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Seventh Annual Report
Overview of the African Site in Uganda

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The Collaborative Program

The IPM CRSP Uganda Site is a collaboration of Makerere University Faculty of Agriculture (MU/FA), the Ugandan National Agricultural Research Organization (NARO), the Ministry of Agriculture, Animal Industries and Fisheries Extension Service, participating farmer NGO groups and scientists from IPM CRSP US Institutions. The program in Uganda operates under a Memorandum of Understanding with Makerere University Faculty of Agriculture (MU/FA). The in-country Site Coordinator located at MU/FA is Dr. S. Kyamanywa, Chairman of the Crop Science Department. He is directly linked to NARO through the Deputy Site Coordinator who is appointed by Dr. Joseph Mukiibi, the Director General of NARO. This past year, Dr. JJ Hakiza temporarily replaced Dr. Bigirwa as the Deputy Site Coordinator, while Dr. Bigirwa was on an alternative assignment. The IPM CRSP collaborates with research scientists at three NARO research institutes and one sub-station: Kwanda Agriculture Research Institute (KARI), Namulonge Agricultural and Animal Research Institute (NAARI), Serere Agricultural and Animal Research Institute (SAARI) and the Kalengyere Potato Research sub-station.

During this past year, the IPM CRSP team in Uganda consisted of 5 co-PIs and 4 graduate students from MU/FA, 8 co-PIs from NARO, and 2 extension agents, representing 9 separate disciplines. In addition, there were seven USA-based co-PIs, from 3 universities: The Ohio State University, Virginia Tech, and Fort Valley State University. A Ugandan co-PI and a Ugandan graduate student also participated in short-term (2 month) training programs in the United States: one at Virginia Tech and one at The Ohio State University Agricultural Research and Development Center. The Site Chair, Dr. Mark Erbaugh, The Ohio State University, coordinates this multi-institutional and disciplinary program. The Site Chair and Coordinator maintain weekly contact and all co-PIs are encouraged to maintain communication with their respective collaborators on individual research activities.

The Site Coordinator administers field research activities with local co-PIs and extension agents. Under a newly reorganized, decentralized Extension System, extension agents report directly to local government officials but rely on NARO and Makerere scientists for assistance in conducting on-farm research and specialized technology transfer activities. Although additional extension agents have been utilized for several activities, the Uganda Site mainly relies on two extension agents to manage scientists and graduate student contacts with 6 participating farmer NGO groups.

There are two NGOs each at research sites in Iganga and Kumi Districts, and an informal grouping of tomato growers in Mpigi District. A pilot IPM farmer field school was conducted with a new NGO group in Kumi District this year. Maintaining direct links between scientists and farmers and providing farmers with direct feedback from research activities has been greatly facilitated by extension agents and NGO groups. This remains a constant challenge, however, requiring innovative approaches that merge research activities with information sharing and farmer technology assessment.

Planning and implementation of Uganda Site activities has emerged into a pattern that roughly mirrors the annual calendar of IPM CRSP project events. These activities seek to maximize interdisciplinary and multi-institutional collaboration and provide consistent contact between Site managers and collaborating co-PIs. An addition to this pattern was the bi-annual meeting of the African Crop Science meetings held in Morocco in mid-October. Six papers were presented at this meeting by IPM CRSP Uganda Site co-PIs and graduate students. Two USA-based Uganda Site co-PIs attended this meeting. A meeting of 17 Uganda Site co-PIs and graduate students and 6 USA-based co-PIs was held in Jinja, on March 9-10, to present brief progress reports, discuss priorities for the next year, and to develop draft work plans for Year 8. Immediately following this meeting, USA co-PIs traveled to respective research sites to discuss and plan implementation of trials prior to the beginning of the first rainy season. The Year 8 draft was discussed with two Deputy Director Generals of NARO, USAID/Kampala, and the Chief of Party of the USAID funded Investing in Developing Export Agriculture Project (IDEA). A final draft of the work plan and budget was then presented at the IPM CRSP Annual Meeting, held at Virginia Tech in May, 2000. A final event in the annual calendar was the Annual Report Preparation Meeting held in Entebbe in mid-September. The purpose of this meeting was to motivate co-PIs to analyze data from the previous two growing seasons; to initiate annual report preparations; and to discuss journal article preparation and submission. At this meeting 21 draft papers were presented to the 16 co-PIs and graduate students in attendance. These two general meetings helped integrate research findings, expose research to multi-disciplinary perspectives, and provide an opportunity for discussions of general program implementation. Research activity trials are implemented during the two rainy seasons: the longer rainy season roughly extends from April through early July, and the short rains extend from October through December.

