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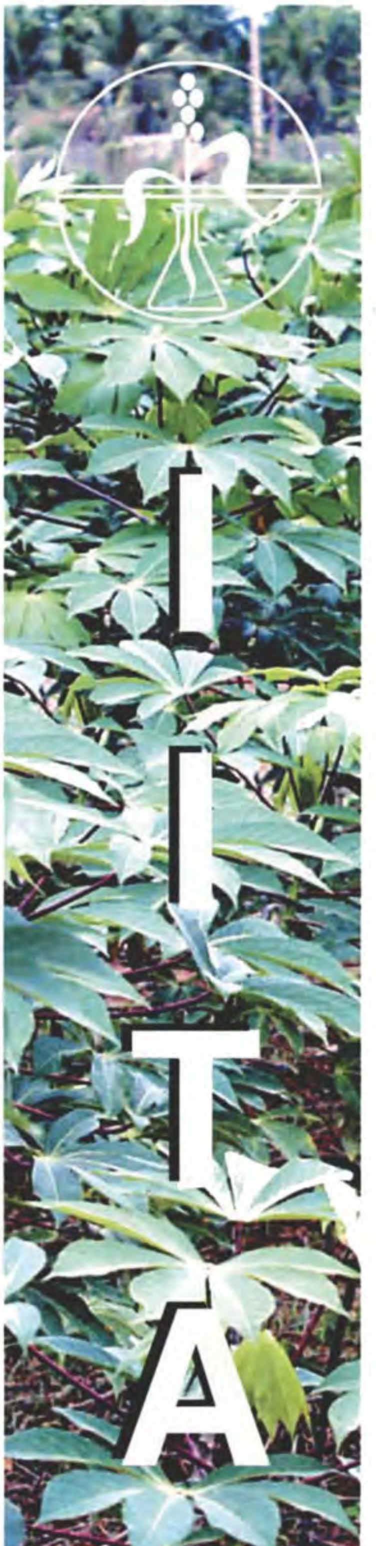
Annual Report



Plant Health Management Division

International Institute of Tropical Agriculture

About IITA

The International Institute of Tropical Agriculture (IITA) was founded in 1967 as an international agricultural research institute with a mandate for improving food production in the humid tropics and to develop sustainable production systems. It became the first African link in the worldwide network of agricultural research centers known as the Consultative Group on International Agricultural Research (CGIAR), formed in 1971.

IITA's mission is to enhance the food security, income, and well-being of resource-poor people, primarily in the humid and subhumid zones of sub-Saharan Africa, by conducting research and related activities to increase agricultural production, improve food systems, and sustainably manage natural resources, in partnership with national and international stakeholders. To this end, IITA conducts research, germplasm conservation, training, and information exchange activities in partnership with regional bodies and national programs including universities, nongovernmental organizations (NGOs), and the private sector.

The Plant Health Management Division (PHMD) of IITA is dedicated to the development of sustainable plant protection of primary food crops in Africa for the benefit of low-income people. The division's research philosophy is to identify the ecological imbalances in the system causing pest problems and to develop environmentally and economically appropriate solutions in collaboration with national programme partners. Research focuses on smallholder cropping systems, with emphasis on cassava, maize, plantain and banana, yam, cowpea and soybean.

PHMD which has staff in Benin, Nigeria, Uganda, Cameroon and Ghana is grateful for the support it receives through the CGIAR and from special projects as listed in this report.

For more information, please contact:
IITA Plant Health Management Division
Biological Control Center for Africa
08 B.P. 0932 Tri Postal
Cotonou, Republic of Benin
Fax: (229) 35 05 56
Tel: (229) 35 01 88, 35 06 00, 35 05 53
E-mail: iita-benin@cgiar.org
Web: www.cgiar.org/iita

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE
PLANT HEALTH MANAGEMENT DIVISION

ANNUAL REPORT 1999

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EDITORIAL NOTE

The 1999 PHMD Annual Report presents the research activities of the four PHMD-centered projects focusing on integrated management of pests, diseases, and parasitic weeds. In addition, three projects centered in CID, but having an important plant health management component, are also included, having a substantial contribution from the PHMD scientists involved. In these cases, the full rationale of the project is presented, but only PHMD activities are described in detail.

Each project is divided in three sections: project rationale, outputs, and completed studies. Activities are listed according to project outputs. The text of each project is self-contained, i.e. all acronyms are spelled out, except major donors (listed in the "Director's Report") and collaborating institutes (listed in the "Outreach" chapter). Latin names are given in full in the text of the main project dealing with the topic.

Scientific project staff is listed after the project title ('by'), followed by their research assistants ('assisted by'). To enable the reader to understand 'who is doing what', the initials of the respective scientists are repeated after each activity, together with major collaborators and students ('in collaboration with'). Students' names are marked with an asterisk and are listed in the "Outreach" chapter. Similarly, all collaborating scientists from universities and other research establishments are acknowledged in the list of collaborators. Also all donors are gratefully acknowledged.

The section on completed studies lists all the scientific papers that were submitted to, accepted by, or published in a journal or conference proceedings in 1999. A back-dated list of all publications by PHMD since 1995 is given at the end of "Achievements and Activities". Earlier publications by PHMD scientists can be found in the relevant IITA annual reports, and previous PHMD Annual Reports.

Given the number of the staff, no comprehensive data sets could be presented. For the benefit of all quarantine authorities, and particularly the Inter-African Phytosanitary Council in Yaoundé, Cameroon, however, lists of insects, mites, and pathogens received and those shipped out of Benin are given in full.

We would like to ask our readers not to cite this annual report as a publication, but to refer to the published papers presented and cited herein. Also we welcome your suggestions for improvements.

M. Tamò

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DIRECTOR'S REPORT

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IITA's structure as instrument for research and implementation

In 1999, the institutional and organisational arrangements for implementing the research agenda of IITA have been consolidated. The work plans of the cross-divisional and object–oriented projects have been revised, their focus sharpened, and the number of projects reduced in line with the reduced number of principal staff at IITA. Early in the year 2000, the following consolidated list of projects was approved (Table 1). Though all through 1999 we still operated with the projects listed in previous reports, we are presenting PHMD research and implementation for 1999 in this report under the new format. The only major change concerned the amalgamation of the old *Striga* project into the relevant IPM and breeding projects.

Table 1. IITA projects (divisional affiliation)

1. Conservation and Use of Plant Biodiversity (CID)
2. Improving Plantain-and Banana-based Systems (CID)
3. Improving Cowpea-Cereals Systems in the Dry Savanna (CID)
4. Improving Maize-Grain Legume Systems in West and Central Africa (CID)
5. Improving Yam-based Systems (CID)
6. Improving Cassava-based Systems (CID)
7. Biological Control and Functional Biodiversity (PHMD)
8. Integrated Management of Legume Pests (PHMD)
9. Integrated Management of Maize Pests (PHMD)
10. Integrated Management of Cassava Pests (PHMD)
11. Protection and Enhancement of Vulnerable Cropping Systems (RCMD)
12. Improvement of High-intensity Food and Forage Crop Systems (RCMD)
13. Development of Integrated Annual and Perennial Cropping Systems (RCMD)
14. Impact, Policy and Systems Analysis (RCMD)

System-wide Program on Integrated Pest Management (PHMD)
Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (RCMD)

Throughout the year, we discussed how to strengthen the demand side for our research and how to coordinate the effort of the various projects to bring measurable benefits to a given environment. In order to achieve this double-goal, four ecoregions (humid forest, moist and dry savanna, and mid-altitudes) are each to be supported by an eco-zonal team. The Plant Health Management Division (PHMD), with its reduced complement of staff, who mostly work across different zones, will contribute few full scientists, but many substantial time allocations to these teams. One of the most fascinating tasks of these teams will be to bring all existing knowledge from the national programmes and IITA, as well as other partners, together and test various combinations of interventions in best-bet options with farmers in farmers' fields in the well described benchmark areas.

Managing PHMD

As concerns principal staff, the main sad event was the accidental death of Paul Speijer in the Kenya Airways crash on 30-1-00. Condolences have been offered to the family and, at this moment, we can only state again how we wish Nicole Smit, Paul's wife, all the necessary strength to carry through and build up a new life with her three small children. We were heartened by the overwhelming support and offer of practical assistance in nematology, which we received from all over the world, particularly from our two main collaborators from the universities of Bonn and Leuven. I take the occasion to thank them once more and can only assure everybody that Paul's position will be filled again and that PHMD

Paul Speijer, a Dutch citizen, was the only scientist employed at IITA as a nematologist. Paul studied at Wageningen Agricultural University, Netherlands from 1977-1982 for his BSc and for his MSc from 1982-1985.

In 1983, Paul married Nicole Smit, a graduate of Wageningen, and in 1985 they went to Tonga, South Pacific. He worked as an Associate Expert on a banana export project by the German Technical Cooperation. Following his PhD, from the University of Bonn for his research at the International Centre for Insect Physiology and Ecology (ICIPE) at Mbita Point, Kenya, Paul joined IITA in Uganda in 1992 to strengthen the newly established banana research project.

Paul trained young scientists in the Uganda national banana programme and tirelessly worked on pest and disease control projects ranging from the use of endophytes to the effective paring of planting material. Paul was involved in numerous farmer support programmes in Kenya, Zanzibar and mainland Tanzania, Rwanda, Ethiopia, Ghana and Nigeria. His contribution to the field of nematode research has been an inspiration to many African researchers and is reported in numerous articles in international journals. His close working colleagues have committed themselves to publishing his uncompleted work.

In his short life, Paul has packed a full scientific career, which brought him numerous friendships all over Africa. He will not be forgotten soon.

will continue his work.

In 1999, the Division again saw some downsizing due to budgetary constraints. Five principal staff and a visiting scientist, mostly from special projects, left without being replaced. On the positive side, the core *Striga* position was filled again in early 2000 and six restricted-core scientists, mostly at junior level, joined the team. In an interesting development, we have now two staff positions which are jointly financed by IITA and the National Resources Institute (NRI). At the same time, a scientist from the Institut de Recherche pour le Développement (IRD) continued his appointment at the IITA Cotonou station, though working now on a different topic.

Our collaboration with the national programmes was good and appreciated by both sides. By accepting the duties for the secretariat of the CGIAR NGO committee on IPM matters for Africa, our links with NGOs improved markedly.

Funding for several restricted core projects was renewed for 2000, but unfortunately mostly at a lower level than for 1999. Thus, PEDUNE (French acronym for ecologically sound cowpea protection), the biodiversity project, LUBILOSA (French acronym for biological grasshopper control), the System-wide Program on Integrated Pest Management (SP-IPM), the banana plant protection project, the East African biological control project against cassava green mite, and the project on strategies to reduce aflatoxin exposure in West Africa, as well as a string of smaller projects, were all renewed. We are grateful to the donors for this continued trust and support.

Overview of achievement for 1999

The following PHMD scientists received prestigious awards in 1999: James Legg won the CGIAR young scientist award for his work on the cassava mosaic disease 'pandemic', and Kitty Cardwell was honoured for her work on downy mildew by the Nigerian Maize Association. Congratulations!

In 1999, plant protection activities permeated most IITA projects. In any one crop, from seed to seed (or planting material), PHMD was involved in solving the following problems:

- *Infestation of seeds and planting material*, requiring sanitation measures to satisfy and uphold quarantine regulations, as done by the Germplasm Health Unit for the safe exchange of germplasm with IITA research partners, or to assure clean planting material on the farm for the next season.
- *Pests (here defined as insects, mites, nematodes, pathogens, viruses) on staple food crops*, requiring sustainable Integrated Pest Management (IPM) options, including biological control (classical against introduced pests, new associations, etc., against local pests), host plant resistance (including the use of endophytes) and habitat management, in a multidisciplinary approach, starting with correct identifications (at the museum).
- *Pests on speciality crops*, like fruit trees, vegetables, but also cover crops, alley crop trees, etc.,

only where IITA has the comparative advantage, as for instance in classical biological control or in situations where synthetic pesticides could be replaced by specific entomopathogens or botanicals.

- *Pests in the farming system*, like termites, or migratory pests (grasshoppers and locusts), only where we have a comparative advantage and where some new intervention point, as for instance the newly developed entomopathogen 'Green Muscle™', exists.
- *Introduced and key native problem weeds*, like floating water weeds or *Chromolaena odorata*, only where biological control or the application of a mycoherbicide look promising or, as in the case of *Striga* spp., where resistant crop varieties, soil management, rotation with other crops, triggering suicidal germination of previously dormant seeds, can be applied in an IPM basket.
- *Loss of functional agrobiodiversity*, threatening the stability of agroecosystems, activities that are executed by the museum staff or are subsumed as basic studies under the other headings.
- *Post-harvest pests*, by making existing (and new) data, after field testing, available in a consumer-friendly decision making tool, which indicates to the farmer/extensionist the results of various intervention options.
- *Post-harvest mycotoxins*, which impact on food quality and consumer health, by raising awareness, developing tools for quantifying the toxin, and by indicating the best storage options under given conditions.
- *Lack of coordination in research and farmers' participation*, by supporting the SP-IPM, NGO involvement, and applying farmers' field school techniques.

We are becoming increasingly aware that insecticides, which have been purchased for use on cotton, cocoa, and other cash crops, either influence the farming system indirectly through drift or are being misused by farmers on food crops in the field and in store. As a consequence, PHMD is moving away from sole development of insecticide-free IPM, often possible under point 2. Increasingly we are also looking into substituting synthetic pesticides with entomopathogens and botanicals, and/or better defining the need for application of insecticides, fungicides, and herbicides. As before, all interventions are to be based on a thorough understanding of the ecosystem.

The 1999 research highlights for PHMD-associated projects and those where PHMD has full staff are given below. Exceptionally, relevant highlights from other projects are added where they fit best and the executing project is indicated in parenthesis. It is, however, not always possible to include in a comprehensive manner all achievements in resistance breeding and deployment of resistant varieties – often the first line of defence. These are reported by the Crop Improvement Division (CID), while PHMD staff contributed by providing insects for homogeneous infestation or testing and by developing methodologies for scoring results and impact assessment.

Training is an important activity and is reported in the chapters devoted to the individual projects. In 1999 again, numerous students were registered for degree-related studies (see table in the Outreach chapter). In addition, a vast number of young scientists and practitioners from Africa, Europe, and America pass through our laboratories and field sites on short-term bench training activities. Increasingly, training and mutual feed-back are, however, achieved in farmers' field schools or similar settings with farmers, extension agents, NGOs, and scientists from national and international organisations.

The highlights of the 1999 achievements attest to the fact that, despite reduced funding and some administrative turmoil, the PHMD team has made headway, contributing with practical solutions to the betterment of many African farmers. In fact, several projects have reached the stage where economic impact could be demonstrated.

Highlights of project 7: Biological control and functional biodiversity

- In Benin, socio-economic studies confirm that termites are a priority pest, thus supporting the further development of a microbial control product.
- Green Muscle™, developed by LUBILOSA, has been recommended by the FAO locust pesticide referee group as the only product rated with highest marks. These concern "low environmental risk" and "unlikely to present acute hazard in normal use", according to WHO human toxicity classes. This recommendation opens the door for the widespread use of this novel technology.
- Under the stewardship of LUBILOSA, and following its successful registration in South Africa, NPP, a commercial producer of Green Muscle™, has applied for registration to the CILSS - Pesticide Committee, covering most Sahelian countries.
- Commercialisation of Green Muscle™: NGOs in Mali and Niger have bought Green Muscle™ for the first time, and a large order has been placed by a major stakeholder (Lux-Development together

with the Niger DPV) involved in grasshopper control.

- The impact of biological control of water hyacinth is now clearly visible over large areas and was publicly acclaimed in Uganda, Tanzania and Benin by the local population and by national authorities.
- Within the framework of functional biodiversity, the insect museum has been updated by 21,000 specimens and now houses the second largest insect reference collection in West Africa.
- Exotic isolates of the pathogenic fungus *Neozygites floridana* released in Benin have led to enhanced infection rates among their pest host, the cassava green mite.
- Exotic isolates of the pathogenic fungus *Neozygites floridana* released in Benin have led to enhanced infection rates among their pest host, the cassava green mite.
- In collaboration with CABI Biosciences, UK, BBA Darmstadt, Germany, NRI, UK, Pace Consulting, San Diego, US, and a previous scientist of IITA, IITA co-founded the International Biopesticide Consortium for Development (IBCD). IBCD is committed to co-operation for development, enabling the globalisation of biopesticide technology and the advancement of biopesticide enterprises in developing countries
- More than 100 national scientists, technicians and students were trained at various levels in biological control methods, IPM, GIS, and impact assessment. Audio- and visual materials were produced on water hyacinth, and *Striga* control.

Highlights of project 8: Integrated management of legume pests

- Orchid and snowdrop lectins were found to be insecticidal to *Maruca vitrata* and hence may be deployed for control of this pest through transgenic approaches.
- Using an artificial seed system, lectins from African yam beans (*Sphenostylis stenocarpa*) were shown to have insecticidal properties against pod sucking bugs (*Clavigralla tomentosicollis*) and cowpea weevils (*Callosobruchus maculatus*.
- A thorough screening of *Mucuna* spp. revealed a novel protein that is highly toxic to *M. vitrata.*
- From the coast in Ghana to Burkina Faso, the flower thrips *Megalurothrips sjostedti* was detected on all known host plants. As previously observed in Benin, the local parasitoid *Ceranisus menes* was the only species associated with the thrips, and this only on some host plants.
- The first experimental release of the exotic thrips parasitoid *Ceranisus femoratus* at the IITA-Benin station in July led to its successful establishment on *M. sjostedti* on *Tephrosia candida*, from where the parasitoid is spreading to adjacent cowpea fields and to *Centrosema pubescens*. In Ghana, the first experimental releases were made in October on *C. pubescens*.
- From Yaoundé, Cameroon, where *C. femoratus* had been spotted for the first time, the parasitoid has now spread ca. 150 km.
- After testing and validation by farmers, the preparation and application of plant-based insecticides from neem and papaya leaves were promoted by 12 NGOs and national extension services in Benin, Ghana, Niger, Nigeria and Senegal. The treatment gave consistent yields of 500-800 kg/ha.
- Improved storage techniques, such as the use of solar drying, hermetic drums, and multiple bagging, allowed cowpea storage for more than 6 months without tangible losses. These techniques have been widely disseminated by PEDUNE to about 3,500 farmers through some 15 NGOs and national extension agents in seven countries.
- In pot experiments, biological control of charcoal rot of cowpea by a strain of *Bacillus subtilis* was demonstrated. Under simulated Sahelian conditions, *B. subtilis* revealed good rhizosphere competence.
- The Beninois cowpea variety Kpodjiguégué was identified as being partially resistant to high soil inoculum of *Macrophomina phaseolina*, which causes charcoal rot.
- Cowpea bacterial blight bacteria were detected on various cowpea-feeding insects, which might implicate them in the direct transmission of this disease.
- During a season-long workshop in Tamale, Ghana, 27 extension trainers from nine countries were trained as facilitators of participatory learning and experimentation. They, in turn, trained 125 farmers at five cowpea IPM farmers' field schools.
- Baseline household surveys in five PEDUNE countries captured the demand characteristics for the different cowpea technologies (varieties, grain size, color, quality, storage technologies,

etc.). The data are used to develop policy recommendations

Highlights of project 9: Integrated management of maize pests

- A sustained reduction of downy mildew of maize in Nigeria, as witnessed from spore trap data and field surveys, has been achieved through a combination of public and private support for the extension of agro-technological solutions.
- To improve screening for *Striga* resistance, agar gel assays were modified to assess the level of stimulant produced by various genotypes.
- Molecular markers have been identified that show polymorphism between *Striga* susceptible and resistant genotypes. Reliable phenotype data were obtained in field trials at two locations, which will be utilised in mapping the resistance genes.
- Several Bt toxins were shown to produce high mortality rates on three major lepidopterous maize pests and were compatible with biological control by significantly increasing parasitism by *Cotesia sesamiae.*
- Five maize varieties with varying levels of resistance to *Sesamia* and/or *Eldana* were identified to have cross-resistance to *Busseola fuscà.* They were successfully deployed in on-farm trials in the Cameroon forest region.
- Planting of grasses as trap plants in border rows of maize fields increased biological control of stemborers, but was not considered a viable option for West Africa because it considerably increased damage to maize by rodents.
- The tachinid parasitoid *Sturmiopsis parasitica,* collected in West African maize fields, was released against *Eldana saccharina* in South African sugar cane fields.
- Using a laboratory assay for kernel screening, 18 inbred lines were found to have aflatoxin levels as low as or lower than the most promising resistant genotypes identified by the collaborating USDA. These lines also showed protein profiles unknown from inbred lines developed in the US.
- Simplified store evaluation procedures, designed to help farmers reduce pesticide use and make sound economic decisions, were developed. Prophylactic insecticide treatment of stores proved to be non-economical. These and other recommendations were incorporated in extension courses with NGOs.

