including carryover funds: $2,762 – Albanian institutions; $0 – University of California; $0 – Penn State; $0 – Virginia Tech. Year 11 only: $2,179 – Albanian institutions |
| II.3. Pheromone-Based IPM in Olive and Effects on Non-Target Species | R. Uka, E. Isufi, J. Tedeschini, M. Baci – Albanian institutions; D. Pfeiffer – Virginia Tech | Including carryover funds: $4,200 – Albanian institutions; $0 – Penn State; $0 – University of California; $0 – Virginia Tech. Year 11 only: $3,000 – Albanian institutions |

| **III. Technology Transfer** | | |
|---|---|---|
| III.1. Olive IPM Symposium | J. Tedeschini, H. Pace, B. Stamo, V. Jovani, B. Huqi, Sh. Shahini, R. Uka, M. Hasani, F. Thomaj, M. Bregasi, M. Baci, Dh. Panajoti, H. Ismaili, B. Ferraj, Z. Veshi – Albanian Institutions; C. Pitts – Penn State; D. Pfeiffer – Virginia Tech; L. Ferguson, B. Teviotdale, M. McGiffen – University of California | Including carryover funds: $10,162 – Albanian institutions; $10,216 – Virginia Tech. Year 11 only: $7,422 – Albanian institutions; $5,785 – Virginia Tech |
| III.2. Farmer schools | J. Tedeschini, H. Pace, B. Stamo, V. Jovani, B. Huqi, Sh. Shahini, R. Uka, M. Hasani, F. Thomaj, M. Bregasi, M. Baci, Dh. Panajoti, H. Ismaili, B. Ferraj, Z. Veshi – Albanian Institutions | Including carryover funds: $3,000 – Albanian institutions; $0 – Virginia Tech. Year 11 only: $2,474 – Albanian institutions |

## YEAR 11 WORKPLAN FOR THE EASTERN AFRICA SITE IN ERITREA

Year 11 IPM CRSP activities in the eastern African site in Eritrea will focus on integrated studies of three crops: sorghum, tomato and chili pepper. Sorghum activities will focus on *Striga* management, assessment of varieties showing promise for resistance to insect pests and diseases, management of sorghum diseases, and monitoring of stemborer populations. Since tomato and chili pepper are both solanaceous crops and are often planted in the same fields in Eritrea, they are combined under a second integrated activity. Crop/pest monitoring of tomato and pepper will be an important activity since no research has been conducted on these two crops in Eritrea up to this point. Leafminers and whiteflies are serious pests of tomato, and therefore a study on IPM possibilities for these pests is included. Finally, isolates of pathogens of these two crops will be collected for identification and to enable development of viable control options.

The IPM CRSP research team in Eritrea is composed of scientists from the Ministry of Agriculture, Government of Eritrea, and Virginia Tech. Those from the Ministry of Agriculture include Asmelash Wolday (plant pathologist), Goitom Gobezai (weed scientist), Kidane Negassi (entomologist), and Dawit Solomon (plant pathologist). From Virginia Tech are Greg Luther (entomologist) and Herman Warren (plant pathologist). Asmelash Wolday is the Site Coordinator and Greg Luther is the Site Chair.

Some of the activities proposed below are continuing activities from the research conducted in 1996-97. After that, research halted due to the war with Ethiopia. We hope to conclude these activities while starting several new ones that have the purpose of positioning us to obtain funding for the future.

In May 2003, Greg Luther, Herman Warren and Asmelash Wolday met with Michael Wyzan and Mussie Hadgu at the USAID-Eritrea Mission to discuss IPM CRSP. The activities detailed below fit well with Mission priorities. To be specific, Wyzan said our planned IPM CRSP activities for Eritrea would fit into Strategic Objective 661-002: Increased Income of Enterprises, Primarily Rural, with Emphasis on Exports; Intermediate Result: Rural, Small and Medium Enterprises Developed; IR: Capacities Strengthened in Public and Private Sectors; and Lower Level IR: Improved and More Sustainable Practices Adopted by Horticultural and Livestock Producers. Wyzan said these are presently in revision, but this is what he estimated the final language would be.