Planning and implementation of IPM CRSP activities in Uganda continues to involve communication and collaboration with USAID/Kampala, the IDEA Project, the Rockefeller Foundation through the Makerere University Legume Improvement Program, germplasm exchanges with IITA, CIP, ICRISAT, a USDA potato research program, and CIMMYT/Harare. Representatives from CIP and ICIPE were present at the work plan meeting held in Jinja. Research collaboration with ICIPE and the Rockefeller Foundation have provided opportunities to cost share graduate student activities at Makerere University. As an indication of USAID/Kampala's support of IPM CRSP efforts in Uganda, the Mission provided support funds to the IPM CRSP to manage a Technical Assistance research effort on coffee wilt (*Fusarium xylarioides*).

IPM Constraints Addressed

The primary IPM constraints addressed at the Uganda Site are : 1) poor linkages between research scientists and farmers that ensure research activities are driven by farmer demand and adapted to farmer socioeconomic conditions; 2) lack of alternatives to multiple applications of chemical pesticides, particularly for important legume crops such as groundnuts and cowpea in Eastern Uganda, but also for important horticultural crops including tomatoes and potatoes; 3) research fragmentation caused by insufficient integration of research activities of multiple institutions and disciplines; and 4) limited distribution and dissemination of IPM technologies.

In order to address these constraints the Uganda Site implemented a participatory approach to the conduct of IPM research. The initial field PA held with farmers at research sites in Iganga and Kumi Districts in 1995, and verified through the initial baseline survey, identified priority crops and pests. This helped orient research to solving farmer problems - demand driven activities. Subsequent activities including farmer field pest monitoring, farmer open days, and on-farm trials added to or amended pest and disease priorities. For example, farmer field pest monitoring activities indicated that the bean fly (*Ophiomyia* sp) was a critical yield reducing agent that prior to this activity was unrecognized by farmers. A survey of maize pests and diseases indicated that gray leaf spot (*Cercospora zeae-maydis*) was a seasonally important foliar disease and that termites (*Macrotermes*) were causing significant stand losses. Recently, the groundnut leaf miner (*Aproarema modicella* Deventer) and thrips (*Thrips palmi* Karny, *Frankliniella schultzie* Trybom, *Scirtothrips dorsalis* Hood, and *Caliothrips indicus*) were determined by farmers and scientists respectively, to be important pests on groundnuts. Researcher interactions with farmers also suggested component technologies that have been integrated into trials. Local farmers suggested the interplanting of *Celosia argentia* with sorghum, and the use of cotton in rotation, to reduce the incidence of striga; and, the use of several locally available bio-rational products in post-harvest storage to reduce bruchid damage.

The frequent use of chemical pesticides on cowpea and groundnuts was first documented during the initial PA and the latter two baseline surveys. On-farm trials have successfully demonstrated that a combination of cultural practices and three well-timed spray applications can reduce pesticide applications and farmer exposure to pesticides while maintaining yields. Intra-institutional cooperation has resulted in the incorporation of improved germplasm to reduce the incidence of major diseases on groundnuts, potatoes and tomatoes. Institutional cooperation has also been facilitated by the use of Makerere University graduate students to conduct field trials. ICIPE, NAARI's Biological Control Unit and Maize Research Team, Dr. H. Willson and Makerere University scientists combined to provide financial and technical support for MU graduate student, Ms. Teddy Kauma, to rear, release and monitor the introduced parasitoid *Cotesia flavipes*. Scientists from SAARI, MU, and the USA supervise MU graduate student Mr. Robert Opulot's work. Graduate student work on identifying insect pests of cowpea and timing of chemical spray applications has been supported by the Rockefeller Foundation and has been integrated into IPM CRSP work on cowpea.