Highlights of project 10: Integrated management of cassava pests

- Africa-wide implementation of cassava green mite (CGM) biological control by exotic phytoseiid predators continued. The exotic phytoseiid predator *Typhlodromalus aripo* is now found in 17 countries. It has newly colonised parts of the dry savanna of West, Central, and East Africa and parts of the subhumid tropics in Malawi, Mozambique, and Zambia. Where this predator has been present for three or more years, cassava productivity has increased between 15 and 43%.
- *T. aripo* was found to perfer 'hairy' over 'glabrous' cassava cultivars, and the predator's abundance on 'glabrous' cultivars could be substantially enhanced by interplanting them with 'hairy' cultivars.
- Brazilian isolates of the fungus *Neozygites floridana* have been successfully established in southern Benin. This pathogen can potentially complement biological control of CGM on cassava varieties that are not preferred by exotic phytoseiid predators.
- To combat cassava mosaic virus disease (CMD) in northwestern Tanzania, Kenya, and Uganda, IITA, in collaboration with its public and private sector partners, facilitated the multiplication and distribution of resistant cassava and imposed phytosanitary restrictions on the movement and cultivation of CMD-diseased cassava germplasm.
- The hybrid virus associated with the spread of severe CMD in East Africa, and known to be present in the Great Lakes region, was recently found in a CMD-outbreak area in the central plateau of the Congo (Brazzaville), and a new cassava mosaic geminivirus variant was found in Zimbabwe.
- Among 24 widely grown cassava varieties in Togo, four indigenous ones and four from IITA were shown to be resistant to several highly virulent cassava bacterial blight strains collected from wide geographic origins.
- Selective media have been standardised to enhance quick identification of highly destructive bacteria (*Xanthomonas manihotis, X. cassavae* and *Pseudomonas*) in cassava (from project 1).
- Training on various aspects of integrated management of cassava pests and diseases was offered

to 72 NARS staff; scientists, extension agents and farmers from seven countries participated in field evaluations of cassava germplasm for resistance to pests and diseases.

Plant protection highlights of project 2: Improving plantain- and banana-based systems

- Based on screening of 45 accessions, susceptibility to banana weevil was found to decline from plantains to East African Highland Bananas, to exotic bananas, and then to wild or hybrid diploids. Antibiosis associated with corm hardness, corm size and resin/sap production, was the most important resistance mechanism.
- Because of the sedentary life of the weevil, insect-repellent green manures (*Canavalia, Mucuna* and *Tephrosia*), had no effect on weevil adult numbers or rhizome damage.
- A root sampling method based on soil cores, which captures more than 80% of the root size, but only requires 5% of the time needed for whole plant excavation, was developed. Likewise, a quick (3 months) screening method for resistance to plant parasitic nematodes was developed.
- To promote the use of clean planting materials and reduce the spread of nematodes, training was carried out for 1623 farmers in Uganda, 659 in Zanzibar and 234 in Rwanda, resulting in the treatment of 10 530 suckers.

Plant protection highlights of project 5: Improving yam-based systems

- AFLP and RAPD markers for yam mosaic virus (YMV), genus *Potyvirus*, were identified.
- Polyclonal antisera were raised against three *Dioscorea* viruses, (and also against different viruses infecting herbaceous legumes, cassava, and banana).
- Only yam mosaic virus (YMV), genus *Potyvirus*, and *Dioscorea alata* virus (DaV), genus *Potyvirus*, were found to infect *D. rotundata* and *D. alata* in Ghana, while many of the leaf samples with virus-like symptoms tested negative for the seven viruses known to infect yams in West Africa, suggesting the presence of still other viruses.
- New sources of genetic resistance to YMV were identified. Five accessions of *D. rotundata*, two of *D. alata*, and one of *D. bulbifera* were demonstrated to have high levels of resistance to the virus.
- Application of recently developed screening techniques to 220 accessions of *D. rotundata* revealed variation in susceptibility to the yam nematode (*Scutellonema bradys*) and the root knot nematode (*Meloidogyne incognita*). Two accessions of *D. dumetorum*, from Ghana and Cameroon, proved highly resistant to *S. bradys*.

Systemwide Program on Integrated Pest Management (SP-IPM)

- With the support of the CGIAR-NGO Committee and the SP-IPM, IITA-Benin hosted a workshop for NGO participants from 14 African countries, providing them with insights into the latest IPM technologies and extension approaches. Researchers from four international research organisations, in turn, gained a better understanding of NGO perspectives on the research-to-implementation process. An e-mail discussion group was formed to enable participants to continue collaboration.
- To achieve better coordination and broader awareness of all IPM research carried out at the international agricultural research centers, the SP-IPM worked with the Impact Assessment Group of the CGIAR to collect information on the role of IPM research in sustainable agricultural development in the CGIAR and other organisations.

P. Neuenschwander

Professional Staff of the Plant Health Management Division[1]

Peter Neuenschwander, PhD, entomologist, director*	Cotonou (Benin)
Administration and Support Services	
Catherine, A. Soboyejo, MA, chief administrator*	Cotonou
Julius B. Akinwumi, MSc, engineer	Cotonou
Jean-Baptiste Adjovi, chief accountant (left in 1999)	Cotonou
Sampson Nyampong, executive assistant to the director	Cotonou
Alain Ratié, maintenance service officer	Cotonou
Principal scientific staff	
Dana Berner, PhD, parasitic weeds biologist, (left in 1999) *	Ibadan (Nigeria)
Kitty Cardwell, PhD, plant pathologist*	Ibadan/Cotonou
Andy Cherry, PhD, insect pathologist (IITA/NRI)*	Cotonou
Hugo de Groote, PhD, economist, (left in 1999)	Cotonou
Cliff Gold, PhD, entomologist*	Namulonge(Uganda)
Georg Goergen, entomologist, curator of insect museum	Cotonou
Kim Green, PhD, plant pathologist (left in 1999)	Accra (Ghana)
Rachid Hanna, PhD, entomologist/acarologist, project coordinator	Cotonou
Winfred Hammond, PhD, entomologist	Cotonou
Jacqueline d'A Hughes, PhD, virologist*	Ibadan
Louis E. N. Jackai, PhD, entomologist (left in 1999) *	Ibadan
Jürgen Langewald, PhD, entomologist, project coordinator	Cotonou
Philippe le Gall, PhD, entomologist (ORSTOM)	Cotonou
James Legg, PhD, virologist/vector entomologist (IITA/NRI)*	Namulonge
Chris Lomer, PhD, insect pathologist (left in 1999) *	Cotonou
Richard Markham, PhD, entomologist, project coordinator	Ibadan
William Meikle, PhD, entomologist*	Cotonou
Fritz Schulthess, PhD, ecologist, project coordinator*	Cotonou
Paul Speijer, PhD, nematologist (deceased)*	Namulonge
Abdoul Aziz Sy, PhD, plant pathologist	Cotonou
Manuele Tamò, PhD, insect ecologist, project coordinator*	Cotonou
Kerstin Wydra, PhD, plant pathologist (left in 1999)	Cotonou
Matthias E. Zweigert, Dipl. Ing., head TT&TU (GTZ) (left in 1999)	Cotonou
Visiting scientists	
Vicky Adenle, PhD, plant pathologist (left in 1999)	Ibadan
Maria Ayodele, PhD, plant pathologist, Germplasm Health Unit	Ibadan
Ousmane Coulibaly, PhD, economist	Cotonou
Assomption Hounsa, medical doctor, epidemiologist	Cotonou
Braima James, PhD, entomologist	Cotonou
Lajide Labunmi, PhD, chemist (left in 1999)	Ibadan
Suleman Okech, PhD, entomologist	Namulonge
Philip Ragama, PhD, biometrician	Namulonge
Muaka Toko, PhD, acarologist	Cotonou
Postdoctoral fellows	
Kerstin Hell, PhD, plant pathologist	Cotonou
Associate experts	
Carine Dochez, MSc, nematologist	Namulonge
Sharif Egal, MSc, geographer	Cotonou
Till Hoffstadt, MSc, plant pathologist	Cotonou
Hans Meerman, MSc, nematologist	Ibadan
Christian Nansen, MSc, biologist	Cotonou

[1]as of 1st January 2000. Project coordinators indicated for this date.
*core principal staff

DONORS

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- Agency for International Development (USAID), United States of America
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Zinsou, V.	Benin	98/01	EC	Wydra

Research achievements and activities

Project 7

BIOLOGICAL CONTROL AND FUNCTIONAL BIODIVERSITY

by A. Cherry, P. LeGall, G. Goergen, B. James, J. Langewald (project coordinator), P. Neuenschwander, M. Tindo

assisted by O. Ajuonu, S. Attignon, H. Davies, O.K. Douro-Kpindou, C. Gbongboui, G. Heviefo, F. Hountoundji

Project rationale

The biological control project groups three areas of expertise: insect pathology, taxonomy and classical biocontrol. The pests targeted within this project are those which cause social or economic losses to farmers in the Sahel, Guinea Savanna or Humid Forest zones. In general, pests affecting the major IITA mandate crops are handled by specific IPM projects. The focus of the current project is those pests which cause inconvenience or damage on a broad range of crops (such as grasshoppers and locusts, termites, spiraling white-fly *Aleurodicus dispersus* Russell (Hom., Aleurodidae), or on non-mandate crops (such as water-weeds and mango). In particular, new pests and approaches are explored within this project.

Classical biological control is the first-choice option, but where, for differing reasons, this is not feasible, or needs amelioration, we investigate the possibility of exploiting pathogens. Target pests for which this approach may prove feasible include locusts and grasshoppers, stem borers, cassava green mite Mononychellus tanajoa (Bondar) (Acari, Tetranychidae), Thrips, the larger grain borer Prostephanus truncatus Horn (Col., Bostrichidae), banana weevil Cosmopolites sordidus Germar (Col., Curculionidae) and a complex of termite species.

In addition to providing taxonomic support to work on thrips, stem-borers, grasshoppers and pathogens, the project houses a specific physical repository for collections, and carries out biodiversity research.

Outputs

7.1. Biopesticides in the integrated management of locusts and grasshoppers

Background

Locust and grasshopper outbreaks in the Sahel and humid forest zones of Africa continue to cause extensive economic losses and social disruption. Widespread use of donor-supplied synthetic pesticides has caused concerns about environmental pollution and human poisoning. Since 1989, donors have supported a quest for environmentally sound alternatives through the LUBILOSA project (LUtte BIoloqiue contre les LOcustes et SAuteriaux), in which IITA collaborates with CABI Bioscience, CILSS and GTZ. With an initially broad mandate to investigate options for biological control of locusts and grasshoppers, the project rapidly focused on oil-based formulation of spores of the deuteromycete fungus *Metarhizium anisopliae* (*flavoviride*) var. *acridum* as the most promising option. The former name of the fungus *M. flavoviride* (Gams and Rozsypal) has been changed since recent studies revealed that there is not enough evidence to split this group which is typically found on Acrididae from *M. anisopliae*. Phase 1 (1989 - 1991) was concerned with investigating options and determining the technical feasibility of formulating and applying spores in oil. Phase 2 (1992 - 1995) concentrated on extensive field testing of these constantly improving formulations, investigating mass production, and organizing a network of NARES collaborators. Phase 3 (1996 - 1998) investigated socio-economic and ecotoxicological issues in depth, and approached the issue of transferring the technology to the private sector. Phase 4 (1999-2001) is mainly focusing on product stewardship and the development of use strategies.

On-going and future studies

7.1.1. Technical support to commercial companies, backstopping commercial production

by J.L. - in collaboration with N. Jenkins

The estimated maximum annual capacity of the IITA fungus mass production plant is about 350 kg conidia at a cost of just over US $200 per kg. LUBILOSA recognized that while this is adequate to meet the likely needs of product development, in the long-term production will have to be scaled-up to

meet market demands. In this respect LUBILOSA phase 3 has established partnerships for industrial scale commercial production. Two companies will produce Green Muscle™ at industrial scale. One, NPP (Natural Plant Protection) in Pau, France, and the other BCP (Biological Control Products) in South Africa.

In 1999 the mass production plant produced over 150 kg of spores, because the commercial partners have not yet started mass producing. Technicians of both companies received training and advice especially on issues concerning spore harvesting. BCP is currently expanding their mass production capacities to include Green Muscle in their product portfolio. NPP is starting production in early 2000.

7.1.2 Technical support regulatory matters

by J.L.

Green Muscle™ has been registered in South Africa and a registration dossier has been submitted by NPP to the Comité Sahélien de Pesticides, responsible for most Sahel countries. The FAO locust pesticide referee group has now listed Green Muscle™ as the only desert locust control product with "low impact on the environment" in all categories and as causing "low risk to humans under normal use".

7.1.3 Development of use strategies

by J.L.

Together with farmers and NARES, use strategies for the Variegated Grasshopper have been developed over the recent years. Farmers should treat young nymphs shortly after hatching, when they are still aggregated. If hatching occurs in non accessible areas, all instars can be sprayed later. Barrier sprays using 20g spores per hectare and 20m distance between swaths, are far less labour consuming compared with blanket sprays.

In the Sahel, farmers adopted a very simple system against the Sahelian Savanna grasshopper complex. Fields and fallow areas are covered with a uniform blanket spray of 50g spores per hectare. It is most important to treat the grasshoppers before they reach the fourth instar, to avoid crop damage.

The Senegalese Grasshopper is the most important grasshopper pest in the Sahel. Its complex migration behaviour makes the development of simple use strategies impossible. An integrated pest management approach is needed, involving all stakeholders in grasshopper control, farmers, NGO's and NARES, to stop Senegalese Grasshopper invasions early. The field testing of such an approach is beyond the scope of LUBILOSA.

Use strategies for desert locust are developed as a part of a collaboration between LUBILOSA and the FAO-EMPRES programme. A new project with support from DFID has been launched to develop Green Muscle™ for control of red locust in Southern Africa.

7.1.4 Product use demonstrations and promotion

by J.L.

For the first time, farmers in Mali (supported by SECAMA) purchased and used Green Muscle™ without any specialist support during their normal grasshopper control operations over an area of 200ha. In Niger, several NGOs sent observers when AGRHYMET and BBA, Darmstadt, Germany, carried out a field trial comparing Green Muscle™ aerial conidia with a product based on the same fungal isolate but produced in liquid substrate. The BBA product was less efficient compared with Green Muscle™. In the same region the Niger Plant Protection agency carried out demonstration trials against rice grasshopper on 150ha, and obtained very good control. During training workshops, the plant protection agency and CARE International trained over 100 plant protection and extension officers in the use of Green Muscle™. With the support of one of their principle donor, Lux Development, the Niger plant protection agency is planning to spray Green Muscle™ over an area of 10,000ha against rice grasshopper in 2000.

7.2. Enhanced biosystematics capacity at IITA and NARES

Background

The development, assessment and follow-up of any biological control projects entail a thorough knowledge of all ecosystem components. The information thereby needed, can be exhaustive especially when potential antagonists of crop pest organisms range from invertebrates to microbial pathogens of

plants or insects. In addition to data on native pest and beneficial organisms further habitat information is necessitated when exotic biological control agents must be introduced into new environments. Thus in every project at PHMD where most individual scientists are biodiversity specialists within their narrow field, ecosystems analysis requires regularly taxonomic support. Moreover in faunistic inventories other, mostly common, organisms in the same ecosystems, which have not been picked up by any of the specialized studies, are also collected and their trophic links need to be verified. The accumulated specimens cover a broad range of cultivated habitats and life-styles. They must be assembled in a central museum for cross-reference, curated, and identified. The present museum supports the research of all IITA entomologists and plant pathologists, and assists NARES scientists. In the framework of the biosystematic network WAFRINET, the western African node of BioNET-INTERNATIONAL, it links field entomologists of the sub-region with oversee centers of expertise.

On-going and future activities

7.2.1. Capacity building for faunistic studies:Insect Museum

by G.G.

Since specimen data provide the core information for improving the knowledge base and understanding of biodiversity, accurate identification, rigorous collection management and steady integration of new acquisitions with their biological references constitute the essential activities of the insect museum aimed at developing the institute's biosystematics capabilities. In the course of this year alone more than 21,000 voucher specimens originating from faunistic surveys conducted in different ecological zones of West Africa, were stage or slide mounted, labelled and integrated into the existing collection. By adding up this year's performance PHMD's insect museum is presently housing over 112,000 specimens, a rank which elevates IITA's reference collection to the second largest of its kind within West Africa. Whilst progressing in pace with both the collection augmentation and the current identification work, the museum's database comprises to date over 2,600 identified species from 258 families. Though much curatorial work remains to be carried out on already preserved specimens, the reference collection holds presently at least one named representative of about half of the 568 recognized insect families in West Africa. In its present state the identified arthropod material represents about 10% of all known arthropod biodiversity from the whole sub-region.

A computerised collection checklist containing data accumulated over the last 6 years is now available to all IITA scientists and their collaborators. This information source is being supplemented by a bibliography catalogue, which includes searchable references of more than 6,000 taxonomic publications that are available for consultation in the insect museum. Further electronic indexes such as the collection's specimen-level database and the nomenclature catalogue of West African insects are constantly being updated. As part of a future global information management program all database types will be merged to become accessible through a central server, and operate from a multi-user platform.

Following the acquisition of large numbers of well-preserved arthropods, external specialists became involved to carry out taxonomic work on certain functional groups, such as the economical important Hemiptera and Diptera. Additional efforts are made, to establish collaborative links with specialists, who are offering their expertise in exchange of duplicate collector's material. This kind of informal collaboration has considerably increased our expertise in Coleoptera and Orthoptera in general, but also in the families Curculionidae, Buprestidae or Cerambycidae.

7.2.2. Capacity building for faunistic studies:BioNET coordination

byB.J.

In response to the lack of adequate taxonomic resources that particularly affects West African countries continuous efforts were made by IITA since 1996 to establish a subregional LOOP of the biosystematics network BioNET-INTERNATIONAL. This initiative newly created in 1993 is aimed at mobilizing and pooling worldwide biosystematics resources to the benefit of developing countries. With the establishment of the sub-regional LOOP WAFRINET, assistance will be provided to interested countries to achieve adequate self-sufficiency in biosystematics for sustainable use of natural resources and to fulfil their commitment to the convention of biological diversity.

Following the second BioNET-INTERNATIONAL Global Workshop held in Cardiff in August 1999 the network's technical secretariat (TECSEC) approved IITA's qualification for catalytic fund release and its function as the WAFRINET network-coordinating institute. Recently, fellowships were made available to promote expertise in biosystematics in the sub-region. Individual LOOPs are now encouraged to develop own initiatives for raising funds to implement their work program. In the first

facet of WAFRINET's work plan, an extensive analysis of existing resources including an concomitant assessment of the requirements for the sub-region is programmed. The second phase will emphasize on information and communication services, training in biosystematics, rehabilitation of existing collections and other resources. Also the development and use of new technologies especially electronic support for insect identification will be an important part of phase II.

7.2.3. Arthropod collection, identification and monitoring activities

by G.G.

As for the past year faunistic activities with emphasis on pests and beneficial insects of IITA's mandated crops were pursued. Special care was taken to collect representative samples from ecologically different zones in West Africa. Because of the large amount of insect material available from Benin, light traps were reduced from 6 to 3 sampling sites in the main ecological zones of the country. Furthermore periodically samples were collected at the agricultural research station Niaouli, Benin, where crops are cultivated next to a protected humid forest. This year, collection activities focused on the humid forest zone at Mbalmayo, Cameroon, where permanent light, malaise and diverse bait trapping continues. Additional arthropod material was steadily sampled in the mid altitude zone in Togo, which is renown for its rich endimism in arthropods. Because of its particular fauna and geographical condition, an arthropod inventory was established during a short expedition at Sao Tome, jointly organised by collaborating scientists of IRD and Cabi BioScience.

The collection activities of this year resulted in an unusual large number of insects. About 150 samples representing roughly 1,200 insect specimens originating from many African countries and from IITA's own research activities were submitted and identified mostly to a satisfactory level (Table 1). Partial resolved requests were directed to group specialists when desired. A considerable part of the identification work derives from the taxonomic support rendered to in house studies. The assistance provided to IITA scientists is being substantiated in joint publications.

Table 1 - Identification requests handled for 1999

	samples	insects	Col.[1]	Dip.	Hem.	Hym.	Lep.	Others	level identified: sp.	gen.	fam.
IITA scientists	58	609	150	42	127	138	26	126	384	165	60
Benin[2]	41	268	177	9	30	32	14	6	226	26	16
Burkina-Faso[2]	3	56	0	0	26	20	0	10	56	0	0
Cameroon[2]	12	107	40	20	0	47	0	0	53	54	0
Congo[2]	6	60	0	0	30	10	0	20	30	30	0
Ghana[2]	1	10	10	0	0	0	0	0	10	0	0
Guinea[2]	1	10	0	0	0	10	0	0	0	10	0
Malawi[2]	3	8	1	0	0	0	0	7	7	0	1
Niger[2]	1	10	0	0	0	0	10	0	10	0	0
Nigeria[2]	11	28	0	1	0	12	7	8	17	11	0
Uganda[2]	18	65	0	0	65	0	0	0	35	30	0
TOTAL	155	1,231	378	72	278	269	57	177	828	326	77

[1] Col.= Coleoptera; Dip.= Diptera; Hem.= Hemiptera; Hym.= Hymenoptera; Lep.= Lepidoptera; sp.= species; gen.= genus; fam.= family.

[2] requests from NARES.

7.2.4. Beneficial micro-organism collection

by A.C., K.C.

Plant and arthropod pathogens comprise a huge reservoir of potential biological control agents for pest species. IITA's Plant Health Management Division accumulates a large number of such pathogens through it's own project activities, from collaborating institutes and from private individuals. The PHMD plant and arthropod pathogens collection and database was recently established at Cotonou Benin. The Systemwide Genetic Microbial Resources Database provides a framework for development of this facility for centralized long-term microbial pathogen storage which sits alongside and enhances the existing biosystematic capacity. The collection currently houses just under 200 lyophilized and

cryopreserved samples arising from IITA's own projects, and comprises mainly insect pathogenic fungi. Many samples are duplicated at collaborating institutes in North America and Europe, which also provide definitive indentification services. Molecular techniques are being developed as tools for in-house pathogen identification.

7.2.5. Biodiversity studies

by G.G., M.T.

Beside routine curatorial activities and the identification service offered to IITA scientists and NARES collaborators, the unit offers special assistance whenever there is a need for additional taxonomic expertise concerning specific studies or emerging pest problems. In the past year, for instance, the insect fauna in cover crops recommended for the preservation of soil fertility in short fallows systems was studied. A first inventory on *Mucuna* showed the system to be well suited, for both a wide range of legume pests but also for their antagonists. This study is currently being complemented by research on further legumes cover crops under different conditions such as the humid forest margin benchmark area in Cameroon.