Wyzan and Hadgu said, when deciding which agricultural activities to fund, the Mission usually follows the requests made by the Eritrean Ministry of Agriculture. A recent request made by the Minister to USAID/USDA to provide experts to Eritrea included a Weed Scientist and a Pesticide Specialist. IPM CRSP activities are in line with these priorities since various activities detailed below deal with weed problems in sorghum, tomato and chili pepper, while all activities deal with either developing alternatives to pesticides or elucidating agroecological aspects of these cropping systems so that pesticide use can be minimized. Thus, most or all of our activities would fit into the category of positioning the site for the future (for the possibility of obtaining funding so IPM CRSP activities in Eritrea can continue beyond Year 11).

IPM CRSP work in Eritrea for Year 11 will be entirely funded by Mission funds (leftover from a training project initiated in the mid-90s). No carryover funds from previous years are included in this year's budget. No biotechnology activities are included in the Year 11 work plan.

## I. Integrated Management of Sorghum Insect Pests, Diseases and Weeds

### I.1. Integrated *Striga* Management for the Lowlands of Eritrea

**a.** **Scientists**: G. Gobezai, A. Wolday – Eritrean Ministry of Agriculture; H. Warren, G. Luther – Virginia Tech; G. Ejeta – Purdue University

**b.** **Status**: Continuing

**c.** **Objectives**: (1) To develop appropriate and cost effective *Striga* management strategies for small scale subsistence farmers in Eritrea. (2) To train an Eritrean weed scientist on *Striga* management technologies.

**d.** **Hypothesis**: Application of nitrogen fertilizer, row planting and intercropping with a legume (soybean) will reduce infestation of the parasitic weed, *Striga hermonthica*, on sorghum. As a result, sorghum grain yield will increase.

**e.** **Description of Research Activity**: *Striga* infested plots will be identified in four farmers' fields in the lowlands of Eritrea. This experiment will use an RCBD. Each farmer's field will be considered as a block/replication. Three treatments and a control will be planted: (1) Row planting of sorghum in monoculture; (2) Same as treatment 1 with nitrogen fertilizer; (3) Row planting of sorghum in polyculture with soybean (2 rows of sorghum and 1 row of soybean), with nitrogen fertilizer; (4) Control: broadcast sorghum monoculture with no nitrogen fertilizer. Plots of 500$m^2$ (20x25m) will be used. Nitrogen fertilizer will be applied at each location according to the recommendations for that location. All plots will be hand weeded once of all weed species except *Striga*. The following data will be recorded: dates of planting, emergence, and flowering; panicle size; stand count of sorghum; *Striga* count when sorghum is knee-height and before flowering (of sorghum); plant height and grain yield of sorghum and soybean. An Eritrean weed scientist will visit Purdue University for one month to train on integrated weed management of *Striga*. The main trainer will be Dr. Gebisa Ejeta.

**f.** **Justification**: These management practices are economically feasible for smallholder farmers in Eritrea, and therefore have the potential to increase their sorghum yields in a cost effective manner. In addition, soybean is beneficial to soil fertility and is an important source of protein for farm families and other consumers. Soybean has been shown to stimulate *Striga* germination but then cause suicide of the *Striga* since it cannot parasitize the soybean. No Eritrean scientist has ever received formal training on *Striga* management. The training proposed herein, therefore, meets a definite need in human resource capacity for Eritrea. Dr. Gebisa is highly qualified to conduct this training that will meet the specific needs of Eritrea.

**g.** **Progress to date**: Emergence of the parasitic weed, *Striga hermonthica*, was reduced when sorghum was intercropped with soybean, received application of nitrogen fertilizer (Urea) and row planted in the 1998 cropping season. The application of these practices reduced the weed emergence by 95% and increased grain yield of sorghum by 46%.