The integration of various disciplines is still a work in progress. Team meetings, at which research work plans and results are discussed with a multi-disciplinary audience, provide a useful platform to exchange disciplinary perspectives. Interdisciplinary work has been greatly augmented by the integration of social science assessments of component IPM technologies for priority crops. The inclusion of co-PIs from various disciplines in PA activities, farmer open days and farmer trial assessments has helped expose biological scientists to the importance of including a farmer knowledge perspective into their own work. It has also helped generate demand for social science assessments in order to help ensure that trial design and technology development take into consideration farmers' social and economic constraints.

Research on strategies to disseminate IPM CRSP results to a broader farm audience has only recently been undertaken. Analyses of the follow-up baseline survey indicate that sole reliance on participatory activities, such as on-farm trials, may not result in rapid diffusion of most IPM technologies. Farmer open days appear to reach a broader audience, as have fact sheets. The IDEA Project has assisted in the printing and distribution of fact sheets on stalk borer, bean fly and gray leaf spot. This year the Uganda Site implemented a farmer field school on IPM management of groundnut and cowpea as a pilot effort to expand and intensify IPM training.

Regionalization of IPM CRSP activities has largely been promoted through the participation of co-PIs in regional fora including the All African Crop Science Society, the International Association for Farming Systems Research, the Rockefeller Forum, collaboration with ICIPE, and the Gray Leaf Spot Collaborative Network and Africa Link. Multi national and institutional collaboration to identify genetic resistance to gray leaf spot, the number one foliar disease of maize in the US corn belt, is the best example of IPM CRSP Uganda Site activities directly benefiting the USA.

Institution Building

The IPM CRSP Uganda Site has placed a great deal of emphasis on human resource development. Graduate student training at Makerere University has helped facilitate domestic and international institutional collaboration and has contributed to research output. Five Ugandan graduate students have completed or are in the final stages of completing their MS degrees. One of these students recently accepted a position with the CIAT program in Uganda. Two Ugandans spent 2-3 months in the USA receiving specialized training. Mr. Godfrey Asea spent several months at The Ohio State University Research Station (OARDC) conducting greenhouse inoculation experiments as part of the activity on gray leaf spot. Upon his return to Uganda he repeated his experiments and this has already led to submission of a journal article. Mr. Archileo Kaaya spent 2 months at Virginia Tech developing laboratory procedures for isolating and identifying fungal pathogens infecting maize and groundnuts. Application of these procedures upon his return to Uganda has again led to the submission of a journal article. In July, Ms. Jackline Bonabana, formerly from Makerere University, joined Virginia Tech to complete her M.S. degree in Agricultural Economics.

USA based co-PIs made eight trips to the Uganda Site this year. In early December, Dr. Luther worked with Dr. Kyamanywa and an undergraduate student to devise a field methodology for the identification of beneficials. The annual work plan development meeting held in Jinja, Uganda, March 9-10, was attended by Drs Gebrekidan, Erbaugh, Warren, Willson, Taylor and Bhagsari. While in Uganda at this time, Drs Warren, Willson, and Taylor provided special lectures to students at Makerere University, and Drs. Erbaugh and Willson helped design and inaugurate the Pilot farmer-training program. Dr. Erbaugh returned to Uganda in early September to Chair the Annual Report Preparation Meeting. Drs. Kyamanywa and Hakiza traveled to the USA to participate in the IPM CRSP Annual Conference held at Virginia Tech.

Networking

Networking in Uganda has already been described. It is facilitated by the functional links between the Site and Deputy Site Chairs and their respective organizations. These linkages are reinforced by courtesy visits made by USA based co-PIs, usually in the company of the Site Chair, to the Director General of NARO, to the Dean Faculty of Agriculture and to Directors of participating research institutes. Meetings with USAID/Kampala are also facilitated by these visits. Preliminary research results are presented by co-PIs at the two annual meetings held in Uganda. Two IPM CRSP Ugandan co-PIs presented their research findings to special symposia hosted by the IDEA Project. Visits by the Site Chair always include update meetings with USAID/Kampala and other USAID sponsored programs such as IDEA and ACDI/VOCA. Personnel from both the IDEA Project and ACDI/VOCA are well acquainted with the Site Chair and Coordinator and include them in meetings pertaining to IPM and pesticide regulatory compliance.