Further assistance is being given to scientists of IITA's project 1, who are investigating alternatives to natural bush fallow for sustaining soil fertility under tropical conditions. A study initiated in 1990 in Ibadan compared the change of soil fertility simultaneously in several land use systems, such as continuous cropping (maize-cassava intercropping), natural fallow and cover crop fallow (*Pueraria* or *Chromoleana*) after an initial forest clearing. Possible interaction between land use systems and arthropod biodiversity is being investigated. The systematic collection of the faunistic data was concluded after 2 sampling years to proceed to a final evaluation.

In Cameroon, the root scale *Stictococcus vayssierei* Richard (Homoptera: Stictococcidae) and its associated fauna was studied. This pest is considered to be an emerging problem to cassava in Cameroon and the adjacent countries. Preliminary diagnostic surveys indicate that the proliferation of this homopteran pest may be due to its obligate association with some ant species. Collaboration was offered to elucidate a possible specific relationship with ants.

7.2.6. Zonocerus research

by P.LG

Twenty oviposition sites of *Zonocerus variegatus* have been studied in South Bénin (Département du Mono). The largest sites were monitored from March 1999 to October 1999. There was generally no preference for certain vegetation types and structures.

At nine sites also the parasitic fly, *Blaesoxipha filipjevi.* (Diptera, Sarcophagidae Miltogramminae) was present. Between 1 and 13 Diptera larvae were counted feeding on one grasshopper, with the majority of the grasshoppers containing 1 or 2 larvae. Male grasshoppers carried more parasites than the females. This is probably because the males spent more time on the reproductive sites compared with the females. Parasitism and mortality were highly correlated. *Z. variegatus* has disappeared from oviposition sites, where high parasitism rates were observed.

The impact of rainfall frequency on the development egg pods was studied. A frequency of one month rain followed by one month of drought and again followed by one month with rain, resulted in the highest hatching rate. This pattern of drought and rain could explain the occurrence of two different times of maximum hatching within the year.

The collection of feces has been completed. Z. Djihou spent one month at the PRIFAS/CIRAD (Montpellier, France) to study their reference collection. This work was funded by the Service de Coopération et d'Action Culturelle of the French embassy in Cotonou. For three species of Asteraceae, the structure of epidermis within three localities was compared: a fallow at Calavi (South Bénin), a fallow in the mid-altitude forest zone at Dzogbégan (Togo) and a guinea savanna site at Lamto (Côte d'Ivoire). No difference between the plant epidermis from the three localities was found. The specific characters remain the same and the reference collection could be used for any location in West Africa.

7.2.7. Training

by G.G.

Regular requests for bench training in basic taxonomy skills by NARES and West African Universities do clearly indicate a sustaining interest in biosystematics within the whole sub-region. In response, the insect museum offers short-term group training courses for Franco- or Anglophone trainees or individual training.

The museum provided numerous insect photographs taken from the collection for the production of the global version of CABI's Crop Protection Compendium CD-ROM. A manual was edited for a 3-week IPM training course, jointly organised by IITA, CIRAD and CNEARC. An identification manual for parasitic Hymenoptera of economical importance in West Africa is currently being produced. This book, which will be distributed in 2001, will include pictured diagnostic characters to 186 genera of parasitic wasps together with colour illustrations. A parallel initiative involving CABI, the Natural History Museum London, and the University of Amsterdam (World Biodiversity Database team) was started to elaborate an electronic identification key to whiteflies of economical importance and their natural enemies.

7.3. *Exploration of possibilities for use of pathogens in biocontrol*

Background

Insect pathogens are rather poorly understood components of the agro-ecosystem, but they can have profound effects on insect population dynamics. They are frequently overlooked as biological control agents, partly because specialized knowledge is needed to collect and identify them, and because they are often unable to spread far naturally. Similarly, the pathogens of stem-borers are being investigated to determine their role in pest population dynamics. In some pest systems, no classical biological control option is available, and in this case, pathogens formulated as biopesticides may offer a solution which, while less elegant than biocontrol, is a better option than chemical pesticides. Exploring sustainable delivery systems for such biocontrol agents is the key element. Where chemical pesticides are already in use, there are good prospects for replacing the chemical with a biological alternative, like the biological pesticide for control of grasshoppers and locusts: an oil formulation of the spores of *Metarhizium anisopliae*.

On-going and future activities

7.3.1. Maize stem borers

by A.C.

Experimental work in 1999 focussed on continuing laboratory, greenhouse and field studies of two pathogens for *Sesamia calamistis* management; the first, a cytoplasmic polyhedrosis virus (CPV) and the second, systemic isolates of *Beauveria bassiana*. CPV *in vivo* production studies allowed us to optimise production parameters for maximum viral progeny per larva, and to efficiently produce inoculum for field and greehouse trials which were designed to investigate aspects of the behaviour of infected larvae, and of the transmission potential of the virus. These trials showed firstly that CPV-infected larvae introduced into maize stems in the greenhouse make shorter tunnels than healthy larvae, and that CPV-treated maize in the field had shorter tunnels than unprotected maize. This effect continued in a subsequent untreated crop sown in adjacent plots overlapping temporaly with the first, and provides the first evidence that the virus was transmitted vertically between *S. calamistis* generations, and between plots.

Two separate field trials were conducted in 1999 to investigate the capacity of endophytic isolates of *B. bassiana* to provide protection against maize stem borers. The first compared rates of endophytic establishment of 6 *B. bassiana* isolates in 4 maize varieties using two methods for inoculative introduction of spores into stems; and the second considered the effect on *S. calamistis* tunnel length following stem injection with *B. bassiana* spore suspensions. Histological and scanning electron microscope studies aimed at shedding light on the invasion pathway for *B. bassiana* into maize plants, while additional laboratory experiments were designed to improve fungal detection and recovery from infected plants. All studies on *B. bassiana* were conducted under a short project awarded by DFID. Results of this work showed the importance of fungal isolate and plant variety interaction, but confirmed that for certain combinations, significant reductions in maize stem tunnneling can be achieved. The invasion pathway remains unclear, and although electron micrographs failed to detect penetration via leaf stomata, which had been thought previously to be the most likely access route, histological sectioning clearly demonstrates fungal establishment in the leaf following topical application.

7.3.2. Establishing *Neozygites floridana* (Entomophthorales: Entomophthoraceae) , a classical microbial control agent, against the cassava green mite, *Mononychellus tanajoa*

by A.C.

Experimental releases of exotic isolates of the fungus *Neozygites floridana* were conducted in Adjohoun,

Benin, during 1998, using a release technique based on sporulated CGM mummies. Post release monitoring surveys indicated recovery and modest levels of CGM infection in some release sites.

The release technique has been improved and promising isolates of *N. floridana* were released in the same area, in January 1999, and followed throughout the year. The first follow-ups showed the development of the fungal infection, although at low levels. In December of the same year, however, higher levels of CGM infection by *N. floridana* (up to 35%) were recorded in three release fields, where imported isolates had been released. The dispersal of *N. floridana* from these release sites is being studied and molecular methods are being developed to assist the identification of separate isolates.

Further releases were made at Ina in northern Benin in late 1999, in the dry savannah agro-ecological zone, to evaluate the effect of environmental variables on the eventual distribution of *N. floridana*. Monitoring will continue throughout the coming year.

7.3.7. Use of *Metarhizium* against termites

by J.L.

Termites often cause problems in maize and cassava. A project in collaboration with ICIPE, IIBC, KARI and the Plant Protection Agency of Benin started in 1998 funded by the DFID Competitive Research Facility. *Metarhizium anisopliea* and *Beauveria bassiana* strains were isolated from soils, termite cadavers and termite mound materials in Benin and Kenya. Bioassays were developed to characterize and compare the collected strains in terms of virulence, repellency, and mass production productivity. The new strains were compared with three standard strains from Australia, US and Kenya. No strain was found significantly better than the already known Kenyan strain. Socioeconomic studies were organized in Benin to better understand the problem. Termites do always range within the tree most important pests mentioned by farmers. Especially in the northern part of the county termites are causing serious damage in the field and in wooden structures like houses and stores. Field test using the Kenyan strain to protect maize seedlings will start in Benin and Kenya.

7.3.8 Evaluation of a viral pathogen *Maruca vitrata*

by A.C .- in collaboration with M. Tamò.

A short project awarded by DFID Crop Protection Programme allowed us to conduct first tier laboratory evaluations of a virus recently found to be infecting *M. vitrata* in the field in Benin. Scanning electron microscope studies, gel electrophoresis of the viral genome and gross larval symptomology identified the agent as a cytoplasmic polyhedrosis virus (CPV) (Reoviridae). Members of this group which are pathogenic to Lepidoptera only infect cells of the midgut, typically cause chronic rather than lethal disease, and are transmitted vertically from one generation to the next. Infected adults may be dysfunctional or have reduced viability/fecundity. Virus production studies gave a maximum virus yield approximately $5x10^7$ occlusion bodies/larva representing a 5000-fold return on inoculum. Those larvae which died did so two to three weeks after after inoculation. Larger larvae tended to survive infection, successfully pupate, but often develop into abnormal adults. The dose-response relationship is a weak one because of the chronic nature of the virus. Further studies will be undertaken to evaluate the geographic and temporal distribution of the virus in Benin, the longer term impact of infection on individuals and populations, and the options for integrating this virus into an IPM programme for *M. vitrata*.

7.3.9 *Metarhizium anisopliae* for control of flower thrips

by A.C. - in collaboration with M. Tamò

Under a 1998 strain release agreement between IITA and the International Centre of Insect Physiology and Ecology, IITA received a sample of a thrips active isolate of *Metarhizium anisopliae*, ICIPE 69. Following successful laboratory evaluation in 1998, the isolate was field tested against *Megalurothrips sjostedji* in cowpea during on-station trials at IITA, using a protocol supplied by ICIPE. *Metarhizium* was as effective as the standard chemical insecticide, and more effective than papaya leaf and neem extracts at controlling thrips and protecting yield.

7.4. Classical biological control of exotic Homopteran pests and floating water weeds.

Background

Introduced pests to Africa have caused enormous economic losses, but often they can be controlled by the introduction of natural enemies from the area of origin. Where a program of research and exploration

is needed, a large project may be necessary, but often, off-the-shelf solutions are available, which require only a minimum of adaptive research.

The mango mealybug *Rastrococcus invadens*, Williams (Hom., Pseudococcidea), a pest of Indian origin, was successfully controlled by the introduction of two natural enemies, *Gyranusoidea tebygi* Noyes and *Anagyrus mangicola* Noyes (both Hym., Encyrtidae), in collaboration with several other institutions. Since this pest insect of mango is still expanding its range, a minimal project is maintained to satisfy the continued demand for parasitoids and biocontrol services by the NARES.

Similarly, monitoring of the spiraling whitefly, *Aleurodicus dispersus* Russell (Hom., Aleyrodidae), of Central American origin, and its two parasitoids *Encarsia ?haitiensis* Dozier and *E. guadeloupae* Viggiani (both Hym., Aphelinidae) is continued on the spreading front of this pest, which attacks cassava, citrus, and ornamentals.

Two exotic weevils, *Neochetina eichhorniae* Warner and *N. bruchi* Hustache (Col., Curculionidae), and a moth *Sameodes albiguttalis* (Warren) (Lep., Pyralidae) had already been introduced against water hyacinth, *Eichhornia crassipes* Solms-Laubach (Pontederiaceae), the most important floating water weed. Because biological control by these agents is notoriously slow, monitoring was continued and new agents are being introduced.

Similarly, the less important, but wide-spread water lettuce, *Pistia stratiotes* L. (Araceae) is being controlled by the weevil *Neohydronomus affinis* (Hustache) (Col., Curculionidae), again on demand by the NARES.

On going and future activities

7.4.1. Mango mealybug

by P.N.

The two parasitoids *G. tebygi* and *A. mangicola* are maintained in the laboratory, while regular surveys were continued in the field, to document the impact of the parasitoids. Localised damage by mango mealybug is restricted to the northern provinces; namely Atakora and Borgou. The parasitoids are well distributed and were recovered in most localities. The monitoring will be continued in the year 2000.

Table 2 - Shipment of natural enemies of mango mealybug from IITA, Benin, during 1999.

Species	Date	Number	Country
G. tebygi	06-03-99	600	Senegal
A. mangicola	15-10-99	500	Senegal

7.4.2. Spiralling whitefly

by P.N., G.G.

After the introduction of *A. dispersus* in 1993, this insect has been spreading in northern direction faster than its parasitoids. Later, the parasitoids caught up with their host and the spread stopped at Natitingou and Bembereke (between 10.15°N to 10.20°N), where *A. dispersus* had been first observed in 1995 and 1996, respectively.

Like their host, both parasitoids are well distributed and are responsible for the decline in damage by *A. dispersus*, especially in southern Benin, when compared to the situation in 1993. Up to 1997, both parasitoids seemed to occupy different geographical niches: *E. ?haitiensis* was commonly found in the south up to latitude 8.30°N while *E. guadeloupae* was predominant in the north. The predominance of *E. guadeloupae* in the north diminished, however, slightly in 1998, then drastically in 1999, while *E. ?haitiensis* maintained its dominant position in the south.

Another whitefly, *Paraleyrodes minei* (Iaccarino) (Hom., Aleyrodidae), was sparsely observed during the 1997 survey and, in 1998, was commonly found in the Mono, Atlantique and parts of Ouémé regions; by 1999 it had spread northwards to Parakou. The most commonly attacked host plant is *Ficus polita*, though this whitefly was also found on other plants like *Ficus umbellata*, *Terminalia catappa*, guava (*Psidium guajava*), *Spondias mombin* and cassava. In Porto-Novo, Igolo, Sakete, Ipinle and Pobè, in the Ouémé province, frequency of *P. minei* on *Ficus polita* was higher than that of *A. dispersus*. In 2000, the spread and impact of *P. minei*, which can easily be confused with *A. dispersus*, will be investigated, particularly in coastal Benin, Togo, and Ghana.

7.4.3. Classical biological control of floating water weeds by means of specific insects: water hyacinth
by P.N.

Cultures of the two weevils, *N. eichhorniae* and *N. bruchi* are maintained in the laboratory and monitoring in Benin continues, at the rate of one visit per site every 3 months.

In the Ouémé river system, reduction of water hyacinth cover by the weevils has been faster in up-stream than in down-stream sites, apparently because of the negative influence of salinity. By the end of 1998, the cover of water hyacinth mats was reduced by 60-90% in two sites, Tévèdji and Sagon. In the same year, similar levels of reduction were observed at Kafedji, where the weevil had spread 2 years after release.

At the end of 1999, the reduction in surface cover was 70-90% in Tévèdji, Sagon, Kafedji, and 60-80% in Akpomè, and Godolo. In all these sites, local populations were asked about their perception of possible changes in damage by water hyacinth. Throughout, respondents were aware of the reduction and approved of it.

The new biological control agent *Eccritotarsus catarinensis* (Carvalho) (Het., Miridae), of South American origin and imported from South Africa in 1998, was maintained in the laboratory. In June 1999, 700 adults were released in Lake Azile near Agonve.

Table 3 - Shipment and release of natural enemies of water hyacinth by IITA, Benin in 1999.

Species	Date	Number	Country
E. catarinensis	22-06-99	700	Benin
N. bruchi	22-12-99	220	Congo Brazzaville
N. eichhornieae	22-12-99	220	Congo Brazzaville

7.4.4. Classical biological control of floating water weeds by means of specific insects: water lettuce
by P.N.

The weevil *Neohydronomus affinis* (Hustache) is maintained in culture at IITA. Regular surveys were continued to determine the spread and the impact on water lettuce. The weevil had spread about 70km from the release site in the Mono province of Benin in 1997, and 115km in 1999, reaching the Ouémé river.

In 1999, a close collaboration with the Ministry of Forests and Water Resources of Congo Brazzaville was established, resulting in a visit by an IITA scientist and training in Cotonou of a Congolese scientist. On 11 August 1999, 200 adult weevils were brought to the Congo and released near Oyo in central Congo and near Pointe Noire on the coast. From Oyo, the weevils were later collected and brought to Impfondo on the Ubangi.

Later in the year, *N. bruchi* and *N. eichhorniae* were also released in these sites. The main floating water weed proved, however, to be *Salvinia molesta.* Since this species does not occur in Benin, no rearing of the specific biological control agent *Cyrtobagous salviniae* Calder & Sands (Col., Curculionidae) was possible. Thanks to good collaboration among biological control specialists, this weevil could eventually be provided by the Plant Protection Institute of Pretoria, South Africa, and shipped directly to the Congo.

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Project 8

INTEGRATED MANAGEMENT OF LEGUME PESTS

by B. Asafo-Adjei, M. Ayodele, O. Coulibaly, K.E. Dashiell, C.A. Fatokun, W.N.O. Hammond, L.E.N. Jackai, B. James, M. Tamò (project coordinator), M. Tindo, K. Wydra
assisted by R. Adeoti, C. Agboton, R. Allomasso, J. Asiwe, A. Avocan, B. Datinon, B. Gbaguidi

Project rationale

The use of modified plants (resistant varieties), beneficial organisms (biological control), and a modified environment (cultural practices), or bio-intensive IPM, continues to be the thrust of our work in the management of the pest and disease problems on cowpea. In an ecosystem such as that of cowpea where the pest spectrum is complex and not likely to be kept under control (except with the use of pesticides), this approach is without doubt the most appropriate. Target insect pests are *Aphis craccivora* Koch (Hom., Aphididae), *Megalurothrips sjostedti* Trybom (Thys., Thripidae), *Maruca vitrata* (=*testulalis*) Fabricius (Lep., Pyralidae), *Clavigralla tomentosicollis* Stål (Hem., Coreidae), and *Callosobruchus maculatus* Fabricius (Col., Bruchidae). The most important diseases are brown blotch [*Colletotrichum* spp. Corda in Sturm. (Deuteromycotina, Coelomycetes)], anthracnose [*Colletotrichum lindemuthianum* (Sacc. & Magnus) Lams.-Scrib. (Deuteromycotina, Coelomycetes)], web blight [*Rhizoctonia solani* Kühn (Deuteromycotina, Agonomycetes)], ashy stem blight [*Macrophomina phaseolina* (Tassi) Goidanich (Deuteromycotina, Coelomycetes)], bacterial blight [*Xanthomonas campestris* pv. *vignicola* (Burkholder) Dye], cowpea aphid-borne mosaic virus (CAbMV), and cowpea golden mosaic virus (CGMV). Other viruses can also cause significant damage.

After wide consultations with the stakeholders, it appeared that a concerted effort focusing on a participatory approach to assemble the technologies for farmer testing, validation and adaptation in a location specific manner would be required to improve the adoption chances for cowpea IPM technologies. Consequently, IITA, with financial assistance from the Swiss Development Cooperation (SDC), initiated in 1994 the pilot phase of a regional project, PEDUNE (Protection Ecologiquement Durable du Niébé).

Through participatory processes and methodologies PEDUNE promotes collaborative cowpea IPM research and learning between IITA and the NARS partner scientists, attracts NGOs and farmers associations for participatory research and training, re-orients training and extension methods towards the farmer field school model, and enhances technology dissemination and adoption. The project further enhances capacity building to strengthen NARS capacity to conduct cowpea IPM research and strengthen national expertise through higher degree, specialized and bench training of scientists, extension agents and technicians. The project implementation is multi-disciplinary to encourage joint activities by scientists and extension agents, plan project operations, diagnose cowpea IPM problems, test, validate and implement technologies and evaluate technology and project impact. It involves sharing of regional expertise to pull human and material resources, promote exchange visits and short-term attachments, and increase effectiveness of project partners.

The pilot phase covered five countries: Benin, Burkina Faso, Mozambique, Niger and Nigeria. Evaluation report of the pilot phase revealed very promising results and formed the basis for PEDUNE extension to four new countries: Cameroon, Ghana, Mali, and Senegal. PEDUNE collaborating institutions in the countries include INRAB & SPV in Benin INERA & DPV in Burkina Faso, IRAD, CPS & University of Dschang in Cameroon, SARI, CRI & PPRSD in Ghana, IER in Mali, INIA in Mozambique, INRAN, DFPV & SPV in Niger, IAR, KNARDA, JARDA in Nigeria, and ISRA & DPV in Senegal. Collaborating partners include national extension services and targeted NGOs in the countries. A third phase, focusing on technology dissemination and impact assessment, should be soon co-financed by SDC and IFAD, though at a substantially reduced funding level as compared to the previous two phases.

In soybean, two diseases are key production constraints: frogeye leaf spot caused by *Cercospora sojina* Hara in West Africa, especially in Nigeria, and red leaf blotch caused by *Dactuliochaeta glycines* (Stewart) Hartman & Sinclair in Zambia and Zimbabwe. A new disease, soybean rust caused by *Phakopsora pachyrhizi* Syd. & P. Syd. has been causing outbreaks in Uganda, and more recently was also found in southwestern Nigeria. Research on frogeye leaf spot, soybean bacterial blight (*Pseudomonas syringae* pv. *glycinea*) and bacterial pustule (*Xanthomonas campestris* pv. *glycines*) focuses on seedborne aspects, like seed transmission and detection of seedborne infection, and is therefore dealt with in project 1.

Unlike in the past, severe yield losses in soybean are increasingly reported to be the consequence of the feeding activity of a complex of pod sucking bugs, and in particular the green stink bug *Nezara viridula* Linn. (Hem., Pentatomidae). It is therefore equally important to assess the extent of the problem, as well as to investigate the factors responsible for this change in pest status.