**h.** **Project Outputs**: (1) Sorghum farmers may have enhanced *Striga* management schemes. (2) Scientist trained in IWM of *Striga*.

**i.** **Project Impacts**: (1) None as yet, but if treatments are successful, sorghum farmers may have cost effective means to manage *Striga*. (2) Human resource capacity for managing *Striga* in Eritrea will be raised.

**j.** **Project Start**: August 1998 but stopped over the past four years due to the war.

**k.** **Project Completion**: September 2004

**l.** **Projected Person-Months of Scientists Time per Year**: 7

**m.** **Budget**: $9,002 – Eritrean Ministry of Agriculture; $5,103 – Purdue University; $639 – Virginia Tech

## I.2. Assessment of Advanced Sorghum Varieties for Resistance to Diseases, *Striga* and Insects in the Lowlands and Highlands

**a.** **Scientists**: A. Wolday, G. Gobezai, K. Negassi, D. Solomon – Eritrean Ministry of Agriculture; G. Luther, H. Warren – Virginia Tech

**b.** **Status**: New

**c.** **Objective**: To evaluate sorghum varieties with enhanced level of resistance toward sorghum diseases, *Striga* weeds and insects in the lowlands and highlands of Eritrea.

**d.** **Hypothesis**: Sorghum varieties with enhanced level of resistance will depress diseases, *Striga* and insects and, as a result, improved sorghum grain yield will be obtained.

**e.** **Description of Research Activity**: Six advanced sorghum varieties and one control that have shown promising results in Golij Research Station will be tested for their resistance against sorghum diseases (leaf blight, rust, anthracnose and other diseases that may arise), insect pests (aphids, stemborers, midges, chafer beetles and other insects that may arise) and *Striga* weeds in the lowland and highland zones.

**f.** **Justification**: This management practice is cost effective, environmentally safe and economically feasible for small scale farmers to improve their production and productivity.

g. **Progress to date**: Infestation levels of diseases and insect pests differed on some other varieties tested in the 1997 cropping season. However, the sorghum varieties to be tested in this activity are new varieties.

h. **Project Outputs**: Determination of resistance among six new varieties of sorghum that have already shown promising results. As a result, increased sorghum yield will be obtained.

i. **Project Impacts**: (1) Small scale subsistence farmers who are suffering from high disease and insect damages can benefit from this trial. (2) Possible reduction of pesticide use due to farmers planting resistant varieties.

j. **Project Start**: June 2003

k. **Project Completion**: September 2004

l. **Project Person-Months of scientists time per year**: 7

m. **Budget**: $7,161 – Eritrean Ministry of Agriculture; $3,831 – Virginia Tech.

**I.3. Study and Characterization of Major Diseases on Sorghum in Eritrea**

a. **Scientists**: A. Wolday, D. Solomon – Eritrean Ministry of Agriculture; H. Warren – Virginia Tech

b. **Status**: New

c. **Objective**: To study and identify the races/patho-types of the major diseases of sorghum in Eritrea (leaf blight, rust and anthracnose).

d. **Hypotheses**: (1) The sorghum varieties used are genetically different in the highlands and lowlands. (2) The environmental conditions in Eritrea differ because of altitude, temperature and rainfall patterns. (3) Different races of the major diseases of sorghum exist in the highlands and lowlands in Eritrea.

e. **Description of Research Activity**: This activity will be carried out in the greenhouse at the Halhale Research Center, and through field surveys.

f. **Justification**: This practice is cost effective, environmentally safe and economically feasible to improve sorghum production and productivity. There is a need to evaluate the major diseases in these different environments.

g. **Progress to date**: new activity

**h.** **Project Outputs**: (1) Develop knowledge of sorghum pathogens that will lead to creation of resistant varieties of sorghum. (2) Reduce the damage from diseases resulting in increased grain quality and sorghum yield.