Regional networking is conducted via communication, research collaborations, and participation in professional societies and symposia. Formal research collaborations with ICIPE and the Rockefeller Foundation focus on mutual contributions to graduate student training and advising. Direct communication between Uganda co-PIs and USA co-PIs have resulted in germplasm exchanges with IITA, CIP, ICRISAT, a USDA potato research program, and CIMMYT/Harare. Regional representatives from CIP and ICIPE participated in this year's work plan development meetings. This year Uganda co-PIs and graduate students and USA based co-PIs presented papers at the All African Crop Science Society meetings held in Casablanca, Morocco. The IPM CRSP was the only CRSP represented at this meeting. Drs Willson and Kyamanywa and graduate student Teddy Kauma recently presented findings at the ICIPE hosted International Workshop and Conference on the Status and Advances in Biological Control of Cereal Stem Borers in Africa, held in Nairobi, Kenya. Additionally, Drs. Kyamanywa and Hakiza participated in the IPM CRSP Annual Conference held in Blacksburg, Virginia.

Research results are also disseminated through publications. This year there are eleven articles that have been accepted for publication and an additional six that have been submitted.

Selected Research Accomplishments

- *Cotesia flavipes* Cameron, a braconid parasitoid of *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae), was first released during the 1st rainy season of 1998 in Iganga and Kumi Districts in Eastern Uganda. Rearing of stem borers collected from maize sites in Iganga and maize/sorghum sites in Kumi during the 2nd rainy season 1999 and 1st rainy season 2000, found parasitism levels of *C. flavipes* on *C. partellus* to be 10.6% and 30.8% in Iganga, and 32.7% and 24.1% in Kumi, for the two seasons. This demonstrates establishment of *C. flavipes* in both districts. Dispersal of *C. flavipes* to sub-counties neighboring release sites has been demonstrated by parasitism levels equal to that observed in the sub-counties where the parasitoid was initially released.

- Past research by the IPM CRSP has confirmed the widespread distribution of Gray leaf spot (*Cercospora zeae-maydis*) in Uganda. Developing resistant varieties and enhanced understanding of the epidemiology of the disease are necessary to provide effective GLS management strategies. In order to more efficiently breed resistant germplasm, screening methods that do not rely on natural infection are needed. During a four-month study conducted at OARDC, Wooster, graduate student (Godfrey Asea, Makerere University) conducted inoculation experiments in order to develop an effective greenhouse assay. Four methods of inoculation were tested and a hypodermic injection method was determined to be as effective and less laborious than other methods.

  OSU graduate student, Stuart Gordon, continued quantitative trait locus (QTL) mapping studies in Ohio. Phenotypic disease reactions of segregating progenies from a resistant X susceptible cross were obtained from one location. Identification of simple sequence repeat (SSR) polymorphisms between the resistant and susceptible parents was continued, and approximately three-fourths of the genome is now covered by suitable markers. Preliminary analyses have identified one major resistance QTL that is consistent across U.S. and African tests.

  Stover (maize residue) is widely used in Central Uganda for mulching bananas. Planting a susceptible local variety LP16 in fields containing infested maize residue demonstrated that distance from residue source significantly affected foliar damage, but direction from the residue foci did not significantly affect disease level, nor was distance by direction interaction significant in both seasons and locations. However, residue level (percentage soil cover) by distance interactions were significant. Gray leaf spot severity, area under disease progress curves, and disease intercepts decreased with increasing distance from the inoculum source.

- Field and laboratory investigations were continued to examine the traditional practice of interplanting *Celosia argentia* (locally known as Striga chaser) with sorghum to control *Striga*. *Celosia argentia* reduced *Striga* emergence on sorghum by 61% and increased sorghum yield by 51% on average over the two seasons of this study compared to sole-cropped sorghum. The laboratory study revealed that *C. argentia* can induce suicidal germination of *Striga* seeds. Thus it can also be used in short-term fallows to reduce *Striga* seed numbers in the soil.