Outputs

8.1. *Cowpea and soybean lines with improved levels of resistance to insect pests and diseases*

Background

Plant resistance to insect pests and diseases will continue to be a major focus in the development of IPM on legumes. A wide range of wild and cultivated cowpea varieties have been shown to possess resistance to different pests and diseases. Among cultivated cowpea high levels of resistance are uncommon particularly to the post-flowering pests such as the pod borer, *M. vitrata* and *C. tomentosicollis*. High levels of resistance have been found to most pre-flowering and storage pests. New cowpea breeding lines are routinely evaluated at three locations (Ibadan, Mokwa and Kano in Nigeria) in different ecological zones for resistance to the borer and pod and seed sucking bugs. Many promising breeding lines were tested in rigorous experiments in 1999.

On-going and future activities

8.1.1. Evaluation of cowpea breeding lines under no insecticide spray.

by C.A.F.

Thirty cowpea breeding lines selected from crosses made between some improved varieties, land races and wild cross compatible cowpea relatives were evaluated at three locations: Ibadan, Mokwa and Kano. In addition, five of the several parental lines crossed to generate the segregating populations from where the selections were made were included as checks. They were planted at these locations so that the reproductive stages will coincide with when the population of Maruca pod borer was highest in the field. Hence planting was carried out at Kano in June, at Mokwa in August and at Ibadan in September. The 'no protection' plots were sprayed with insecticide which controls other pests except *M. vitrata* while those given full protection were sprayed with 'karate' three times. Karate is a broad spectrum insecticide.

Grain yield was highest at all the locations when the plants were given full insecticide protection (Table 1 and 2). Among the locations yield was highest at Ibadan followed by Kano and lowest at Mokwa. This observation further attests to Mokwa as the hot spot for Maruca pod borer. This location (Mokwa) remains appropriate for screening cowpea for Maruca resistance. Pod evaluation index (ipe) value was used to rank the cowpea lines and one selection from a farmer's field (IT91K-180) exhibited the highest ipe of 60. This line is early and uniformly maturing. Its seeds are however, generally small in size. The highest yielding line at Ibadan when plants were not protected against Maruca was 95M-22-1 with grain yield of 1757.4 kg/ha while 95M-305-2 had the lowest with 1128.7 kg/ha. Lowest grain yield (369.27 kg/ha) among the top ten performing breeding lines was obtained from 95M-73 at Mokwa.

An interesting observation from this study on the performance of several cowpea breeding lines is that none of them was best at all the locations. This is an indication of the existence of genotype x environment interaction in cowpea. The implication of this is that cowpea lines should be developed for specific niches for them to give their best yield.

8.1.2. Create soybean breeding populations using rust resistant parents and select among segregating progeny

by B.A-A.

Resistant lines previously identified through our collaborative research with NAARI in Uganda will be used as parents. Crosses will be made in the screen house at Ibadan and the F1s will be planted in the field at Ibadan. F2 populations and early generation lines will be planted at the IAR&T farm at Oniyo village near Ogbomoso, Oyo State. This is the village where the disease was first reported in Nigeria and the level of incidence and severity of the disease in the area makes it an ideal hot spot for our field screening/evaluation activities. We shall also use the area as one of the test environments for all multi location evaluations of the breeding lines selected from the rust resistant populations.

Table 1. Grain yield (kg/ha) and pod evaluation index (ipe) of top ten selected cowpea lines (Ibadan and Mokwa, 1999)

	Ibadan			Mokwa		
	No protection		Full protection	No protection		Full protection
Variety	**Grain yield**	**IPE**	**Grain yield**	**Grain yield**	**IPE**	**Grain yield**
91K-180 (CK)	1614.32	60.0	1858.74	1362.38	32.0	1204.31
95M-17	1459.66	58.0	1393.07	918.86	31.8	1592.27
95M-264-1-4	1322.69	56.2	1246.02	843.96	29.2	1554.06
TVU14476 (CK)	1873.70	56.2	1627.52	551.09	24.0	1422.69
95M-249-2	1432.48	54.2	1502.91	789.00	30.3	1300.65
95M-307-1	1223.53	52.2	1176.49	859.95	26.2	1146.54
95M-73	1335.63	52.2	1285.19	369.27	25.0	716.72
95M-21-1-1	1515.36	51.2	940.21	599.69	26.7	1030.70
95M-22-1	1757.40	50.7	2111.94	588.83	28.7	1422.81
95M-7	1526.19	50.7	2261.99	431.02	25.7	733.01
95M-305-2	1128.74	47.5	1241.05	1188.50	31.0	1218.62
95M-22-3	1508.88	47.2	1355.12	648.58	24.5	1190.06
86D-719 (CK)	1486.39	40.9	1688.22	262.01	11.5	1464.71
89KD-288 (CK)	1807.24	39.2	993.20	385.69	16.7	1230.60
Mean	1499.44	51.21	1548.69	698.30	25.9	1229.28
CV	35.06	13.66	41.55	37.16	28.1	21.09

Table 2. Grain yield (kg/ha) and pod evaluation index (ipe) of top ten selected cowpea lines (Kano and Mokwa, 1999)

	Kano			Mokwa		
	No protection		Full protection	No protection		Full protection
Variety	**Grain yield**	**IPE**	**Grain yield**	**Grain yield**	**IPE**	**Grain yield**
95M-75	836.75	41.2	1252.38	517.68	28.5	779.26
91K-180 (CK)	787.83	40.2	926.38	805.16	29.2	746.10
95M-305-2	955.85	40.0	755.11	587.20	23.7	852.06
95M-303	956.84	37.5	958.53	755.12	26.5	962.56
95M-21-1-1	998.58	36.7	1326.77	511.54	29.7	1007.89
95M-311-1	707.59	35.7	919.82	708.82	30.7	1031.25
95M-305-1	1019.11	35.5	954.83	1029.74	28.0	1081.12
95M-13	1363.38	35.5	1566.12	745.16	27.0	1168.30
95M-268-1-4	1408.48	35.0	2443.12	583.97	28.5	1090.85
95M-249-2	995.48	34.7	859.99	747.98	29.7	1142.64
95M-22-1	1044.27	31.7	1053.67	651.79	27.7	621.03
86D-715 (CK)	1314.86	30.5	1137.58	755.16	21.5	1331.59
TVU14476 (CK)	953.82	28.2	1113.68	374.43	29.7	483.13
86D-719 (CK)	1007.55	20.2	1637.37	874.92	13.7	1479.94
Mean	1025.03	34.5	1207.52	689.19	26.7	984.12
CV	28.29	17.0	26.08	33.54	20.9	39.29

8.2. *Identification of new sources of resistance to key pests and diseases, or novel genes/ gene products*

Background

The development of resistant cultivars is a dynamic process that requires constant addition of new resistant germplasm. Given the present scenario in which the level of resistance in both cowpea and soybean is inadequate, work has been going on to identify new sources in order to expand the resistance base. New germplasm from a wide variety of sources is evaluated each cropping season. This work is fundamental to the development of new cultivars with better levels of resistance to the important pest problems. Parallel research is in progress to search for foreign genes to use in the transformation of cowpea. Already, transformation of cowpea with the bacterial gene, *Bacillus thuringiensis* Berliner has been initiated (see Project 1 for details).

On-going and future activities

8.2.1. Mechanisms and basis of resistance of cowpea varieties to the flower thrips

by J.M., M.T. – in collaboration with O.Y. Alabi

On the susceptible control cultivar (Vita7), the survival of the developmental stages of *M. sjostedti* was higher than on the resistant cultivar, TVu1509. On Vita7, 80% of the individuals survived to the adult stage, while on the rest of the cultivars the preadult survival was between 0 – 38%. The second larval stage is most critical for all cultivars except KVx404-8-1, IT90K-277-2, Kpodjiguegue Vita7 and TVx3236. Most individuals died during this second larval stage. By the pupal stage all the insects had died except in TVu1509, Moussa Local, Kpodjiguegue, and IT90K-277-2 that recorded survival of 5 – 38%. Death of larvae indicated that the plants were not suitable for the growth of the insect, which is an indication of antibiosis. Insects that fed on Vita7 (SC) and Kpodjiguegue survived to the adult stage. A growth index for the development of *M. sjostedti* on the floral structures of cowpea varieties was conducted. All cowpea varieties having suitability indices less than 0.15 were considered resistant to infestation by *M. sjostedti*. These varieties are: IT90K-277-2, KVx404-8-1, Moussa Local, Sanzisabinli, Sewe, TVu1509, TVx34236, and IT91K-180. The Growth index of these varieties was 0 because the larvae did not develop into adult stage. Floral buds of Vita7 and Kpodjiguegue were highly suitable for the development of the thrips.

8.2.2. Evaluation of phenylalanine ammonia lyase (PAL) activity in cowpea cultivars

by J.M. – in collaboration with O.Y. Alabi

The onset of heavy thrips infestation is normally observed in conjunction with high level of primary metabolites. This also leads to increases in the level of secondary metabolites and the associated activity of such enzymes as phenylalanine ammonia lyase (PAL), tyrosine ammonia lyase, peroxidase (PO) and polyphenoloxidase (PPO) mediating the mobilization of such compounds as the phenolic acid. Determination of PAL content in three weeks old plants was undertaken. Out of the ten cultivars, Sanzisabinli had the highest concentration of this enzyme. This suggests that the cultivar produce large quantities of secondary metabolites, which are deterrents to insect feeding. Work is still going on to determine PAL concentrations in four weeks old plants, floral buds, racemes and flowers in the ten cultivars.

8.2.3. The seed proteins of African yam beans (*Sphenostylis stenocarpa*)

by J.M. – in collaboration with O.G. Okeola, I.O. Fasidi*

One (1-D)- and two- (2-D), dimensional sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) was used to resolve proteins extracted from seeds of the African yam bean (*Sphenostylis stenocarpa*). Total protein extracts separated using size exclusion chromatography on Biogel P100 contained at least five highly prominent and abundant polypeptides. Under reducing(1-D) SDS-PAGE conditions, only two major albumin polypeptide bands (30 and 18 kDa) were visualized, in comparison to seven prominent globulin bands which were resolved at 6.5, 18, 22, 27, 34, 49, 59 kDa. Native (1-D) PAGE, under both reducing and non-reducing conditions, led to a reduction in the number of globulin bands resolved on acrylamide gels. Based on the measurement of isoelectric points on 2-D gels, it was concluded that most of the seed proteins are acidic. A comparison of albumin fractions from AYB, cowpea, common bean, lima bean, jack bean, velvet bean and pea revealed that each of these legumes has its own distinctive seed albumin profile.

8.2.4. Phenylalanine ammonia-lyase from African yam bean, cowpea and *Vigna vexillata*
by J.M.

Phenylalanine ammonia-lyase (PAL) is the primary enzyme involved in metabolism of secondary metabolites in plants. These compounds in turn play a key role in the defense mechanisms of plants against pests and pathogens. This paper reports the endogenous activities of PAL in African yam beans (AYB) (*Sphenostylis stenocarpa*), cowpea (*Vigna unguiculata*) and *Vigna vexillata* (accession TVnu 72) grown in Nigeria. PAL activity was highest in a cowpea accession from Ghana (Sanzi) that is also highly resistant to thrips. Moderate or low levels of PAL were observed in AYB, TVnu 72 (resistant to most cowpea insect pests) and Vita 7, a cowpea cultivar that is susceptible to several pests, including thrips. AYB PAL was purified by ammonium sulphate fractionation, DEAE-Sephacel column chromatography and preparative native polyacrylamide gel electrophoresis. As a first step towards the characterization of genes encoding PAL, degenerate PCR primers were used to amplify a genomic PAL clone from AYB. These results are discussed against the background of the role of PAL in plant defense and the potential for genetic manipulation of this key enzyme to achieve resistance against pathogens and insect pests of cowpea.

8.2.5. Screen IITA soybean breeding lines and introduced germplasm for rust resistance.
by B.A-A.

In order to identify resistant lines to be used for the hybridization program, about 100 elite lines from our program and 20 exotic germplasm from AVRDC, Uganda and Zimbabwe will be planted in the field at Oniyo. Lines will be rated for disease incidence and severity using a 0 - 5 scale (0= No rust spots on leaves; 5=severe infection, <90% of leaves become chlorotic, leave abscission).

8.3. Biological control of major cowpea and soybean pests and diseases

Background

The results of past and on-going studies let us assume that both *M. sjostedti* and *M. vitrata* might not be of West African origin. This could be the main reason why the locally present natural enemies are found to be poorly adapted and inefficient in controlling the pest populations. In the past, this inefficacy of the naturally occurring antagonists had lead to the conclusion that biocontrol was not a viable strategy. Now, in the light of the facts that two of the key insect pest might indeed be of foreign origin, classical biocontrol becomes an option, whose feasibility needs to be tested. Thus, the first step is to identify the area of origin of the pest, and conduct foreign exploration for efficient natural enemies there. After obtaining of import permits, the most promising candidates are evaluated under lab and greenhouse conditions.

The cowpea field is an unstable, man-made ecosystem, surrounded by more stable, natural habitats which can serve as breeding sites for cowpea pests during the dry season, but also as a refuge for their natural enemies. The interactions between these two systems influence the dynamics of pests and related antagonists; both must be considered when technologies to improve agricultural practices are being developed.

A similar approach is used for evaluating the feasibility of biocontrol against major soybean pests.

On-going and future activities

8.3.1. Comparison of the efficacy of Benin vs. Asian strains of *C. menes* as biocontrol candidates against flower thrips
by M.T. - in collaboration with K. Diop, J. Ayertey*

Two strains of *C. menes* form India and one from Peninsular Malaysia were compared to the Benin local strain in terms of efficacy of parasitizing the bean flower thrips *M. sjostedti*. A series of 3 laboratory experiments simulating the natural chronological sequence of events during the parasitization process were conducted. The first experiment studied the behavior of host thrips larvae and *C. menes* parasitoid at the host selection phase. For this, parameters have been defined, and determined for host resistance, host acceptance, and host handling time, from the various reactions of the host larva, and the wasp.

Generally, it was found that one and two days old larvae were slightly faster to handle, and also significantly less resistant, and more likely to be accepted by all strains of *C. menes*. Thus larvae from these two age groups were used to maximize parasitization success in the subsequent tests.

The results of this investigation indicated that there were in fact biological differences between the four strains of *C. menes*, on *M. sjostedti* host. There were significant differences between strains in the

sub-components, but no difference in the overall host handling time. The average host handling time for the Malaysian, the two Indian strains, and the local strains were respectively 27.4, 29.0, 25.8, and 31,6 seconds. The acceptance of *M. sjostedti* was definitely more successful with the local than with the exotic strains. In fact, 25% of the non resistant larvae were accepted by the local strains for oviposition. The acceptance decreases in the order, the two Indian strains with 3.3%, and 4.7%, and the Malaysian strain for which it was practically null (0.4%).

Thus, this study revealed that at the host selection phase of the parasitization process, the behavior of the local strain was the most compatible for a successful parasitization of *M. sjostedti*. This could be explained by the longer history of co-existence of the two organisms. However, at the physiological test, the suitability of *M. sjostedti* was found to be practically null for the local strain, as well as for the second Indian strain. Their survival rates (proportion of eggs that survive up to adult stage) in this thrips species was estimated at 0.06 for both strains. unexpectedly, it was significantly higher (0.36) for the first Indian strain. After the second test, it came out that none of the strains, including the local strain, would be able to parasitize successfully *M. sjostedti*. Each of them was hampered by behavioral and/or physiological incompatibility with this thrips species. This was confirmed by the results of the 3rd experiment concerning their life history. In fact, each of the 4 populations of *C. menes* was unique in the biological features it exhibited when *M. sjostedti* was offered as host. This could be an onset of biotypes differentiation among the 4 populations of this species of parasitoid.

While the west African *C. menes* shows physiological incompatibility, one of the Indian stains might be more suitable if it can overcome behavioral incompatibility at the host handling level.

8.3.3. Pre-release assessment of locally available thrips parasitoids

by M.T – in collaboration with A.B. Salifu, T. Cudjoe

Pre-release surveys to assess both thrips species composition and their associated natural enemies on cultivated and wild Leguminosae were carried out between March and August 99 starting from the coastal savanna of Ghana throughout the Sudan savanna of Burina Faso. During the long dry season, *M. sjostedti* was, as expected, the most common thrips species found in the flowers of the various legume host plants, followed by *Frankliniella shultzei* Trybom. In the coastal savanna, major host plants were *Centrosema pubescens*, *Pueraria phaseoloides* and *Lonchocarpus* spp., mostly found in wetlands and around creeks. The first two plants were also very common in the forest area, particularly on forest margins, but disappeared completely north of Techiman. In the north, the tree *Pterocarpus santalinoides* was the major host plant for *M. sjostedti* during the dry season, especially along all affluents of the Volta watershed system. During the rainy season, apart from cowpea, the tree *Piliostigma* spp. was the most important host plant throughout the savanna. Among the natural enemies, the parasitoid *C. menes* could be found in low numbers only, with exception of samples collected from *P. santalinoides* in the forest zone, where surprizingly high numbers could be observed. During the rainly season, *C. menes* could be observed in all agro-ecological zones where the survey has been conducted. It is noteworthy to mention that, apart from *C. menes*, no other larval parasitoid could be observed. while *Orius* sp. was the most common predator.

These surveys are considered important for providing baseline data on the presence of both *M. sjostedti* and *C. menes*, and for assessing the impact of the newly released parasitoid *C. femoratus* Gahan (Hym., Eulophidae) (see 8.3.5).

8.3.4. Monitoring the distribution and impact of *C. femoratus* in Cameroon

by M.T., M.Ti.

Surveys to monitor the presence and impact of the thrips parasitoid *C. femoratus* encountered for the first time around the Yaoundé area in 1998 also continued in 1999. This parasitoid could be found along the road to Sangmélima in the south, and along the road to Bertoua just before the town of Abong Mbang in the East, about 150 km from Yaoundé. So far, it could be recovered from *M. sjostedti* larvae feeding in flowers of cowpea, *C. pubescens*, *P. phaseoloides*, *Tephrosia candida*, *Dioclea guianeensis* and *Milletia* spp. Apparent parasitism rates average 20%, with peaks over 60%.

8.3.5. Experimental releases of *C. femoratus* in Benin and Ghana

by M.T. – in collaboration with J. Sagbohan, M. Noudofinin, G. Dixon, T. Cudjoe

The first experimental release of *C. femoratus* was carried out in July 1999 at the IITA-Benin station in Agounkamey on two plots of *Tephrosia candida* using 100 adult females. While on the plot located in the moister area *C. femoratus* could be recovered already after two generations, on the other plot it

disappeared and could not establish at all. Possibly because this second plot was located on a poorer soil and *T. candida* was attacked by various homopteran (including the cowpea aphid *Aphis craccivora*), different species of ants (mostly *Crematogaster* sp.) were observed attending to the homopteran, and thus preventing the build-up of large thrips populations. In fact, there were only very few *M. sjostedti* larvae in the flowers of this plot, which might not have allowed the establishment of *C. femoratus*.

The second experimental release was carried out late October at two different locations in southern Ghana, Fette Buduatta on the road to Winneba, and at the PPRSD station in Pokuase. A total of over 150 adult females and 80 pupae of the parasitoid were released on patches of *C. pubescens*. Both places will be monitored very closely to detect establishment and possible dispersal.

8.3.6. Host plant-natural enemies interactions

by M.T. - in collaboration with D. Arodokoun, N. Zenz, C.P.W. Zebitz*

On-going studies in the moist savanna are focusing at the importance of alternative host plants both as a reservoir for major pests and also as a possible source of natural enemies. The hypothesis to be tested is whether the antagonist complex on the natural vegetation is more diverse and/or more efficient than the one present on cowpea. Although data collected and analyzed so far indicate a shift in parasitoid guilds from herbaceous legumes to trees, it is still too early to draw definitive conclusions. This is part of a long term study which is on-going at the forest margin benchmark area in Cameroon.

The influence of NPK application and mulching with leaves of *Senna siamea* (Caesalpinaceae), *Imperata cylindrica* (Poaceae), *Azadirachta indica* (Meliaceae) on the population dynamics of both *M. vitrata* and *M. sjostedti* is studied in three regions of Benin, IITA Station, Cotonou (on-station), Allada (on-farm) and Dassa (on-farm). Possible effects on the parasitization rate by the respective parasitoids, *Trichogrammatoidea* sp., *P. leucobasis* and *Braunsia* sp. on *M. vitrata*, and *C. menes* on *M. sjostedti* are also taken into consideration. Sampling is carried out in repeated measures design to allow for analysis of time effect of treatments. The data collected over 3 years are being analyzed.

Five monitoring sites are set up in farmer's fields (Lama Forest, Bonou, Nikki, Karimama, Materi) to study population development on a north-south gradient and work out particularities for the different regions. Dry season and wet season cropping is compared with regard to population dynamics.

8.3.7. Evaluation of a viral pathogen *Maruca vitrata*

by M.T. - in collaboration with A. Cherry

A short project awarded by DFID Crop Protection Programme allowed us to conduct first tier laboratory evaluations of a virus recently found to be infecting *M. vitrata* in the field in Benin. Scanning electron microscope studies, gel electrophoresis of the viral genome and gross larval symptomology identified the agent as a cytoplasmic polyhedrosis virus (CPV) (Reoviridae). Members of this group which are pathogenic to Lepidoptera only infect cells of the midgut, typically cause chronic rather than lethal disease, and are transmitted vertically from one generation to the next. Infected adults may be dysfunctional or have reduced viability/fecundity. Virus production studies gave a maximum virus yield approximately 5×10^7 occlusion bodies/larva representing a 5000-fold return on inoculum. Those larvae which died did so two to three weeks after inoculation. Larger larvae tended to survive infection, successfully pupate, but often develop into abnormal adults. The dose-response relationship is a weak one because of the chronic nature of the virus. Further studies will be undertaken to evaluate the geographic and temporal distribution of the virus in Benin, the longer term impact of infection on individuals and populations, and the options for integrating this virus into an IPM programme for *M. vitrata* (see project 7).