**i.** **Project Impacts**: Small scale subsistence farmers who are suffering from high disease damage could benefit from this trial.

**j.** **Project Start**: June 2003

**k.** **Project Completion**: September 2004

**l.** **Project Person-Months of scientists time per year:** 7

**m.** **Budget**: $9,564 – Eritrean Ministry of Agriculture; $383 – Virginia Tech.

## I.4. Monitoring Seasonal Activity of Adult Stemborer (*Chilo* sp.) Populations Utilizing Pheromone Traps in the Lowlands

**a.** **Scientists**: K. Negassi, A. Wolday – Eritrean Ministry of Agriculture; G. Luther – Virginia Tech

**b.** **Status**: New

**c.** **Objective**: To monitor the activity of adult stemborer populations in the lowland zones of Eritrea.

**d.** **Hypothesis**: Stemborer populations differ according to season and time of year in the Eritrean lowlands.

**e.** **Description of Research Activity**: This activity will be carried out in lowland zones to monitor the activity of adult stemborer populations using pheromone traps. These traps will be placed at regular intervals in major sorghum growing regions in the lowlands. Counts will be made regularly to determine population dynamics.

**f.** **Justification**: Pheromone trapping will elucidate population dynamics of the stemborer, *Chilo* sp., in the lowlands. This will enhance our ability to time control measures more efficiently, which will, in turn, make control of this insect in sorghum more cost effective and reduce insecticide use.

**g.** **Progress to date**: new activity

**h.** **Project Output**: (1) Helps to create annual control plan/scheme and IPM measures for stemborers. (2) Increases knowledge of ecology of *Chilo* sp. in the Eritrean lowlands.

i. **Project Impacts**: Small scale subsistence sorghum farmers who are suffering from high stemborer damages can benefit from this trial.

j. **Project Start**: June 2003

k. **Project Completion**: September 2004

l. **Project Person-Months of scientists time per year:** 7

m. **Budget**: $4,972 – Ministry of Agriculture; $3,831 – Virginia Tech.

## II. Integrated Management of Tomato and Chili Pepper Insect Pests, Diseases and Weeds

### II.1. Monitoring of Crop Pests and their Natural Enemies in Tomato and Pepper Cropping Systems

a. **Scientists:** A. Wolday, G. Gobezai, K. Negassi, D. Solomon – Eritrean Ministry of Agriculture; H. Warren, G. Luther – Virginia Tech

b. **Status:** New project

c. **Objectives:** (1) Determine incidence, seasonality, and abundance of pests and natural enemies; (2) Determine damage levels; (3) Determine parasitism rates of major insect pests; (4) Identify species and initiate reference collection of pests and natural enemies; (5) Determine the major weed species dominant in tomato and chili pepper; and (6) Determine differences or similarities in weed species and growth patterns in tomato and pepper cropping systems.

d. **Hypotheses:** (1) Pest and natural enemy population fluctuations affect crop production in tomato and pepper cropping systems; (2) Weed species and growth patterns are affected by the vegetable cropping system.

e. **Description of research activity:** Monitoring will be carried out in farmers' fields in the western lowlands, eastern lowlands and the highlands. Weed, insect pest, disease and nematode monitoring will be carried out over a large number of fields at one-month intervals. Insect pests and natural enemy populations will be monitored by direct counts/sweep-net sampling/pitfall traps/water traps/ colored sticky traps, etc. Parasitism rates will be determined by collection of eggs, larvae and pupae and rearing in the laboratory. Crop damage will be estimated by direct counts or by using a scoring scale. Disease levels will be monitored using appropriate scoring scales. On tomato, the following pest species will be sampled: bollworm, whiteflies, aphids, leafminer (*Liriomyza*), early blight, late blight, downy mildew, powdery mildew, bacterial wilt, viruses, *Orobanche*, *Dodder*, *Stramorium*, *Oxygonum* sp. and any others that arise. On pepper, the following pest species will be sampled: bollworm, whitefly, downy mildew, powdery mildew, anthracnose, bacterial wilt, *Orobanche*, *Dodder*, *Stramorium*, *Oxygonum* sp. and any others that arise.