  An economic assessment of these striga control treatments using data from two seasons in 1999, indicates that all treatments involving the farmers' variety have negative net benefits. Only treatments involving the improved sorghum variety, Seredo, had positive net benefits.

  A third season rotation experiment was conducted in order to evaluate the effectiveness of rotating sorghum with trap crops (cowpea and cotton) to manage *Striga*. The accumulated evidence indicates that growing cowpea and cotton in sequence for two seasons before planting sorghum reduces *Striga* seed numbers in the soil by 77.5%. This indicates that use of trap crops in rotation with sorghum is an effective long-term management strategy of *Striga* in heavily infested fields.

- Farmers in Iganga District now rank termites (*Macrotermes*) as the second most important pest on maize. Local farmer knowledge indicated that predatory ant species might effectively control termites. An innovative biological control strategy for enhancing ant (*Lepisiota* sp.) activity was initiated in Year 6. This strategy called for the application of protein (powdered fish) or sugar-based (molasses) baits in maize fields to attract and concentrate ants in maize fields. The protein-based baits attracted significantly larger numbers of ants compared to molasses and resulted in greater ant nesting near maize plants. There was significantly higher termite damage in plots of maize without baits than those with baits. Maize yields in fish-treated plots were 36.2% higher than yields in control plots suggesting that ant predation was a major factor in reducing pest damage.

- In Year 6 the efficacy of using biorational products, solarization, and synthetic insecticides to control bruchid damage (*Acanthoscelides obtectus* and *Callosobruchus* spp) in stored beans and cowpea was compared. The most effective post-harvest treatments for beans in controlling damage were tobacco dust, Actellic, ash, and solarization. Solarization, tephrosia and tobacco were the most effective treatments for cowpea.

  In Year 7 an economic viability assessment of these same treatments was undertaken. This analysis indicated that wood ash, solarization, tephrosia, and tobacco provided economically viable post-harvest protection of beans and cowpeas for up to 3 months. The additional benefits from these controls were realized mainly as a result of higher returns from delayed marketing and/or sowable surplus or lower cost of grain protection. Although the economic analysis generally confirms the results of the biological analysis there were two important differences. First, admixing cowpeas with tobacco powder was viewed favorably from a biological perspective though this option was not found as economically viable. Conversely, treatment with wood ash did not appear to be very efficacious from a biological perspective but was preferred from an economic context because ash was valued at zero opportunity cost.

- At IPM CRSP research sites in Eastern Uganda, cowpea is the crop most likely to be sprayed frequently with chemical pesticides. Two pest management packages that integrate well timed insecticide spray applications (once each at budding, flowering and podding) with cultural practices including early planting, intercropping and/or manipulated plant densities, planting and/or cowpea/sorghum intercrop have been found to be effective in reducing insect pests on cowpea and increasing grain yield by over 90%.

  The economic injury level (EIL) for thrips (*Megalurothrips sjostedti*), one of the most important insect pests on cowpea, has been established at 12 thrips per flower. The relationship between thrips population density and cowpea grain yield loss has been demonstrated to be linear and negative.

- Controlling podding pests of cowpeas in the field was found to significantly reduce bruchid carryover in storage. There was a positive and significant relationship between pod damage by field pests (*Riptortus* spp., *Nezara viridula*, *Acanthomia* spp., *Anoplocnemis* and *Maruca* sp.) and bruchid infestation in storage. Use of botanicals and synthetic insecticides to control field podding pests resulted in reduced bruchid (*Callosobruchis chinesis*) infestation in storage.

- A great diversity of arthropod predators exists in the cowpea cropping system. An initial study indicates that lady bird beetles (*Coccinellidae*), ground beetles (*Carabidae*), Assassin bugs (*Reduviidae*), and spiders are the most prevalent predators; while members of *Braconidae*, *Chalcididae* and *Ichnumonidae* were among the common parasitoids. These natural enemies were most prevalent during the flowering and podding phases.