8.3.8. *Metarhizium anisopliae* for control of flower thrips

*by M.T. - in collaboration with A. Cherry, A. Ngakou**

Under a 1998 strain release agreement between IITA and the International Centre of Insect Physiology and Ecology, IITA received a sample of a thrips active isolate of *Metarhizium anisopliae*, ICIPE 69. Following successful laboratory evaluation in 1998, the isolate was field tested against *Megalurothrips sjostedti* in cowpea during on-station trials at IITA, using a protocol supplied by ICIPE. *Metarhizium* was as effective as the standard chemical insecticide, and more effective than papaya leaf and neem extracts at controlling thrips and protecting yield (see project 7). Similar experiments are also planned in different ecological zones of Cameroon, in conjunction with the application of Endomycorrhizae and Rhizobia as biological fertilizers.

8.3.9. Inventory and impact assessment of locally available antagonists of soybean pests

*by M.T., L.E.N.J. - in collaboration with L. Kumbe**

Eggs of *N. viridula* collected from soybean fields in Ibadan, Mokwa, and different localities in Benin showed, as already observed in the past years, a high incidence of parasitization by *Trissolcus* sp. (Hym., Scelionidae). In Ibadan, larvae of the leaf roller *Lamprosema indicata* (F.) (Lep., Pyralidae) were parasitized by *Brachimeria* spp. (Hym., Chalcididae). Among the predators attacking the larvae of *L. indicata*, the most prevalent ones were *Paederus sabaeus* Erichson (Col., Staphylinidae), and *Eurystyllus rubroscutellatus* (Odhiambo) (Het., Miridae).

It was observed that, apart from *N. viridula*, there are other pod sucking bugs attacking soybean in West Africa, such as the pentatomid *Acrosternum* sp. and the coreid *Riptortus dentipes* (Fabricius). On-going studies are presently investigating the natural enemy complex of these pests.

8.3.10. Identification of antagonists against *M. phaseolina* and test of their rhizosphere competence in pot experiments

*by K.W. - in collaboration with G. Wolf, L. Afouda**

The antagonistic activity of 13 bacteria was tested *ad planta* by soaking cowpea seeds in suspensions of antagonists (approximately 1.7 x 10^9 CFU/ml of 0.1% $MgSO_4$) prior to sowing into soil inoculated with *M. phaseolina*. The tested antagonists exhibited variable potential to control charcoal rot, ranging from not satisfactory (A2, B8, B10, C7, C16, C17, C18) and averagely promising (A9, B6,C19, C28) to very good (A11). The *Bacillus subtilis* isolate A11 was selected as the most promising. Plants infected with *M. phaseolina* and treated with *Bacillus subtilis* A11 showed the lowest disease incidence (13%) and the highest percentage of germination (70%), as compared to 72% disease incidence and 40% germination for controls inoculated only with *M. phaseolina*. The efficiency of *Bacillus subtilis* A11 *ad planta* was confirmed by the disease assessment with ELISA. A high inoculum level (E_{405} = 0.74) of *M. phaseolina* was detected in plants inoculated with *M. phaseolina*, without antagonist treatment (K+), whereas inoculum level of *M. phaseolina* in the plants treated with *Bacillus subtilis* A11 was low (E_{405} = 0.24).

The ability of *Bacillus subtilis* to colonize the plant surface was studied by using a spontaneous rifampicin-streptomycin-mutant (A_{11}^{m}) of *Bacillus subtilis* A11. Applying *Bacillus subtilis* A_{11}^{m} to seeds before sowing, high population densities (2.7 x 10^6 CFU/g) of the mutant were recorded on the roots up to 4 weeks after sowing. On the hypocotyl, bacterial populations were high at the end of the 1st week (1.1 x 10^6 CFU/g), but decreased significantly after the 3rd week .

8.4. Evaluation of plant-based insecticides against field and storage pests of cowpea and soybean

Background

The effects of insecticide misuse around the world include costly environmental pollution and disruption of the balance of nature. Africa has in general escaped this treadmill. Insecticides have been found to increase cowpea yields over tenfold; soybean, which has fewer pest problems is not so dependent on insecticides as cowpea. Another problem with synthetic insecticides is their high cost and inaccessibility. While we concede that the high yields obtained with insecticides cannot presently be obtained with any other control strategy, we believe acceptable grain and fodder yields will be possible using alternative insecticides derived directly from plants, in combination with other insect control methods. Past and on-going studies suggest that this is possible using insecticides from the neem plant. The efficacy of neem insecticides against field and storage pests of cowpea and soybean will be evaluated at the pest species level, and proper recommendations developed for its use. Ease of preparation and lack of disruption of the natural balance between pests and their natural control agents are the motivating reasons for this work. Although neem is primarily used as an insecticide and nematicide, it has been reported to have some fungicidal action, therefore, disease severity is being assessed in trials using neem to control insect pests on cowpea.

On-going and future activities

8.4.1. Field efficacy of neem and other plant-based insecticides on cowpea pests

by W.N.O.H., M.T., L.E.N.J. - in collaboration with T. Adam, D. Arodokoun, A. Emechebe, A.B. Salifu, D. Seck, M. Touré

On-farm trials in Benin, Ghana, Niger, Mali, Nigeria, Burkina and Senegal confirmed that spraying cowpea with ULV formulations of neem leaf extract (15 kg /10 l water) could double yields. Similar results were also obtained on-station in Cameroon, Mozambique.

Extracts from papaya leaves at the same dose as neem gave slightly better results than neem in two PEDUNE pilot sites in Benin where over 120 farmers were involved in the trials.

8.4.2. Insecticidal and antifeedant properties of *Khaya* spp.

*by W.N.O.H., M.T. – in collaboration with O.M. Osanyi**

Leaf and bark extracts of the forest trees *Khaya anthotheca* and *K. grandifolia* proved to have same insecticidal and anti-feedant properties as neem on *M. vitrata*. The development of first instar larvae reared on treated flowers of susceptible cowpea was significantly inhibited as compared to the control. In choice assays, the larvae refused to eat the treated parts of pods, while in no-choice assays, acute toxicity was observed. Also, the fecundity of adult females emerged from the few larvae that survived was greatly reduced. This could be related to the observed disturbances in total lipid concentration. Adult insects that emerged from the larvae feeding on treated pods has deformed wings, and many larvae died just before pupation. It remains to be investigated whether the insecticidal compounds can also be extracted from the seeds of *K. anthotheca*, *K. grandifolia*, *K. ivorensis* and *K. senegalensis*.

8.5. New knowledge on biology and host plant-environment interactions

Background

The first step in trying to control a given pest or disease is to gather detailed information on which part of the life cycle the organism is most susceptible to a particular control method. Although, much is known about most cowpea and soybean pests and diseases, large gaps in knowledge still exist, particularly on the interactions of the pest/pathogens with the host plant and the environment, which prevents us from properly focusing our control strategies and allow for failure of pest/disease control by current methods.

On-going and future activities

8.5.1. Testing synthetic pheromones for *M. vitrata*

by M.T. – in collaboration with M. Downham

A new collaborative project with NRI was started in July, to complete optimization of the design and operation of pheromone traps for *M. vitrata* (started as a pilot project in 1998), and to integrate their use with other novel IPM technologies to provide improved methods for control by small-holder cowpea farmers in West Africa. The project also aims to provide a better understanding of the population dynamics, ecology and behaviour of *M. vitrata*, based on long-term monitoring with pheromone traps; this will aid the further development of sustainable control methods.

Unusually for synthetic pheromone lures, the traps for *M. vitrata* have previously caught a variable proportion of females. As in 1998, that proportion of females appeared to increase through the period July to November. This might in some way be related to catches earlier in the season being of immigrant individuals, while later on they are probably of individuals who have pupated/eclosed very close to their point of capture.

A trap height experiment showed that 120 cm was most effective (better than 20, 70 or 170 cm). A trap design experiment had compared a conventional sticky, delta trap with 3 designs produced from locally purchased materials: a 5 liter plastic jerry-can, a 2 liter jerry-can and a 1 liter plastic bottle – all using water as the trapping agent. Of these the two jerry-cans were clearly superior to the others. A lure age/shielding experiment showed no effect of shielding (using aluminum foil wrapped around the lures) for lures aged up to 6 weeks under field conditions, in sticky, delta traps. Catches by lures aged 0-2 weeks and 2-4 weeks were similar, but those with 4-6 week old lures were reduced by about 50%.

A third pheromone blend experiment compared the effect of varying levels of one of the minor components, (E)-10-16:Ald. It showed clearly that the blend which has come to be regarded as 'standard' – major and two minor components in the ratio 100:5:5 - was the most effective. Traps baited with

lures containing the other two components together with (E)-10-16:Ald at 0%, 0.05% or 0.5% caught fewer than half the moths trapped using lures containing the monoene at 5%.

Another lure age comparison seems appropriate – this time to be carried out in the 5 liter jerry-can traps (which may expose the lures to sunlight to a greater degree than the delta traps), with unshielded lures in the age ranges 0-1, 1-2, 2-3 and 3-4 weeks. The purity of pheromone blend components will be an important determinant of their cost. To determine how critical chemical purity is to trap catches, a further experiment was proposed which will compare lures with the >99% pure components used hitherto with three lower levels of purity – the lowest being the equilibrium ratio. It may also be useful to determine the effect of frequency of checking traps. In trapping experiments this has been done daily, but this may not be feasible or desirable for farmers (or researchers) in the longer term.

8.5.2. The nutritional ecology of *Maruca vitrata*: development on pods of wild and cultivated *Vigna* species.

by L.E.N.J. – in collaboration with N.O. Oigiangbe F.K. Ewete, L. Lajide*

Demographic parameters and fecundity of *Maruca vitrata* were studied on artificial diet and pods of some wild and cultivated *Vigna* species to determine their resistance to the insect. The constant growth ratios of the head capsule width were significantly ($P < 0.05$) higher during molting from second to third instar than from first to second, third to fourth and fourth to fifth instars. Larval weight and the head capsule width were linearly related in all the treatments but only those of IT89KD-457, VICAM-1 and IT91K-180 had significant ($P < 0.05$) coefficients of determinations ($Y = 0.0311 + 0.4781$, $Y = 0.0342 + 0.4812$, $Y = 0.0298 + 0.4680$, respectively). Pupal weight, growth and development indices, percentage adult emergence and fecundity were highest on artificial diet followed by pods of cultivated cowpea and least on *V. vexillata* and *V. oblongifolia*.

Larval weight predicted survival, pupation, adult emergence and fecundity more accurately than other demographic parameters studied. The eigenvalue of the principal component analysis revealed that 86.53 per cent of the total variance in these demographic parameters were explained by three principal components. A plot of the second against the first of these principal components grouped the pods into four levels of suitability. TVnu 42, TVnu 957, TVnu 594, TVnu 979 and TVnu 863 (group 1) were unsuitable, TVnu 72 (group 2) fairly suitable, Moussa Local, IT89KD-457 and VICAM-1 (group 3) suitable, while IT84S-2246, IT91K-180 and TVu 13731 (group 4) were very suitable for larval development, growth and survival.

8.5.3. Evidence of reduced consumption and utilization of pods of wild *Vigna* species by *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae).

by L.E.N.J. – in collaboration with N.O. Oigiangbe F.K. Ewete, J.d'A. Hughes, L. Lajide*

The consumption and utilization of pods of some *Vigna* species by *M. vitrata* were investigated in the laboratory under ambient temperature of $25 \pm 2°C$ and 60 ± 20 % relative humidity. The effect of some morphological and anatomical characteristics of the pods on their nutritional status was also assessed. Larval weight gain on pods of IT84S-2246 (5.20 mg) and TVu 13731 (4.30 mg) was significantly ($P < 0.05$) higher than on pods of TVnu 863 (3.00 mg), IT91K-180 (2.50 mg), TVnu 42 (2.50 mg) and TVnu 72 (0.10 mg). The RCR and RGR were significantly ($P < 0.05$) lower on TVnu 72 pods compared with other treatments while AD was significantly ($P < 0.05$) higher on pods of IT91K-180, TVnu 42 and TVnu 863 compared with other treatments. There was no difference between treatments for ECI and ECD. Significant ($P < 0.05$) positive correlations were found between weight gain and ECD ($r = 0.8972$), RCR and RGR ($r = 0.8877$), as well as RGR and ECI ($r = 0.8430$). The density of glandular trichomes on pods of TVnu 72 was significantly ($P < 0.05$) higher than on pods of IT84S-2246 and TVnu 863. The density of non-glandular trichomes was similar among treatments, but these trichomes were significantly ($P < 0.05$) longer on pods of TVnu 72 than on other *Vigna* species. There were significant ($P < 0.05$) negative correlations between the length of the non-glandular trichomes and RCR ($r = -0.8482$), RGR ($r = -0.8413$) and ECI ($r = -0.8228$). Of the 3 to 4 different layers of cells found in the pod wall of the *Vigna* species, thickness of the fourth (innermost) layer (endocarp) had significant ($P < 0.05$) negative correlation with RGR ($r = -0.8430$) and ECI ($r = -0.8453$). Similarly, the thickness of the entire pod wall had a significant ($P < 0.05$) negative correlation ($r = -0.8333$) with larval weight gain. The implications of these findings in developing effective host-plant resistance strategies in cowpea against *M. vitrata* are discussed.

8.5.4. Screen locally available fungicides for their efficacy in controlling *P. pachyrhizi*
by B.A-A.

At least 5 fungicides, commonly available on the Nigerian market, will be evaluated for their efficacy in controlling the newly encountered soybean rust disease. The study will be conducted at Oniyo. Three soybean varieties will be used in the study. Yield loss assessment will also be made.

8.5.5. Studies on effect of variety and planting dates on incidence and severity of *P. pachyrhizi*
by B.A-A.

Early, medium and late maturing soybean varieties will be planted at 2 and 4wks before and after the normal planting period at Oniyo, and compared with planting at farmers' usual planting period (i.e. 3 varieties and 5 planting dates). Rust disease incidence and severity ratings, yield and other agronomic data will be taken.

8.6. Ecological and economic benefits of integrating IPM components

Background

Cowpea and soybeans have more than one major pest each. Over the years, different methods of pest control have been developed, and some tested on cowpea and soybeans. Individually, each control method may control only one pest, thus requiring other controls for use against the other pests. Emphasis in the past was on plant resistance, but now there are other control methods that need to be used in conjunction with host plant resistance and little or no input from synthetic insecticides. Different combinations of control methods are possible under different conditions. We will determine those combinations that can be used for different sets of conditions as guidelines, but leave the location-specific fine tuning to our colleagues working in the various locations where application will be made.

On-going and future activities

8.6.1. Effect of sowing date and intercropping of cowpea with maize or cassava on symptom development by cowpea bacterial blight
*by K.W. in collaboration with R. Sikirou**

Data on sowing date and intercropping of cowpea with maize or cassava were analyzed. Two cowpea varieties susceptible to Xcv were used to test the effect of sowing date on symptom development of cowpea bacterial blight. The local variety Kpodji from Benin was used in the FST (Forest Savanna Transition) zone and the IITA variety IT84D-449 in the dry savanna. Seeds were sown on 30 May and 9 August, respectively. Three sowing times at the interval of 2 weeks and 2 infection times at the interval of 3 weeks beginning 3 weeks after sowing were used. The result revealed that in the FST zone and in case of an early infection, early sowing, and in the dry savanna zone late sowing significantly reduced the severity of cowpea bacterial blight by 63% as compared to the regular sowing in FST zone and 40.1% as compared to the early sowing in the dry savanna. In case of the late infection, late sowing significantly reduced the disease severity in the FST zone by 46% as compared to the early sowing. In the dry savanna the sowing time had no effect on symptom development when infection was late.

The effect of maize and cassava intercropping on symptom development in cowpea variety IT84E-124 were tested. Seven cropping systems as treatments replicated 3 times were used in a randomized complete block design. The treatments were the following: T1- Cowpea monoculture at high density at a spacing of 60 x 25 cm (66666 plants/ ha); T2- Cowpea monoculture at low density at a spacing of 50 x 50 cm (40000 plants/ ha); T3- Cowpea-maize within row at a spacing of 50 x 50 cm for cowpea and 50 x 50 cm for maize; T4- Cowpea-maize in alternate rows at a spacing of 50 x 50 cm for cowpea and 60 x 50 cm for maize ; T5- Cowpea-cassava in alternate rows at a spacing of 100 x 100 cm for cassava, 50 x 50 cm for cowpea; T6- Maize monocropping at a spacing of 60 x 40 cm (41666 plants/ha); T7- Cassava monocropping at a spacing of 100 x 80 cm (12500 plants/ha). In 1996 the analysis of variance of the disease severity showed a significant difference between treatments only 21 days after sowing (P=0.006). The mixed cropping significantly reduced the disease severity at 21 days after sowing as compared to cowpea monocropping at high density. For disease incidence, the analysis of variance did not show any significant difference with P= 0.29, P= 0.40 and P= 0.25 at 21, 36 and 51 days after sowing. The mixing of cowpea with maize or cassava did not significantly reduce the disease incidence. In 1997, the analysis of variance did not show a significant difference during the trial in disease severity with P= 0.23, P= 0.34 and P= 0.24 at 21, 36 and 51 days after sowing, respectively. The disease

severity was low in all mixed plots and the plots with cowpea at low density as compared to plots with cowpea monocropping at high density. But, the differences were not significant. The disease incidence was significantly reduced only in cowpea -maize row and cowpea-cassava alternate row variants (P= 0.047) and (P= 0.008) at 21 days after sowing as compared to monocropping of cowpea at high density. The incidence remained low in mixed plots, but with non-significant differences. The cropping system cowpea-cassava in alternate row seemed to reduced the disease incidence; these trials should be repeated to receive clearer results.

8.6.6. Detection of *X. campestris* pv. *vignicola* (*Xcv*): Production and testing of a monospecific

by K.W. - in collaboration with K. Rudolph, G. Khatri-Chhetri *

Polyclonal, monospecific antisera may be more specific than polyclonal, polyspecific antisera for detection purposes. Specific proteins for *Xcv* were searched by SDS-PAGE, native (SDS) PAGE and Western blot, using various homogenous and gradient gels and gel thickness. A specific protein for *Xcv* could not be found by using denatured protein in the SDS-PAGE system. Some denatured proteins of *Xcv* were found also in other bacterial species and other pvs. of *X. campestris*, but not in *X. campestris* pv. *malvacearum*. Separating native proteins in a native (SDS) PAGE system (the whole system was native except that SDS was used in electrophoretic buffer) using 7.5% acrylamide, a protein of ca. 60 kD of the Xcv strains 28a1g, 31 and 536a1g was found specific to *Xcv*, but not to *X. campestris* pvs. *glycines*, *malvacearum* and *phaseoli* and other species. The specific protein of the strain 28a1g was eluted from the gels and used for polyclonal, monospecific antiserum production. Immunization of rabbits, blood drawing and extraction of antisera are under process.

8.7. Enhancing the capacity of NARES and farmers to develop, implement and disseminate IPM technologies

Background

The implementation phase of the PEDUNE project (Protection Ecologiquement Durable du Niébé), which aims at increasing the production of cowpea in the sahel and savanna regions of Africa, by assembling ecologically and economically sustainable cowpea protection strategies that can be implemented by subsistence farmers, was inaugurated in 9 countries at the beginning of 1997. The original 5-year workplan was reduced to 3 as a result of funding limitations. During the year under review, a number of technologies which were developed and/or tested on-station during the pilot phase were transferred on-farm for validation in most of the key countries; namely Benin, Burkina Faso, Niger, and Nigeria. At the same time on-station technology development and testing continued in all nine countries. Socioeconomic studies included (i) farmer participatory diagnosis in 2 associate countries (Ghana and Senegal), (ii) cost benefit analysis and (iii) cowpea commercialization and marketing channels in some key and associate countries.

On-going and future activities

8.7.1. Technology transfer from on-station trials to farmers fields for testing and validation

by W.N.O.H., M.T., S.K.A., L.E.N.J. - in collaboration with T. Adam, D. Arodokoun, C. Dabire, A. Emechebe, D. Seck, M. Touré

Although, impact and adoption of IPM technologies will be assessed in detail in the next phase, there are already substantial numbers of farmers who have tested and adopted some of the proposed innovations during the current phase. The figures presented in Table 3 have been obtained mostly from PEDUNE pilot sites, but there are already indications that farmer-to-farmer dissemination has started outside these pilot sites. The adoption rate for botanical pesticides in Benin is close to 100% after one year. However, this technology is relatively new to the farmer, as compared e.g. to resistant varieties, so we should be cautious and avoid premature conclusions.

Related to pest and disease management is the challenge to reduce pesticide use against the field and storage pests. Most farmers are aware that the use of pesticides (and particularly insecticides) can raise their yields. In Burkina Faso, the socio-economic surveys (PEDUNE 1999) showed that 88% of farmers in cotton producing zones use pesticides on cowpea. The reality is, if farmers can afford them at all, they will use, quite often, inappropriate pesticides destined for other crops such as cotton, not to talk about the complete lack of protective measures in handling and applying such toxic pesticides.

Table 3: Adoption of IPM technologies in PEDUNE countries

		Improved varieties		Plant-based pesticides		Improved storage	
	NGOs involved	Farmers	Adoption (%)	Farmers	Villages	Farmers	Adoption (%)
Benin	3			1027		529 (drums) 553 (solar drying)	
Burkina Faso	7	1850	95	2423	81	1683	68
Mali	3				10		
Niger	2		82		7		72
Nigeria	2	2590					
Senegal	4				30		

8.7.2. Farmer field schools

by W.N.O.H., B.J., M.T. - in collaboration with all national PEDUNE coordinators

Farmer Field School (FFS) which is a dynamic participatory model for farmer training and agricultural technology testing, adaptation and dissemination, is highly encouraged in PEDUNE. A farmers field school is a group of farmers who learn on a fixed field through experimentation, frequent and regular monitoring and measurements of crop growth, incidence and abundance of weeds, pests with associated natural enemies, and pest/disease damage severity. In group sessions, farmers present and discuss their experimental results and observations on soil, crop, weeds, pests, natural enemies, and indigenous knowledge. This 'bottom-up' approach enables farmers to 're-discover' and further understand scientific knowledge particularly in terms of trophic interactions and damage-yield loss relationships, and conduct location specific adaptation of research recommendations. The participatory activities form the basis of informed decision making by the farmers themselves and thereby strengthen technology dissemination and adoption.