Several representatives of each pest and beneficial will be preserved in a reference collection. The weed species composition, density, distribution and biomass will be identified and determined using a quadrat sampling system in farmers' fields. Weed counts and fresh weight will be recorded by species.

**f.** **Justification:** The pest and natural enemy complex in tomato and pepper cropping systems is little understood. It is important to understand the seasonal fluctuations of pests and natural enemies and their association as it will lead to the identification of research issues and priorities for solving pest problems in these systems. Weeds reduce yield of vegetables and contribute to increased production cost. In the development of a weed management strategy, the first step is to know the weeds and their infestation levels and seasonal patterns in a particular crop.

**g.** **Relationship to other research activities at the site:** The study will help in prioritizing research in other IPM CRSP activities. It will also help us to distinguish which problems are major and which are minor.

**h.** **Progress to date:** New project

**i.** **Projected outputs:** (1) Improved knowledge of key pests, population fluctuation patterns and associations between pests and their natural enemies; (2) Parasite-host relationships between parasitic weeds and host crops; (3) Identified pests and natural enemies, and reference collection initiated; (4) Improved understanding of the role of natural enemies in pest management.

**j.** **Project impacts:** Effective control strategies for weeds, diseases and insect pests will be developed from data generated from this study.

**k.** **Project start:** July 2003

**l.** **Projected completion:** September 2004

**m.** **Projected person-months of scientist time per year:** 31

**n.** **Budget**: $7,480 – Ministry of Agriculture; $3,831 – Virginia Tech.

## II.2. Tomato IPM Technology Development

**a.** **Scientists**: K. Negassi, A. Wolday – Eritrean Ministry of Agriculture; G. Luther – Virginia Tech

**b.** **Status**: New

**c.** **Objective**: To elucidate effective intercropping and cultural control IPM strategies for leafminers and whiteflies on tomato in Eritrea.

**d.** **Hypotheses**: (1) That an onion intercrop will reduce leafminer and whitefly numbers on tomato; (2) That use of a portable sticky trap will reduce whitefly and leafminer numbers on tomato.

**e.** **Description of Research Activity**: This experiment will test the following intercropping and cultural control treatments: (1) Tomato intercropped with onion; (2) Use of a portable sticky trap on monoculture tomato; (3) Control: monoculture tomato with no portable sticky trap. Leafminers, whiteflies and possibly other pests will be sampled on tomato. Major predatory species will also be sampled. Plot size will be at least 10x10m. A RCBD with at least 4 replications will be used. This experiment will be conducted two seasons during Year 11.

**f.** **Justification**: Many studies have shown that intercropping will reduce pest numbers, particularly if the intercrop is a non-host plant of the pest. The portable sticky trap has been shown to be a successful whitefly control measure on tomatoes by scientists at the IPM CRSP / Guatemala site.

**g.** **Progress to date:** New activity

**h.** **Project Output**: Technologies developed that help reduce costs and insecticide use for controlling leafminers, whiteflies and possibly other pests on tomato.

**i.** **Project Impacts**: If successful: (1) reduced insecticide use on tomato; (2) higher profits for tomato growers.

**j.** **Project Start**: October 2003

**k.** **Project Completion**: September 2004

**l.** **Projected Person-Months of scientists time per year:** 7

**m.** **Budget**: $3,729 – Eritrean Ministry of Agriculture.

## II.3. Collection of Isolates of Pathogens of Chili Pepper and Tomato

**a.** **Scientists**: A. Wolday, D. Solomon – Eritrean Ministry of Agriculture; H. Warren – Virginia Tech

**b.** **Status**: New

**c.** **Objective**: To study and identify the races/patho-types of the major diseases of tomato and pepper in Eritrea (early blight, late blight, powdery mildew, downy mildew and bacterial wilt).