- Field trials on groundnuts have focused on developing an integrated pest and disease management package to control groundnut rosette virus disease, aphids (*Aphis craccivora* Koch the vector of rosette disease) and Cercospora leaf-spot (*Cercospora arachidicola*). Data indicate that an effective IPM package for groundnut would be comprised of a combination of cultural, host plant resistance and reduced pesticide usage. Recommended cultural practices would be early planting (after the on-set of rains), an intermediate plant density (45 x 15 cm^2), and the use of the rosette resistant variety Igola-1. An intermediate plant density is recommended because the highest plant density (330,000 plants/ha) had the lowest incidence of rosette while the lowest plant density (60,000 plants/ha) had the lowest incidence of Cercospora leaf spot. Marginal Rate of Return analyses indicate that spraying 2-3 times with pesticides was most efficacious. Spraying groundnut more than 3 times increased the severity of leaf miner damage. Twelve introduced genotypes from ICRISAT indicated consistent resistance to rosette and thirteen showed resistance to Cercospora leaf spot. In addition, a study launched this year established the importance of several new pests on groundnut including groundnut leaf miner (*Aroarema modicella*), foot rot (*Sclerotium rolfsii*) and thrips (*Thrips palmi* Karny, *Frankliniella schultzie* Trybom, *Scirtothrips dorsalis* Hood, and *Caliothrips indicus*).

- For three seasons, the main disease observed on tomatoes was late blight (*Phytophthora infestans*) and the main insect pest was thrips (*Thrips tabaci* and *Frankliniella* sp.). On-farm and station trials revealed that late blight is best controlled by two applications of Dithane M45 per week during heavy rains and one spray per week during dry spells. All fungicide treatments increased thrips populations by over 60% compared to the control. Use of cover crop (*Macroptilium atropurpureum*) had no impact on disease suppression; however, it suppressed weeds by 36-45%, and in combination with reduced fungicide treatments registered lower thrips infestations. The combination of pre-established cover crop mulch and baker's yeast provided the most effective control of thrips. Of the three bacterial wilt (*Ralstonia solanacearum)* tolerant varieties introduced, farmers indicate a preference for MT56 because of its heavier flowering and fruit setting.

- Potato late blight (*Phytophthora infestans*) is one of the most serious diseases hampering potato production in Uganda. Monitoring disease and spraying when essential (2 sprays) reduced the need for spray applications and was as effective as bi-weekly application of Dithane M45. Integrating host resistance, disease monitoring and then spraying, reduced pesticide application by >50% without causing yield loss.

- Mycotoxigenic moulds that were isolated and identified include *Aspergillus*, *Fusarium* and *Penicillium* species. They occurred in greater quantities in samples stored for 5-7 months than in newly harvested samples. In Kumi, 48% of the groundnuts stored 5-7 months and 28% of those newly harvested tested positive for aflatoxin. In Iganga, 50% of the groundnuts and 40% of the maize stored 5-7 months tested positive. No aflatoxins were found from newly harvested maize. Generally, positive samples had low levels of aflatoxins.

- CRSP activities are having a positive impact on knowledge and awareness of IPM and crop specific pest management practices among project participants in Eastern Uganda. A survey of 200 farmers at or near IPM CRSP research sites in Eastern Uganda was used to evaluate the impact of IPM CRSP activities to-date on farmers' knowledge and awareness of IPM and crop specific pest management knowledge. A one-way analysis of variance test indicated that as project participation increased so did knowledge of IPM. Mean scores on the IPM Knowledge Scale went up dramatically and significantly at each level of participation. The impact of project participation on knowledge of crop specific management practices, assessed using a t-test for equality of means, indicated that for each set of crop specific test questions, significant knowledge differences occured between non-participants and participants in IPM CRSP activities.

Using ex-ante economic surplus analysis to assess the aggregate benefits to the Ugandan economy of two IPM CRSP interventions demonstrates that the maize variety, longe-1, and seed dressing for beans give higher net returns than farmers' practices and that efforts should now turn to promoting further adoption of these two technologies.

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