A pre-requisite of FFS training is an effective residential Training of Trainers (ToT) to empower local cadres extension trainers to facilitate participatory action learning and research by farmers groups. In this regard, PEDUNE conducted regional ToT in Tamale, Ghana (June to October, 1999) to equip 27 extension/farmer trainers from 9 countries with the technical knowledge and skills required to establish and run FFS for ecologically sound cowpea IPM decision making in their respective countries. A preliminary activity had been a study tour of FFS in Zimbabwe by 14 participants from the 9 member countries. Twenty six national extension participants from all 9 PEDUNE countries were trained as FFS facilitators/trainers and 150 farmers trained in the PEDUNE ToT/FFS in Northern Ghana. The participants were trained in facilitation skills, agroecosystems analysis, experimentation by farmers and data recording and reporting through visual literacy and by which farmers 're-discover' key IPM concepts for ecologically sound decision making. Participants were also exposed to the importance of a sound IPM national policy support base for greater FFS impact. The regional ToT and FFS training was conducted in collaboration with the Ghana National IPM Programme and the FAO Global IPM Facility.

Training and empowerment of farmers through FFS create incentives for optimal choices and adoption of sustainable cowpea production and protection technologies. In the PEDUNE ToT/FFS evaluation sessions, for example, farmers recorded the benefits of harrowing the land and testing seed quality before planting, ecological knowledge of food webs in natural pest control, and were better informed on the personal and environmental hazards associated with pesticide use. The newly trained FFS facilitators recorded that they learnt efficient and effective use of bottom-top farmer-extension interactions and training in which the farmer is involved in all the activities including decision making. These newly trained facilitators were equipped with the knowledge and skills to spearhead similar ToT/FFS training in their respective countries in PEDUNE phase III for cowpea technology transfer.

8.7.3. Delineation of benchmark sites

by O.C., M.T., W.N.O.H. - in collaboration with T. Adam, D. Arodokoun, C. Dabire, A. Emechebe, A.B. Salifu, D. Seck, M. Touré

The multidisciplinary teams led by social scientists have assessed the economic importance and farmers perceptions of pests and diseases and associated crop losses. They have designed technology baskets based on farm resource endowments and the agroecological and socio-economic circumstances in which farmers operate. A benchmark has been therefore delineated in each of PEDUNE collaborative countries to focus the research and address the constraints of production and storage of cowpea. The benchmark in which are already operating the national teams, is a set of sites representing different recommendation domains and has been a useful tool for the multidisciplinary-based cowpea research. The benchmark sites have been delineated along a gradient of resource use intensity which is a function of agroecology (altitude, soil type and vegetation type) and socio-economic factors like population density, access to input and output markets etc. These characteristics have been chosen because of their potential impacts on the cropping systems and the incidence of pests and diseases and on the corresponding management and control strategies. The IPM technology development in these benchmark sites is cost effective as the research has been concentrated in key areas with 'extrapolable' results to similar agroecological and socio-economic settings in the country with spill-over effects in other areas and regions. With multidisciplinary targeted research to specific farmers circumstances in different agroecological regions, the technologies developed have a greater chance to be adopted by farmers.

8.7.4 Socioeconomic studies: baseline farmhousehold surveys

by O.C., M.T., W.N.O.H. - in collaboration with G. Ibro, C. Agli, M. Sorgho, D. Ilboudo, J. Voh, L. Ab, A.O. Kergna, A. Sene

Baseline farmhousehold surveys have been carried-out in at least 80 households in the benchmark sites of all PEDUNE countries except Mozambique. The first step of the surveys consisted of an extensive preliminary investigation in the sample villages through a rapid appraisal. The questions were related to key issues on pests and diseases knowledge and management. The second step was the intensive survey trough a structured questionnaire which resulted from the rapid appraisal. The surveys results show that 55% of the farmers in Western Cameroon had to substitute cowpea with less susceptible, but also less appreciated common beans (*Phaseolus vulgaris*) in their cropping systems, because of serious pest attacks on cowpea, and could not access any meaningful pest control solutions. Furthermore, the survey revealed that 50% of farmers lack access to cowpea IPM information/technologies and hence do not use any pest control method on cowpea despite the high pressure of pests and diseases in the field. However, these farmers indicated their willingness to adopt any technological package which can ensure some modest yield increases. In Burkina Faso, North Cameroon and Niger, 88, 80 and 70%, respectively, of farmers in cotton producing zones use inappropriate pesticides on cowpea and do not use proper measures of handling and applying toxic insecticides. Improved varieties of cowpea are well adopted by farmers. The surveys results show that 95 and 82% of farmers are using improved varieties of cowpea in Burkina Faso and Niger, respectively. Other new technologies in the pipeline and being increasingly used by farmers include the use of plant-based pesticides in Burkina Faso, Senegal, Benin and Mali.

8.7.5. Socioeconomic studies: marketing surveys

by O.C., M.T., W.N.O.H. - in collaboration with G. Ibro, C. Agli, M. Sorgho, D. Ilboudo, J. Voh, L. Ab, A.O. Kergna, A. Sene

As the demand for cowpea is growing, scientists, policy makers and traders are confronted with the challenge of increasing production, improving access to good quality stored cowpea products for higher market value, and reliable food security. Cowpea yields, storage and grain quality control and the availability of markets become important factors in the adoption of improved cowpea technologies. To achieve these objectives, a trader perception subsector analysis of cowpea has been completed in Cameroon, Benin, Burkina Faso, Mali, Senegal, Ghana, Nigeria and Niger. The results are aimed to guide scientists, policy makers and economic agents involved in improving cowpea research, production and marketing. An important component of trader's perceptions is dealing with pest management issues. The results show that losses in storage are substantial compared to other products. The majority of traders (more than 75%) use chemicals to treat cowpea in storage (storage facilities, bags or grains with Actellic powder, Phostoxin) in Mali, Niger, Burkina Faso, while less than 50% of traders using chemicals is reported from Cameroon. All the traders believe that chemicals are more effective than all

the traditional pest control practices but, at the same time, they would be interested in less poisonous botanical extracts.

The results from the preference ranking of cowpea seeds by traders show a high demand for white color seeds compared to red and black/white. Also the size of grain plays a key role in the demand as the sale turnover is higher for large size grain compared to small one .

Completed studies

Journal articles and book chapters

Asante, S.K., L.E.N. Jackai & M. Tamò. Efficiency of* Gryon fulviventris *(Hymenoptera: Scelionidae) as an egg parasitoid of* Clavigralla tomentosicollis *Stål. (Hemiptera: Coreidae) in Northern Nigeria. Environ. Entomol. (submitted).

A field survey was conducted on cowpea and pigeon peas in 1995 and 1996 to assess the natural control exerted by indigenous egg parasitoids on *C. tomentosicollis* populations in northern Nigeria. From *C. tomentosicollis* egg masses collected, 3 species belonging to 3 families of Hymenoptera were recorded namely, *Anastatus* sp. (Eupelmidae), *Ooencyrtus utetheisae* (Risbec) (Encyrtidae) and *Gryon fulviventris* (Crawford) (Scelionidae). Among them, *G. fulviventris* was found to be the most effective parasitoid. The life-cycle was completed in 11-13 days and adult wasps lived for 13-46 days (mean: 34.3 ± 0.5 days) when fed on pure honey in the laboratory. Parasitization was found to be higher on 0-1 day old eggs than = 2 days old eggs. Out of a total of 3,502 egg masses collected on cowpea from four geographical locations, 2,587 (73.9 %) were found to contain at least 1 egg parasitized by *G. fulviventris*. From 56,072 eggs discovered, the parasitoid was able to exploit 38,935 (69.4 %). Overall 74,724 eggs were collected from the four different locations and out of these 52 % were parasitized by *G. fulviventris*. The effectiveness of the parasitoid was, however, found to vary with time and location. At Minjibir, Kano, where weekly samples were collected throughout the growing season, the discovery efficiency, exploitation efficiency and overall impact increased significantly ($P < 0.001$) from July to October. However, the proportion of eggs parasitized was found to be inversely related to the size of an egg mass. The emergence (field) sex ratio (proportion of males in the populations) ranged from 0.19-0.34 (mean: 0.28) at all locations. These findings are discussed in relation to the biological control and integrated pest management (IPM) of this economically important pest.

Asante, S.K., M. Tamò & L.E.N. Jackai. Integrated management of cowpea insect pests using elite cultivars, date of planting and minimum insecticide. African Crop Science Journal (submitted).

Trials were conducted in Kano, northern Nigeria during 1996 and 1997 cropping seasons to determine the influence of planting date and two well-timed insecticide sprays on the incidence of four insect pests namely, the legume pod-borer, *M. vitrata.*, legume bud thrips, *M. sjostedti* Trybom, the brown cowpea coreid bug, *C. tomentosicollis* and cowpea aphid, *A. craccivora* and their effect on grain yield of elite cowpea cultivars from IITA breeding programme. Six cultivars were planted at 4 different dates between 13 June and 12 August 1996 whilst 12 cultivars were planted at 5 different dates between 5 June and 12 August 1997 with and without insecticide protection. Aphid infestation occurred only on cowpea planted between the first week of June and mid-July with the highest incidence recorded on the crop planted in the last week of June. Cowpea planted in June flowered and podded between early to mid-August when post-flowering pests (*M. vitrata, M. sjostedti* and *C. tomentosicollis*) densities were relatively low and produced significantly higher grain yields without insecticide protection compared to other planting dates. The flowering and pod formation stages of late planted (July and August) crops coincided with the peak population densities of the three major post-flowering pests resulting in a considerable reduction of grain yield. Two sprays of insecticide, Cypermethrin + Dimethoate (Sherpa plus) (30 + 250 a.i./ha) at bud initiation and 50% flowering stages increased grain yield considerably from 225 to 900 kg/ha for cowpea planted in July and August. Cost-benefit analysis indicated that the insecticide application was more profitable for cowpea planted in late July and August than was the case when planted in June and early July. This seems to suggest that early maturing elite cultivars could escape economic damage caused by post-flowering pests when planted early in the season. The implications of these findings to the grower and the breeding strategy by IITA is discussed further in this paper.

Dreyer, H. & J. Baumgaertner. Adult movement and dynamics of* Clavigralla tomentosicollis *(Heteroptera: Coreidae) populations in cowpea fields of Benin, West Africa. J. Econ. Entomol. (in press).

In southern Benin the temporal dynamics and adult movement of *C. tomentosicollis* were investigated in cowpea fields during 1991 and 1992 by visual counting and mark-recapture methods. The phenology and adult movement of this pest were related to the pod and seed formation period. A rapid colonization by immigrating adults closely coincided with the pod formation phase of the plants. Oviposition occurred at the beginning of pod maturation and was succeeded by an increase of the nymphal density until pod harvest. The analyses of adult movement yielded daily emigration rates of 7 - 20% of the resident adult densities, whereas the daily percentage of in situ adult mortality was <5%. The decline in the number of adults toward harvest time is therefore mainly due to

emigration rather than to field mortality. The high mobility of *C. tomentosicollis* and the rapid field colonization are important elements in the planning of adequate pest management strategies.

Fritzsche, M.E. & M. Tamò. Influence of thrips prey species on the life-history and behavior of* Orius albidipennis *(Reuter) (Heteroptera: Anthocoridae). Entomol. Exp. Applic. (in press).

The effects of two diets, i.e. cowpea leaves plus *Megalurothrips sjostedti* larvae vs. cowpea leaves alone, on nymphal development and mortality of *Orius albidipennis* were studied under controlled laboratory conditions in Benin, West Africa. Nymphal development was longer when *O. albidipennis* was fed with cowpea leaves only, compared to the diet complemented with *M. sjostedti* larvae (17.6 days vs. 14.8, respectively). Nymphal mortality was very high (79.5 %) if fed with cowpea leaves only, and still relatively high if the diet was complemented with thrips larvae (44.4 %).

In a separate study on the longevity and fecundity of *O. albidipennis* adult females feeding on *M. sjostedti* larvae, an average 6.8 eggs per day (maximum 16 eggs) and mean total fecundity of 61.1 eggs were observed. The females lived on average 13.5 days.

Finally, observations on the predation by *O. albidipennis* adults on three different thrips species revealed that *M. sjostedti* larvae were killed at a lower rate than larvae of *Ceratothripoides cameroni* and *Frankliniella schultzei*. Higher predation rates were measured using unmated females and males than in mated females. However, the rate of first attack, measured as first larva attacked in dual-choice assays, was higher for *M. sjostedti* when a *F. schultzei* larva was offered simultaneously, and not different when a *C. cameroni* or *Sericothrips adolfifriderici* larva was offered.

The results of this study are discussed with regard to the lack of efficacy of *O. albidipennis* as biological control agent for *M. sjostedti*.

Machuka, J.S. Heterogeneity in the seed globulin and albumin fractions from African Yam Bean* Sphenostylis Stenocarpa *(Hoechst. Ex Rich) Harms.* African Crop science Journal *(in press).

Machuka, J., 2000. Characterization of the seed proteins of velvet bean (*Mucuna pruriens*) from Nigeria. Food Chemistry 68:421-427.

Machuka, J. & O.G. Okeola One and two dimensional gel electrophoretic identification of African yam bean (*Sphenostylis stenocarpa*) seed proteins.* J. Agricultural and Food Chemistry *(in press).

Machuka, J.S., O.G. Okeola, M.J. Chrispeels & L.E.N. Jackai, 2000. The African yam bean seed lectin affects the development of the cowpea weevil but does not affect the development of larvae of the legume pod borer. Phytochemistry 53:667-674.

Machuka J., E.J.M. Van Damme, W.J. Peumans & L.E.N. Jackai, 1999. Effect of plant lectins on larval development of legume pod borer,* Maruca vitrata. *Entomologia Experimentalis et Applicata 93:179-187.

Machuka, J.S., O.G. Okeola, E.J.M. Van Damme, M.J. Chrispeels, F. Van Leuven & W.J. Peumans, 1999. Isolation and partial characterization of new galactose-specific lectins from African Yam Beans,* Sphenostylis Stenocarpa *Harms. Phytochemistry 51: 721-728.

Oigiangbe, N.O., L.E.N. Jackai, F.K. Ewete & L. Lajide. The nutritional ecology of* Maruca vitrata *I. Development on flowers of wild and cultivated* Vigna *species. Insect Sci. Applic. (submitted).

Growth, development and fecundity of *M. vitrata* were studied on artificial diet and flowers of two accessions each of three wild *Vigna* species namely *V. vexillata* (TVnu 594 and TVnu 72), *V. oblongifolia* (TVnu 957 and TVnu 42) and *V. unguiculata* ssp. *dekindtiana* (TVnu 979 and TVnu 863) and six accessions of cowpea, *V. unguiculata* ssp. *unguiculata* (Moussa Local, VICAM-1, TVu 13731, IT84S-2246, IT89KD-457 and IT91K-180). Percentage survival of the larvae, larval weights as well as growth and development indices were significantly higher in artificial diet, flowers of cowpea cultivars and those of *V. unguiculata* ssp. *dekindtiana* compared to those of *V. vexillata* and *V. oblongifolia*. Fecundity of females from larvae reared on artificial diet and flowers of cowpea was also significantly higher than that of females from the wild *Vigna* genotypes. All variables were included in principal component analysis. Two components accounted for 81.79 percent. On the basis of this analysis, the diets appeared to fall into four categories based on their suitability for supporting development of *M. vitrata*: unsuitable (TVnu 42 and TVnu 957), fairly suitable (TVnu 72, TVnu 594, TVnu 979, Moussa Local, and TVnu 863), suitable (IT89KD-457, IT91K-180, VICAM-1, TVu 13731 and IT84S-2246), and very suitable (artificial diet). The importance of these findings in the development of host plant resistance of cowpea to *M. vitrata* is discussed.

Conference papers, workshop proceedings, abstracts, newsletters

Afouda, Leonard 1999: Approach to the biological control of* Macrophomina phaseolina, *causal agent of charcoal rot of cowpea, and development of serological methods for its detection. PhD thesis. University of Göttingen, Germany. pp. 140

The aim of the present study was to develop biological control methods as a component of integrated control of charcoal rot caused by *M. phaseolina*, the major disease of cowpea in the African Sudan Savannah zone. Therefore,

a reproducible pathogen-soil-plant test system, as well as enzyme-linked immunosorbent assay methods were developed to elucidate some important aspects of the biology of *M. phaseolina*. Three cowpea genotypes were tested for resistance to charcoal rot. The genetic variability within populations of *M. phaseolina* was studied with polyacrylamide gel electrophoresis (PAGE). These studies revealed the heterogeneity of *M. phaseolina* populations in Niger. For the specific detection and quantification of charcoal rot in plant tissues, antibodies were raised against the cytosol and extra-cellular components of *M. phaseolina*, used in a double antibody sandwich ELISA (DAS-ELISA), and allowed the detection of *M. phaseolina* in protein extracts of the fungus as well as in samples from infected plants. These antibodies were also used to estimate the contamination level of cowpea seeds. The distribution of *M. phaseolina* in infected plants was studied with ELISA, and it was demonstrated that *M. phaseolina* was essentially located in the roots, in the hypocotyl and to a smaller extent in the epicotyl of infected plants.

The second part of the present work consisted of developing biological methods for the control of *M. phaseolina*. Bacterial and fungal antagonists were isolated from soil samples collected in Niger. These antagonists suppressed to different extent the growth as well as microsclerotium formation of *M. phaseolina in vitro*. The antagonistic activity of 13 bacteria was tested *ad planta* and the tested antagonists exhibited variable potential to control charcoal rot, ranging from not satisfactory to very good (A11). The *Bacillus subtilis* isolate A11 was selected as the most promising. The ability of *B. subtilis* to colonize the plant surface was studied by using a spontaneous rifampicin-streptomycin-mutant (A_{11}^{rm}) of *B. subtilis* A11. Applying *B. subtilis* A_{11}^{rm} to seeds before sowing, high population densities of the mutant were recorded on the roots up to 4 weeks after sowing. Susceptibility / resistance to *M. phaseolina* of 3 cowpea genotypes, IT93K-734, TN5-78 and Kpodji, was assessed in the growth chamber , where the genotype Kpodji tolerated high populations of *M. phaseolina* in the soil and showed low disease incidence and mortality after 3 weeks of growth. Kpodji was identified as having a partial resistance to *M. phaseolina* and will be recommended to breeders.

Assigbétsé, K., V. Verdier, K. Wydra, K. Rudolph & J.P. Geiger 1999: Molecular characterization of the incitant of cowpea bacterial blight and pustule,* Xanthomonas campestris *pv.* vignicola. *Abstracts 9th Internation. Conf. Plant Pathogenic Bacteria, Centre for Advanced Study in Botany, University of Madras, India. p. 36.

Diop, K., 1999. Comparison of biology and behavior of different strains of* Ceranisus menes *Walker, a parasitoid of* Megalurothrips sjostedti *(Trybom). PhD thesis, University of Ghana, Lagon, Ghana.

A solitary thrips endoparasitoid, *Ceranisus menes* walker (Hymenoptera: Eulophidae), is found in Africa and in Asia associated with congeneric species of Megalurothrips. *Megalurothrips* spp. are not considered agriculturally important pests in the Asiatic region, most probably due to the action of this parasitoid. Conversely, the population of this parasitoid in West Africa is inefficient in controlling its associated thrips host, *M. sjostedti*, a major pest of cowpea. Three (3) selected strains from South East Asia, i.e. one from Malaysia and two from India, and the local strain from Benin were studied.

The results of this investigation indicated that there were in fact biological differences between the four strains of *C. menes*, on *M. sjostedti* host: the study revealed that at the host selection phase of the parasitization process, the behaviour of the local strain was the most compatible for a successful parasitization of *M. sjostedti*. This could be explained by the longer history of co-existence of the two organisms. However, at the physiological test, the suitability of *M. sjostedti* was found to be practically null for the local strain, as well as for the second Indian strain (Indian2). Their survival rates (proportion of eggs that survive up to adult stage) in this thrips species was estimated at 0.06 for both strains, unexpectedly, it was significantly higher (0.36) for the first Indian strain (Indian1).

After the second test, it came out that none of the strains, including the local strain, would be able to parasitize successfully *M. sjostedti*. Each of them was hampered by behavioral and/or physiological incompatibility with this thrips species. This was confirmed on results of their life history notes in the last test. The Indian2 strain was not able to reproduce in *M. sjostedti*, contrarily to the local and Indian1 strain.

In fact, each of the 4 populations of *C. menes* was unique in the biological features it exhibited when *M. sjostedti* was offered as host. This could be an onset of biotypes differentiation among the 4 populations of this species of parasitoid. The difference on the two Indian strains both originating from the same geographical area was discussed.

In conclusion, this study has brought into insight the biological diversity among the different geographical populations of *C. menes*. Secondly, it has shown that physiological incompatibility must have been the only reason why the local strain could not perform as well on *M. sjostedti* as the Asian strains did on their native hosts. Finally it has demonstrated that none of the 3 selected strains of *C. menes* from Southeast Asia would be able to provide a better control of the cowpea thrips than the African population of this parasitoid.