**d.** **Hypotheses**: (1) The tomato and pepper varieties used are genetically different in the highland and lowland. (2) The environmental conditions in Eritrea differ because of altitude, temperature and rainfall patterns. (3) Different races of the major diseases of tomato and pepper exist in the highland and lowland in Eritrea.

**e.** **Description of Research Activity**: This activity will be carried out in the greenhouse at the Halhale Research Center, and through field surveys.

**f.** **Justification**: This is a need to evaluate the major diseases in the different environments.

**g.** **Progress to date**: new activity

**h.** **Project Outputs**: (1) Develop knowledge of tomato and pepper pathogens that will lead to creation of resistant varieties of these crops. (2) To reduce the damage from diseases resulting in increased tomato and pepper quality and yield.

**i.** **Project Impacts**: Small scale subsistence farmers who are suffering from high disease damage could benefit from this trial, because this activity will enable development of better control methods.

**j.** **Project Start**: July 2003

**k.** **Project Completion**: September 2004

**l.** **Project Person-Months of scientists time per year:** 7

**m.** **Budget**: $3,267 – Eritrean Ministry of Agriculture.

**GENERAL SITE FUNDS**: Eritrean Ministry of Agriculture - $ 6,490; Virginia Tech - $1,022

## Site Activity Summary – Eritrea – Year 11

| ACTIVITY | SCIENTISTS | BUDGET ($) |
|---|---|---|
| **INTEGRATED MANAGEMENT OF SORGHUM INSECT PESTS, DISEASES AND WEEDS** | | |
| I.1. Integrated *Striga* Management for the Lowlands of Eritrea | Goitom Gobezai, Asmelash Wolday – Eritrean Ministry of Agriculture; Herman Warren, Greg Luther – Virginia Tech; Gebisa Ejeta – Purdue University | Min. of Ag. $ 9,002<br>VA Tech $ 639<br>Purdue $ 5,103 |
| I.2. Assessment of Advanced Sorghum Varieties for Resistance to Diseases, *Striga* and Insects in the Lowlands and Highlands | Asmelash Wolday, Goitom Gobezai, Kidane Negassi, Dawit Solomon – Eritrean Ministry of Agriculture; Greg Luther, Herman Warren – Virginia Tech | Min. of Ag. $ 7,161<br>VA Tech $ 3,831 |
| I.3. Study and Characterization of Major Diseases on Sorghum in Eritrea | Asmelash Wolday, Dawit Solomon – Eritrean Ministry of Agriculture; Herman Warren – Virginia Tech | Min. of Ag. $ 9,564<br>VA Tech $ 383 |
| I.4. Monitoring Seasonal Activity of Adult Stem Borer (*Chilo* sp.) Populations Utilizing Pheromone Traps in the Lowlands | Kidane Negassi, Asmelash Wolday – Ministry of Agriculture; Greg Luther – Virginia Tech | Min. of Ag. $ 4,972<br>VA Tech $ 3,831 |
| **INTEGRATED MANAGEMENT OF TOMATO AND CHILI PEPPER INSECT PESTS, DISEASES AND WEEDS** | | |
| II.1. Monitoring of Crop Pests and their Natural Enemies in Tomato and Pepper Cropping Systems | Asmelash Wolday, Goitom Gobezai, Kidane Negassi, Dawit Solomon – Ministry of Agriculture; Herman Warren, Greg Luther – Virginia Tech | Min. of Ag. $ 7,480<br>VA Tech $ 3,831 |
| II.2. Tomato IPM Technology Development | Kidane Negassi, Asmelash Wolday – Ministry of Agriculture; Greg Luther – Virginia Tech | Min. of Ag. $ 3,729 |
| II.3. Collection of Isolates of Pathogens of Chili Pepper and Tomato | Asmelash Wolday, Dawit Solomon – Ministry of Agriculture; Herman Warren – Virginia Tech | Min. of Ag. $ 3,267 |