Kassa, H., N. Zenz, M. Tamò & C.P.W. Zebitz, 1999. Etude comparative de cinq profils enzymatiques sur différents organes de niébé (*Vigna unguiculata *L. Walp) cultivé avec ou sans apport d'engrais NPK. p 185-191. In: G. Renard, S. Krieg, P. Lawrence & M. von Oppen (eds) Farmers and scientists in a changing environment: Assessing research in West Africa, Margraf Verlag, Weikersheim, Germany. Proceedings of the regional workshop, University of Hohenheim, INRAB, INRAN, and UNB/FSA, 22-26 February 1999, Cotonou, Benin.

Studies on population dynamics of the two cowpea pests *M. vitrata* and *M. sjostedti* indicated clear feeding preferences for reproductive organs (e.g. flowers) over vegetative parts (e.g. shoot tips). They also showed that the respective pests have attacked plants, which received additional nitrogen, more severely. Proteins not only cater for nutritional requirements but also influence feeding behaviour. Acrylamide gel electrophoresis was used to compare 5 profiles of enzymes in different organs of cowpea, with and without NPK supply. These enzymes have been Esterase, Phosphatase, Leucine Amino-Peptidase (LAP), Glutamate Oxaloacetate Transaminase (GOT) and Super Oxide Dismutase (SOD). Enzymatic profiles differed in the expression of their zymograms for vegetative plant tissue from those for reproductive organs. Additionally, profiles among NPK levels could be separated towards the end of the growing season. Whereas Esterase responded to divergences in flowers and grains, Phosphatase, GOT and LAP have been expressing distinct profiles in grains only. This study aimed at visualizing the underlying enzymatic characteristics within and among plants, which are likely to explain pest feeding preferences. The results obtained confirmed existing quantitative data on plant-pest interactions as well as the impact of nitrogen on the pest-antagonist complex from literature.

Khatri-Chhetri, Gopal 1999: Detection and characterization of *Xanthomonas campestris *pv.* vignicola *strains, incitant of cowpea bacterial blight and bacterial pustule, and studies on genotype/strain interactions. PhD thesis. University of Göttingen, Germany. 162pp.

The aim of the present study was to develop quick, easy and reliable detection methods, to characterize pathogenic *Xcv* strains originating from different geographical areas, virulence groups and symptom types by metabolic, biochemical and genetic analyses, to determine the possible existence of bacterial races, and to identify resistant cowpea genotypes.

The strains isolated from blight symptoms and pustules originating from Cameroon, Nigeria, Niger and Benin belong to the same pathovar "*vignicola*", since they could not be differentiated by pathological, metabolic, biochemical and genetic analyses. Although the few pustule strains from Mozambique appeared to possess different pathological, metabolic and biochemical characters, they may be regarded as very weakly virulent strains and not as a separate pathovar "*vignaeunguiculatae*". Virulence of the strains was not related to physiological, biochemical or genetical characters. Variation in virulence of the strains and resistance of the genotypes appeared to be a quantitative multigenic feature. Therefore, "races" of *Xcv* could not be clearly identified.

Khatri-Chhetri, G., K. Wydra & K. Rudolph 1999: Development of a semi-selective medium for quick and easy detection of *Xanthomonas campestris *pv.* vignicola, *incitant of cowpea bacterial blight, pp. 127-134. In: Mahadevan, A. (ed.), Plant Pathogenic Bacteria, Proceed. 9th Internation. Conf., Centre for Advanced Study in Botany, University of Madras, India.

Khatri-Chhetri, G., K. Wydra & K. Rudolph 1999: Variability of strains of *Xanthomonas campestris *pv.* vignicola, *incitant of cowpea bacterial blight and bacterial pustule, collected in several African and other countries, pp. 296-302. In: Mahadevan, A. (ed.), Plant Pathogenic Bacteria, Proceed. 9th Internation. Conf., Centre for Advanced Study in Botany, University of Madras, India.

Koona, P., 1999. Anatomical and biochemical bases of the resistance of wild and cultivated *Vigna *species to the coreid bug *Clavigralla tomentosicollis *Stål. PhD thesis, University of Ibadan, Ibadan, Nigeria.

Eight *Vigna* species were used to investigate the role of the plant surface (pod wall toughness and pubescence) and of secondary metabolites in cowpea resistance to the pod-sucking bug *C. tomentosicollis*, namely IT84S-2246, TVu 3354 and TVu 1890 (*V. unguiculata* subsp. *unguiculata*, cultivated), TVnu 151, TVnu 369, TVnu 517 and TVnu 707 (*Vigna unguiculata* subsp. *dekindtiana*, wild subspecies of the cultivated genotypes), and TVnu 72 (*Vigna vexillata*, wild).

The overall interest of the present study is the identification of some level of resistance in the wild *V. unguiculata* subsp. *dekindtiana* species and its characterization, because of their potential as parents in breeding programs for resistance to *C. tomentosicollis* and other pod bugs. It suggests that anatomical and biochemical factors can operate together in the resistance of *Vigna* genotypes to *C. tomentosicollis*. For instance, tough pod walls and high glandular trichome density could provide enhanced resistance in cultivated *Vigna* genotypes. This knowledge is important in that by acting exclusively on the pod surface to enhance cowpea resistance to pod-sucking bugs, there is reduced risk of increasing the amount of antinutritional factors present in the seeds for which cowpea is mostly grown in Africa. In addition, the observed oviposition preference of *C. tomentosicollis* for pigeon pea leaves as compared to cowpea pods is of interest in the integrated management of this pest on cowpea. Pigeon pea (*Cajanus cajan* Millsp) is usually grown contiguous to cowpea and may serve as trap crop for oviposition. Reduced oviposition by the bugs on cowpea would lead to the reduction of the population build-up of the insects on the plant; this would allow the crop to escape damage from the growing nymphs which, because of their aggregation behavior and lack of wings, are incapable of long distance movement.

Nkamleu, B., O. Coulibaly, S. Thyggard & M. Tamò. Farmers decision making in cowpea pest management in Western Highlands of Cameroon. Third World Cowpea Research Conference, Sept 4–8, 2000, Ibadan, Nigeria.

Pest management technologies recommended by the national extension systems have been largely targeted to export crops, coffee and cocoa. Food crops and mainly cowpea have not received due attention. Most of the pest control strategies proposed for these food crop were not well adapted to the particular case of cowpea pest control, nor did they take into consideration socioeconomic constraints. The paper assesses the key factors behind the decision to control pests and diseases on cowpea and advises researchers and extensionists for appropriate integrated pest management technologies to be adopted by farmers. A sample of 132 farmers have been interviewed in western highlands of Cameroon about the farm characteristics, the cowpea based farming systems, the pest and disease knowledge, the pest control strategies used and the perceptions about the constraints and opportunities of pest control in cowpea-based cropping systems. The results from this survey shows that farmers do not have access to recommended pest control and that high input costs are reported as the main constraint after the removal of subsidies and the devaluation of the CFA Franc. The damages of pests and diseases are high and led to the substitution of cowpea by common beans, a less susceptible crop to pests in the region. The use of cropping techniques, botanical insecticides and varietal choices are key integrated pest management options to be recommended.

Oigiangbe, O.N., 1999. Bases of resistance in some* Vigna *species and their effect on the nutritional ecology of* Maruca vitrata *Fabricius (Lepidoptera: Pyralidae), University of Ibadan, Ibadan, Nigeria, pp.

Three wild *Vigna* species, each of two accessions, namely *V. vexillata* (Acc. TVnu 72 and TVnu 594), *V. oblongifolia* (Acc. TVnu 957 and TVnu 42) and *V. unguiculata* ssp. *dekindtiana* (TVnu 979 and TVnu 863) and six cultivars of cowpea, *V. unguiculata* ssp. *unguiculata* (IT84S-2246, IT91K-180, IT89KD-457, TVu 13731, VICAM-1, and Moussa Local) were used in several laboratory, screen house and field experiments. Survival, growth, development and fecundity of *M. vitrata* reared on flowers and pods of cowpea and *Vigna unguiculata* ssp. *dekindtiana* were significantly better ($P < 0.05$) than those reared on *V. vexillata* and *V. oblongifolia*. The consumption and utilization of pods of the *Vigna* species was in the following order of decreasing suitability: cowpea (*V. unguiculata* ssp. *unguiculata*) > *V. unguiculata* ssp. *dekindtiana* > *V. oblongifolia* > *V. vexillata* while consumption of flowers was IT84S-2246 > TVu 13731 > TVnu 72 > IT91K-180 > TVnu 863 > TVnu 42.

Pubescence on stems, leaves and pods of these *Vigna* species consisted of glandular and non-glandular trichomes. There were significant differences ($P < 0.05$) in the density of these trichomes (range 1.00 to 21.00 mm^{-2} for glandular and 0.00 to 10.80 mm^{-2} for non-glandular) and length of the non-glandular trichomes (range 58.52 to 2064.00 μm). In the field, percentage damage to flowers and pods was significantly higher ($P < 0.05$) on cowpea and *V. unguiculata* ssp. *dekindtiana* (range 15.81 to 50.26 % for flowers and 2.33 to 7.67 % for pods) compared to *V. vexillata* (11.48 % for flowers and 1.00 % for pods) and *V. oblongifolia* (0.90 % for flowers and 1.00 % for pods). Density of glandular trichomes on leaves influenced the variability ($r = -0.8590$; $P = 0.05$) in the number of eggs laid on each *Vigna* species by *M. vitrata* females. Pubescence on pod also significantly ($P < 0.05$) reduced consumption and utilization of the *Vigna* species by *M. vitrata*.

There were significant ($P < 0.05$) variations in the size and shape of petal cells of flowers of the *Vigna* species. Highest length and width of epidermal cells, 262.20 μm and 147.00μm were recorded on flowers of TVnu 863 while those of IT91K-180 were the least, being 84.82 μm and 53.04μm, respectively. The length : width ratio was significantly ($P < 0.05$) lower in petal cells of TVnu 42 (1.08) and TVnu 72 (1.02) flowers compared with those of TVu 13731 (2.24) and IT84S-2246 (2.35). Significant ($P < 0.01$) positive correlation was found between the length : width ratio and percentage pupation ($r = 0.9301$), adult emergence ($r = 0.9283$), growth index ($r = 0.9233$) and fecundity ($r = 0.9589$) of *M. vitrata* reared on the flowers as well as relative growth rate ($r = 0.8608$; $P < 0.05$) of the larvae.

Four distinct cell layers of varying thickness were found in the pod wall of TVnu 72, TVnu 863 and IT91K-180 while only three were found in those of TVnu 42, TVu 13731 and IT84S-2246. The entire pod wall of TVnu 72 (358.83 μm) was significantly ($P < 0.05$) thicker than those of the cowpea accessions (range 90.33 to 250.01 μm). Significant ($P < 0.05$) negative correlation was established between thickness of the pod wall and percentage pupation ($r = -0.8497$), adult emergence ($r = -0.8550$), growth index ($r = 0.9603$) and fecundity ($r = -0.8169$) of *M. vitrata* reared on the pods.

The proximate and mineral composition of the flowers and pods influenced their nutritional status for optimal growth and development of *M. vitrata*. Water and chloroform extracts of IT91K-180 and TVnu 42 glandular trichomes, respectively, caused reduction in weight of *M. vitrata* when incorporated into artificial diet fed to the insect. Similarly, hexane and ethanol crude extracts of pods of TVnu 42 and TVnu 72 showed some antifeedant and/or toxic effects on *M. vitrata* larvae when incorporated into artificial diet. Acidic and basic fractions of TVnu 42 and TVnu 72 pod extracts, respectively, as well as neutral fractions of TVnu 72, TVnu 42 and IT84S-2246 reduced feeding, growth, development and fecundity of *M. vitrata* when fed on artificial diet containing these fractions.

Sikirou, Rachidatou 1999: Inoculum sources of* Xanthomonas campestris *pv.* vignicola *strains, incitant of cowpea bacterial blight and bacterial pustule, and identification of hosts besides* Vigna unguiculata. *MSc thesis. University of Göttingen, Germany. 48pp

Field and glasshouse experiments were carried out to study the survival of *Xanthomonas campestris* pv. *vignicola* (*Xcv*) in plant debris. Considering the fast decreasing number of the pathogen in crop residues in the soil and its short survival on weeds, plant debris and weeds are not regarded as principal sources of inoculum, but may contribute to the spread of *Xcv* during the cropping season. Specially in the humid savannah and forest zones with 2 cropping seasons, separated only by up to 1 month of dry period, cowpea plant debris may serve as an inoculum source of *Xcv* in the following small cropping season. Hence, a cowpea crop rotation and weeding of cowpea fields during the growing period is recommended to reduce inoculum sources. Alternative host plants may also play a role in spreading the disease. Thus, the legume species *Stenophylis sternocarpa* can be considered as a host plant of *Xcv*. Further studies are needed for *Vigna angularis* and *Lablab purpureus*, which developed weak transient disease symptoms.

Sikirou, Rachidatou 1999: Epidemiological investigations and development of integrated control methods of bacterial blight of cowpea caused by* Xanthomonas campestris *pv.* vignicola. *PhD thesis. University of Göttingen, Germany. pp. 218

The objective of these studies was to evaluate the epidemiology of bacterial blight in cowpea genotypes and in the field under different ecozones, to assess the loss of seed weight and to develop integrated control methods. The isolated strains from which the marker strain used for epidemiological investigation were identified as *Xanthomonas campestris* pv. *vignicola*. In general, susceptible cowpea genotypes carried highest epiphytic population of *Xcv* but they were also detected in higher number on some resistant genotypes. In a susceptible genotype, virulent strain colonize the whole plant within 2 weeks, while the low virulent strain could not colonized the whole plant up to 25 dpi. Bacteria multiplied very fast and in higher number in susceptible genotype compared to moderately susceptible and resistant one. Seeds from susceptible as well as resistant genotypes can carry seed born *Xcv*.

Depending to cowpea genotypes, ecozones and seasons, cowpea bacterial blight caused up to 64 % of seed loss with highest losses in genotypes IT84E-124, IT84S-2246-4 and IT86D-472 followed by IT81D-1137 and the lowest in genotypes IT86D-719 and IT81D-1228-14 followed by IT86D-715. The disease was more severe in the forest-savanna transition zone than in the dry savanna zone. Rain played an important role in the spread and the severity of the disease. The long rainy season versus short rainy season had an effect on the development of the disease. The antibiotic Plantomycin protected plants against an early natural infection. An insecticide showed a suppressive effect on the disease. Of 46 tested genotypes for resistance selection, 17 were screened as resistant, 13 as moderately susceptible and 16 as susceptible. May sowing time was found best in FST zone for reducing the disease severity, while in DS zone, September sowing reduced the disease severity.

Maize in alternate rows with cowpea reduced the disease severity up to 43% and the disease incidence up to 41%, while cassava in alternate row with cowpea reduced the disease severity up to 42% and the disease incidence up to 34%. Maize and cassava associated in alternate rows with cowpea made these cropping systems benefit in reducing the disease severity. Hot water 60 °C for 30 min and 70 °C for 10 min eliminated *Xcv* from seed without inhibiting seed germination. Hot air at 65 °C for 120 h and 144 h and 70 °C for 96 h eliminated bacteria from seeds without the inhibition of seed germination.

Wydra, K. & K. Rudolph 1999: Development and implementation of integrated control methods for major diseases of cassava and cowpea in West-Africa. In: H.S.H. Seifert, P.L.G. Vlek & H.-J. Weidelt (eds.), Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen. Tropentag 1998. Stabilisierung und nachhaltige Entwicklung land- und forstwirtschaftlicher Systeme in den Tropen, 133: 174-180.

Wydra, K. & K. Rudolph 1999: Integrated control of bacterial diseases and root rots of cassava and cowpea in West Africa: report on a collaborative project. DPG AK Plant Protection in the Tropics and Subtropics, Phytomedizin 29: 35-36.

Wydra, K., A. Fessehaie, A. Fanou, R. Sikirou, J. Janse & K. Rudolph 1999: Variability of strains of* Xanthomonas campestris *pv.* manihotis, *incitant of cassava bacterial blight, from different geographic origins in pathological, physiological, biochemical and serological characteristics. Abstr. 1996, pp. 53-54. In: Mahadevan, A. (ed.), Plant Pathogenic Bacteria, 9th Internation. Conf., Centre for Advanced Study in Botany, University of Madras, India.

Zenz, N., M. Tamò & C.P.W. Zebitz, 1999. Cowpea cultivation and the migratory interaction of two pests, the pod borer,* Maruca vitrata, *and the flower thrips,* Megalurothrips sjostedti, *shifting between the wild and cultivated habitat, p 193-201. In: G. Renard, S. Krieg, P. Lawrence and M. von Oppen (eds) Farmers and scientists in a changing environment: Assessing research in West Africa, Margraf Verlag, Weikersheim, Germany. Proceedings of the regional workshop, University of Hohenheim, INRAB, INRAN, and UNB/FSA, 22-26 February 1999, Cotonou, Benin.

Polyphagous pests such as *M. vitrata* . and *M. sjostedti* maintain a permanent population without diapause on a wide range of wild and cultivated host plants, alternating throughout the year. This study aims at estimating the effect of spontaneous vegetation in the constitution of the pest population on alternative host plants and subsequent

migrations to fields adjacent to cowpea. Flowers from a wide range of alternative host plants were sampled regularly close to cowpea fields in south Benin, for five rainy and dry seasons consecutively. *M. sjostedti* was found permanently all year long where host plants were abundant whereas the distribution of *M vitrata* was more irregular. Depending on the species' composition, there was a rapid increase in the pest population, particularly of adults which were observed on host plants following the establishment of cowpea crops. Increasing pressure of the pest on the natural habitat led to its migration into cowpea fields. More parasitized larvae of *M vitrata* were found in cowpea than in alternative host plants. As for *M sjostedti*, parasitation rates were generally higher in wild hosts than in cowpea.

Project 9

INTEGRATED MANAGEMENT OF MAIZE PESTS

by V. Adenle, S.O. Ajala, K.F. Cardwell, O. Coulibaly, B.M. Dixon, J.M. Fajemisin, G. Goergen, K. Hell, J.G. Kling, R.H. Markham, W.G. Meikle, A. Menkir, C. Nansen, F. Schulthess (project coordinator) assisted by O. Ayinde, J.O. Bukola, P. Degbey, S. Gounou, S. Odubiyi, S. Olojede, D. Onukwu, A. Tchabi

Project rationale

Maize was introduced to Africa from its native Mesoamerica, in the 16th century. It became the most important cereal crop in East Africa where it is a staple for a large proportion of the population. In West Africa, maize is an important component of the farming systems and the diet of many people and is increasing in importance as it expands into the savanna zones. Yields are reduced by numerous plant pathogens such as maize streak virus, *Cercospora zeae-maydis* (Tehon & Daniels) Shoenaken, *Exserohilum turcicum* (Passerini) Leonard & Suggs, *Puccinia* spp., and the downy mildew fungus (*Peronosclerospora sorghi*). Insect pests such as stem and cobborers (e.g. *Sesamia calamistis* Hampson, *Busseola fusca* (Fuller) (Lep.: Noctuidae), *Eldana saccharina* (Walker), *Mussidia nigrivenella* Ragonot (Lep.: Pyralidae)) have moved on to maize after having evolved on native grasses or cereals such as sorghum and millet, and other host plant species. Other pests such as the stemborer *Chilo partellus* (Swinhoe) (Lep.: Pyralidae) and the larger grainborer *Prostephanus truncatus* (Horn) (Col.: Bostrichidae) have been accidentally introduced from Asia and the Americas. In many areas, maize is replacing indigenous cereal crops such as sorghum and millet, as well as wild habitats. As a result, maize has become the major host of insect pests and diseases of these crops and wild host plants.

IITA's first approach to controlling maize pests and diseases has been host plant resistance. Resistance to maize streak virus and the downy mildew fungus, and tolerance to Striga has been developed. IITA's maize germplasm also has some resistance to the blight and rust fungi such as *B. maydis*, *E. turcicum*, *Puccinia* spp. Nevertheless a potential for damaging outbreaks of these pathogens exists given a change in host genotype and environmental conditions. These factors also influence the population dynamics of leafhoppers *Cicadulina* spp. which are vectors of the maize streak virus. Hence, 'habitat management' studies are especially important to understand fluctuations in the populations of organisms relative to climate, cropping intensity, management practices, and genotype. For insect pests such as *S. calamistis* and *E. saccharina* only moderate levels of host plant resistance are likely to be obtained while maintaining a good agronomic background, thus habitat management and biological control are alternatives which are receiving increased attention. IITA germplasm, as well as germplasm obtained from collaborative work with CIMMYT and local West African varieties, are also being evaluated for resistance to postharvest pests such as *P. truncatus* and *Sitophilus zeamais* Motschulsky (Col.: Curculionidae). The effects of varietal resistance on insect ecology have been integrated into an IITA decision-support tool for stored product systems.

Food security and human nutritional status of the target clients of the CGIAR are directly impacted by losses in quantity and quality of the harvested crop. In some cases, the losses to pests and microbes post-harvest, far outweigh any reasonable hope for increases in productivity through improved germplasm and pre-harvest management. There are reports from Africa of post harvest losses averaging 30% of grain dry weight in maize stored on farm due to *Tribolium castaneum* Herbst (Col., Tenebrionidae), *S. zeamais* and *Sitotroga cerealella* (Olivier) (Lep., Gelechiidae). *P. truncatus* can cause much higher losses where it occurs. Lepidopterans riding in the cob coming from the field cause additional losses in grain weight. Compounding the problem of actual grain weight losses, insect damaged kernels are highly likely to be contaminated with dangerous levels of aflatoxins which are known carcinogens, and are also thought to be immuno-toxic and growth suppressants. A Rotary International (RI) Health, Hunger, and Humanity project has been designed with IITA, governmental organizations (GO), and Rotary Clubs from 5 countries to increase trader and consumer awareness of the deleterious nature of poor grain quality in West Africa. Information campaigns in Bénin, Togo, Ghana, and Burkina Faso will target urban centers with messages about how to recognize and eliminate poor quality grain, and how to recognize symptoms of aflatoxin intoxication in children. Grain quality in these markets will be monitored biannually by the official food quality laboratories of each country. Animal husbandry will be the target of another set of RI campaign messages about how to render safe low quality feeds in order to provide a legitimate alternative market for poor quality grain.

The other important factor in food quality management is government policy. Most governments in West Africa have toxicology monitoring capability and regulatory aflatoxin limits as statutes of law.

The problem is lack of prioritization and insufficient funding. Countries with a low tax base and a large social load must have economic prioritization of the state-run programs. Real information about macroeconomic impact of mycotoxins in terms of lost human resource potential and public-health costs is needed to move this issue to the top of policy concerns. This will be the purpose of a medical interface study, funded by BMZ to begin in 1999, which will attempt to assess the immune-suppressive effect of mycotoxins in small children. The Government of Holland is helping sponsor the collection of socio-economic covariant factors to nutrition, thus isolating variables which have confounding effects on health.

Finally, in the event that aflatoxin control becomes a priority policy issue in Africa, research into host plant resistance and biological control solutions is being done with collaboration between the USDA and IITA. With this basic research the hope is to find single efficacious technologies that would not require complicated changes in crop management systems of small-scale producers, resulting in greater ease of dissemination and adoption of the intervention. Temperate maize germplasm with high levels of *Aspergillus flavus* resistance in the U.S. are being converted to lowland tropically adapted lines. Atoxigenic isolates of *A. flavus* from West Africa have been characterized and are being tested as biocompetetive agents in the field against toxic indigenous populations.

Outputs

9.1. Knowledge of pest and disease systems in pre- and post-harvest maize

Background

Country-wide surveys and farmer questionnaires are conducted to determine the extent of losses in maize production due to pests and diseases in the field and in storage, and farmers perceptions of these losses. Multivariate analyses of the survey data generate hypotheses on the interactions among physical components of the cropping system such as edaphic and crop management factors with biotic components of the system. The hypotheses are being tested in selected benchmark sites, on-farm participatory trials, on-station, or in the lab or greenhouse, using controlled experiments (See 9.3.). The survey protocols are regularly modified to incorporate findings from the controlled experiments. Yield assessment surveys are repeated in areas with critical pest densities and after an intervention technology has been introduced to assess impact on pest or pathogen populations and yield of maize.

Downy mildew disease of maize reached epidemic proportions in the southern half of Nigeria beginning in 1989, and began to spread. New infections began to appear sometimes as far as 100 km away from the nearest infection foci. It had previously been reported to be spread only by means of airborne conidia, as no alternate host had been located and none had found oospores in the maize infecting strain. In 1993, a program was designed to understand the mode of spread of the pathogen, and to begin practical implementation of a control program. By the end of 1995, the disease had spread into seven states and could be found within 50 km of the international frontier with Benin Republic. In 1998, the disease control campaign appeared to be having effect as the pathogen was not reported to have crossed into previously uninfected areas. In 1999, disease levels continued to decline as efforts continue to move downy mildew resistant maize seed further into the country by pyramid extension efforts in partnership with NGOs.

The larger grain borer was accidentally introduced from its area of origin in Mexico and Central America to East and West Africa in the late seventies and early eighties, respectively. It has been confirmed from many countries in West, East and Southern Africa. In the affected countries, larger grain borer has become one of the most important pests of farm-stored maize and cassava, particularly for small-scale farmers. In addition, grain and cassava postharvest losses to *S. zeamais*, the maize weevil, continue to be severe. The general approach of the Stored Product Pest Management project has been to use simulation modelling and GIS to provide a framework for putting together information on the ecology and economics of the pests, and then to examine the framework to develop specific lab and field experiments. On-farm surveys continue to be used to identify possible control options as well as farmer practices that may be ineffective or even dangerous, such as the application of field pesticides to grain stores. Properly arranged on-farm trials to ensure the immediate relevance of our work to farmers in the region, and the results are being used as the basis for courses developed in collaboration with NGOs and NARES. The simulation models themselves, as well as programs useful for developing sampling plans specific to a particular region, are to be included in a decision-support tool for release in 1999.

On-going and future activities

9.1.1. Diagnostics and loss assessment studies

by F.S., K.F.C., O.C. - in collaboration with G. Bigirwa, M. Botchey, E. Darkwa, A. Fofana, S. Hauser, S. Weise, C. Nolte, M. Koubé, R. Ndemah, Z. Ngoko*, W. Marasas, M. Sétamou*,*

The distribution of lepidopterous maize stem borers and diseases was assessed in farmers' fields in the southern regions of Ghana during three consecutive years. Maize stem borers encountered during the surveys included, in order of importance, *E. saccharina*, *Sesamia botanephaga*, *S. calamistis*, *B. fusca*, *Chilo aleniellus* and the cobborers *M. nigrivenella* and *Cryptophlebia leucotreta*. Highest infestations of stemborers was found in the Ashanti region. Seven fungi (*Bipolaris maydis*, *Puccinia polysora*, *Physoderma maydis*, *Stenocarpella macrospora*, *Curvularia* spp. *Marasmiellus paspali*, *Cercospora zea-maydis*), two viruses (maize streak and maize mottle virus) and 'physiological spot' of unknown origin contributed to leaf area destruction of 8-20% depending on season and region. Decreased soil fertility and high plant density favored the spread of *Puccinia polysora*. Physiological spot was negatively related to soil organic matter indicating perhaps that lack of soil organic matter promotes this condition of unknown aetiology. The complex of factors responsible for foliar loss varied with season and region. However, maize streak virus *P. polysora*, *B. maydis*, *Curvularia* spp., and nitrogen. deficiency were the most important across regions in all the surveys. Across regions, *B. maydis* and crop density caused 76.48 g per plant yield loss in the early season of 1996 while in the late season, more than twice this quantity was lost to maize streak virus, nitrogen deficiency, crop density, and stem borer tunneling. Cob weight reduction across the benchmark sites was about the same for both seasons in 1998 (45.86g/ plant). Factors that were responsible for losses in the early season included maize streak virus, nitrogen deficiency, crop density, *Marasmiellus paspali*, *Cercospora zea-maydis*, physiological spot and stem lesions but in the late season, the causal factors were maize streak virus, *Stenocarpella macrospora*, *P. polysora* and *Sesamia* spp. (For pest and disease diagnostics in Cameroon see R. Ndemah 1999 and Z. Ngoko et al. under completed studies.)

9.1.2. *M. nigrivenella*: a cob feeding pest of maize in western Africa

by F.S.- in collaboration with M. Sétamou, S. Gounou

Investigations on the ecology of and control options for the maize cob borer, *Mussidia nigrivenella* Ragonot (Lepidoptera: Pyralidae), were conducted in the different agro-ecological zones of the Republic of Benin, West Africa. Country-wide surveys in maize fields and on-station experiments revealed that the borer is the most abundant and the most damaging pest of pre-harvest maize. The damage of *M. nigrivenella* also continues during the first two months of the storage period. A simple mathematical model, relating *M. nigrivenella* cob infestation levels at harvest and maize yield losses due to the borer was developed. Yield losses caused by *M. nigrivenella* in the field could be determined by calculating the percentage of cobs infested by the borer. Infestation of maize cobs by *M. nigrivenella* was also associated with *Aspergillus flavus* infection and subsequent aflatoxin production in maize grains. The incidence of the borer varied with the agro-ecological zones. The borer is particularly damaging in the Guinea Savannas of central and northern Benin. The evaluation of the host plant range revealed the polyphagous feeding behaviour of *M. nigrivenella*. Moreover, the high abundance of *M. nigrivenella* in the Guinea Savannas was most likely due to the overlapping fruiting periods of host plants in these zones.

Life table studies of *M. nigrivenella* on natural host plant materials demonstrated the preference of the borer for jack beans, *Canavalia ensiformis* (L.) DC. (Fabaceae). In order to avoid that this new cover crop in West Africa constitutes a potential source of infestation of *M. nigrivenella* for neighbouring maize fields, planting of jack beans should be timed in such way that its fruiting period does not precede that of maize. Larvae of *M. nigrivenella* showed an aggregated distribution on fruits of most wild and cultivated host plant species, except for *Gardenia* spp. (Rubiaceae). Spatial distribution on a particular host plant species was highly correlated to the respective fruit sizes. Sample sizes and time expenditures needed to estimate *M. nigrivenella* populations at a precision level of 25% on the various host plants were determined. The flight activity of *M. nigrivenella* moths was affected both by weather factors and availability of fruits of major host plant species. Delaying the harvest of maize increased the incidence of the borer. Sun-drying of cobs at harvest for a week, however, reduced further damage in store. Investigations on the natural enemies revealed only few parasitoid species attacking *M. nigrivenella* and their presence was associated with the different wild host plant species. No natural enemies could be collected from maize and other crops. Parasitoids were found only on wild host plant species with the pupal parasitoid, *Antrocephalus crassipes* Masi (Hymenoptera: Chalcididae) being the most abundant species. Levels of parasitism were rather low. In future, biological control of

M. nigrivenella should therefore pursue the 'novel-association' or the re-distribution approach of natural enemies. Search for efficient natural enemies should concentrate on areas where *M. nigrivenella* doesn't pose a problem to annual crops as in East and Southern Africa.

9.1.3. Study of stem and earborers x storage pests x mycotoxic fungi interactions

by K.F.C., F.S., J.G.K., B.M.D. - in collaboration with O. Ayinde, A.A. Baba-Moussa, Z. Ngoko*, W.F.O. Marasas, S. Odubiyi*

Several field experiments have shown that higher numbers of all types of insects can be found in cobs that were infected with *F. moniliforme.* Many insect species including the lepidopteran *E. saccharina* and *M. nigrivenella*, and known storage pests such as *S. zeamais, Carpophilus spp.* and *Cathartus* spp. have been found in higher numbers when the fungus is present. Work in 1997 and 1998 has revealed that stem borers numbers were also higher in plants with endophytic *F. moniliforme* than plants without. Greenhouse and lab experiments showed that on plants inoculated with *F. moniliforme, E. saccharina* and *M. nigrivenella* laid significantly more eggs than on fungus free plants, and survival of immatures was higher. Similarly, olfactometer studies revealed that both *S. zeamais* and *Carpophilus dimidiatus* are strongly attracted to grain infected with Fusarium. By contrast, development time on infected plants was significantly shorter and longer for *S. zeamais* and *C. dimidiatus*, respectively. It is concluded that keeping the plant fungus free would also partly solve the insect problem in the field and store.

9.1.4. Improvement of maize quality through the reduction of aflatoxin contamination

by KFC, KH, AH in collaboration with Koubé, S. Egal, Ayin

At the beginning of 1999 a special project on the 'Improvement of maize quality through the reduction of aflatoxin contamination' received funding from BMZ/GTZ. A planning workshop was convened to assemble researchers working on the problem in Benin and Togo with resource persons. The results of this workshop were a project activity plan for the three research areas involved in the project: e.g. socio-economic, medical and agronomic. The agronomic activities are the participatory evaluation of management practices to reduce aflatoxin contamination in stored grains. Some of the management practices studied are timing of harvest, drying, influence of storage structure and insect control in 6 villages in two agro-ecological zones in Benin and Togo. On-station trials look at the influence of insect control methods on toxin levels. These technologies are being evaluated separately with the aim of developing technology packages that effectively reduce toxin load. Applied research is looking at the effect of variety on aflatoxin, biological control options and influence of N-source.

The socioeconomic actions are household level surveys in 12 villages in Benin and Togo to get basic socioeconomic data on the 50 households in each village involved in this study e.g. income, expenses etc. and the cost-benefit analysis of technology packages to reduce aflatoxin contamination.

The medical team will look in the first phase at the effect of aflatoxin exposure in 50 infants (0-3 years) in each of 16 villages in Benin and Togo. In a second phase a more intensive study will look at differences in vaccine response and growth of children and the relationship with aflatoxin contamination in low and high toxin areas.

Up till the end of 1999 the 16 villages participating in this study in Benin and Togo have been selected and characterized. The participatory tests have started and the protocols for the medical and socioeconomic village based activities have been prepared.

9.1.5. Biology and ecology of *P. truncatus* outside grain stores

by C.N. W.G.M. - in collaboration with A. Tchabi, T. Adouhoun, S. Awande, R. Kleespies

Analytical tools for analysis of P. truncatus flight activity have been identified and were used to link abundance of trap catches with vegetational variables. Changes over time in P. truncatus flight activity were compared for traps near grain stores and in a forest environment, and trap catches showed quite similar changes over time in the two environments. For this reason it is believed that, although the magnitude of trap catches is probably determined by the environment in a restricted range from the trap site, the overall changes over time are determined by weather driven changes influencing traps on a larger spatial scale. Spatial distribution analyses of pheromone trap catches are being conducted to examine the spatial association of P. truncatus and its natural enemy.

Intensive field sampling of woody substrates, shown from laboratory experiments to be susceptible to *P. truncatus*, failed to document these as potential substrates to *P. truncatus* in the forest environment. Screening of potential non-wood substrates (roots and seeds) for *P. truncatus* in the forest was conducted as a subsequent phase to previous screening of woody substrates. The importance of substrate quality (woody substrates

compared with maize) on male produced pheromone was studied by quantitative (field studies) and qualitative (extractions and gas chromatography of pheromone in laboratory experiments) comparisons of attraction

9.1.6. Modeling of storage pest population dynamics and grain losses

by W.G.M., R.H.M. C.N.- in collaboration with N. Holst

The first draft of an "electronic book", in the form of a CD ROM and downloadable from the internet, was assembled jointly by workers at IITA and the Danish Institute of Agricultural Sciences. The book contains chapters on simulation modelling of stored product pest population dynamics, and grain store sampling plans, as well as a brief history of larger grain borer research. The simulation models are linked to each other, via functional response, to a "systems" model of the grain store environment. Executable files of simulation models for *P. truncatus, S. zeamais* and the predator *Teretriosoma nigrescens*, and of programs for constructing sampling plans, are included, along with all the C++ coding and the datasets used to validate the models.

Iterative statistical techniques involving 43 datasets of experimental stores in different locations (Benin and Nigeria) and from different years were used to estimate the daily per capita rate of maize damage for *P. truncatus* and *S. zeamais*, and the results accepted for publication. Different models, one linear and one nonlinear, were examined. The nonlinear model, based on the prey/ predator functional response, was found to have a much better fit, although it requires more parameters. The per capita rates are used to link the pest models to the grain store environment described above, and to link model output with economic analyses.

The field experiment to monitor store conditions, insect density, and fungal infection and aflatoxin contamination in nine rural maize stores in southern Benin, was completed. Several stores suffered high infection rates by fungi as well as high densities of *S. zeamais*. However, the most common fungi were Fusarium spp.; the rates of infection by *Aspergillus* spp. were comparatively low and aflatoxins were found in some but not all samples. Statistical analysis of the data has not been completed.

9.1.7 Economic analysis of stored products

by W.G.M., C.N., R.H.M. - in collaboration with N. Holst

A database of maize prices was used to create a monthly map of average prices across Benin. The coordinates of the data from 20 markets were obtained, values were interpolated across all of Benin, and maps generated using the real and interpolated values. The maps show two peaks in prices, one in the south centered around Cotonou and occurring from March to June, and another one, centered around Natitingou in northern Benin, and occurring from June through August. These price maps will be linked to insect growth maps to estimate the potential value of IPM strategies. Data will be obtained for cassava.

9.2. Disease and insect resistant germplasm (pre- and post-harvest)

Background

The front line defense of choice for most pest and disease control is host plant resistance. The wide genetic variability that exists in most domesticated plant species offers one of the most powerful tools used in agriculture. Many plant diseases and some insect pests are characterized by an intimate host-parasite relationship, which involves specific mutual recognition genes. These intimate relationships have the greatest potential for host resistance development through classical breeding methods, yet these relationships are also the most susceptible to catastrophic resistance failure. Breeders, entomologists and pathologists must be constantly aware of what kind of pressure is being exerted on the pathogen/pest population as the breeding strategy unfolds.

Concurrent with upgrading of the levels of resistance to stem borers and maize downy mildew, extraction of inbred lines continues for both of these biotic constraints. A multiple-trait selection approach whereby only lines showing highly reduced levels of leaf feeding and stem tunneling are advanced to the next generation.

Currently, breeding efforts are continuing to develop resistance to the African complex of stem boring Lepidopterans, the Grey Leaf Spot disease (*Cercospora zea-maydis*), the grain mold fungi *Aspergillus. flavus* and *Fusarium verticillioides (ex F. moniliforme)*, and the larger grain borer, *P. truncatus*, among others. In these cases, host plant resistance is usually not the only line of defense that needs to be employed to achieve acceptable control, and the research program must be well coordinated to create control packages such that the component technologies complement each other. Nevertheless, whether or not it is likely to obtain high levels of resistance, breeders and plant protectionists must ensure that susceptibility is not being inadvertently introduced into germplasm that is being developed for other characteristics. Thus screening trials for pathogens and pests must be a constant collateral activity.

On-going and future activities

9.2.1. Mass-rearing of stemborers and development of field increase systems with NARES

by F.S. - in collaboration with S. Odubyi, S. Gounou

Mass rearing of *S. calamistis* and *E. saccharina* is a routine activity of the IITA-Ibadan laboratories. Approximately ten million eggs of the two species are produced every year. These are used for field infestations of breeding trials and for biological studies. In 1997, insect production at the IITA-Ibadan lab was drastically reduced to maintenance level due to financial constraints.

Besides *S. calamistis* and *E. saccharina*, IITA-Benin established small lab colonies of *B. fusca*, *M. nigrivenella* and *S. poephaga*. These insects are also used for testing their suitability for indigenous and exotic natural enemies' species and strains, and for mass rearing natural enemies including entomophagous organisms.

The major constraint in NARES HPR programs is to achieve uniform field infestations. Since rearing of stemborers on artificial diet is too expensive to be afforded by NARES, other field increase methods have to be sought such as the use of diapausing larvae for egg production (e.g. for *B fusca*) or the synchronizing of planting time with peak adult flight in areas with reliably high naturally occurring infestations. These methods are being developed and tested in Cameroon in collaboration with IRAD within the framework of a IFAD funded project on plant health of maize. First results show that sequential planting of spreader rows yielded uniform *B. fusca* infestation in the third maize plantation. In 1999 additional trials were carried out by NARES in Ghana and Cameroon financially and technically backstopped by the CIMMYT/IITA project on breeding for stress resistant maize in Africa (AMS).

9.2.2. Improve stem borer resistant populations/lines

by S.O.A., F.S.

A total of 706 S1 progenies from four maize populations (ICZ5BC2A, ICZ5BC2B, TZBR Syn WC1 and TZBR Syn YC1) with resistance to Sesamia or Eldana stem borer were evaluated at three location one of which was under artificial infestation with Sesamia or Eldana. S2 lines from selected S1 progenies were recombined in the irrigation season of 1999-2000 to form new cycles of the populations. Furthermore, 192 S1 lines from a newly formed stem borer resistant population (TZBR Eldana 4 C0) were evaluated in three locations one of which was under artificial infestation with *Eldana saccharina*. TZBR Eldana 4 was formed by introgressing adapted germplasm into TZBR Eldana 1. Results obtained from the evaluations indicated that enough variability exists for effective selection to be practiced. S2 lines from selected S1 progenies were recombined in the irrigation season to form the cycle 1 of this new population.

A 10 parent diallel of germplasm with resistance to *Sesamia calamistis* and/or *Eldana saccharina* was completed under artificial infestation with Sesamia and/or Eldana and at a hot spot location in South East Nigeria. Results (table 2) from the evaluation and from knowledge of the germplasm permitted the assignment of four and five populations respectively to form two broad reciprocal populations (TZBR Comp 1 and TZBR Comp 2) with some levels of resistance to both Sesamia and Eldana. The tenth population, AK9443DMRSR, although a very good general combiner, did not really fall into a particular group but was included in the formation of TZBR Comp 1 because of its high specific combining ability with two populations that were assigned to TZBR Comp 2.

Table 1. Means, ranges and coefficient of variability (CV) of traits used in an index to select for a new adapted stem borer (E. saccharina) resistant population – TZBR Eldana 4 C0 evaluated at three environments in Nigeria.

Variable	Average	Min	Max	Range	CV
*Cob damage Rat.	4	2	7	5	24
Cob damage count	6	0	18	18	59
Stalk breakage (count)	2	0	10	10	84
Silk (days)	59	46	72	26	7
Plant height (cm)	197	91	292	201	11
*Ear aspect Rat.	3	1	6	5	29
Yield infested (kg/ha)	2703	87	8343	8343	46
Yield uninfested (kg/ha)	2996	379	8623	8244	42

*Ratings on 1-9 scale

Table 2. GCA (on-diagonal, underlined) and SCA effect (off-diagonal) for grain yield from a ten parent diallel of stem borer resistant populations evaluated in ten environments of Nigeria from 1998-1999

Crosses	1	2	3	4	5	6	7	8	9	10
1*	-75.7	322.2	-258.5	147.1	-183.3	-2.9	92.6	-16.6	18.3	-119.0
2		49.7	60.4	-185.8	208.3	-42.9	-130.1	-72.5	-101.7	58.6
3			-130.8	-33.7	-85.8	-190.3	-28.9	35.9	246.0	254.4
4				47.1	-25.1	307.7	3.0	-323.5	9.5	100.9
5					-144.3	85.0	141.6	6.6	-33.0	-114.3
6						-99.3	145.8	102.7	-222.9	-183.0
7							-112.2	35.0	-43.6	-215.9
8								259.4	12.0	199.8
9									113.3	115.4
10										92.8

*1 = TZBR Eld. 1; 2 = TZBR Eld. 3; 3 = TZBR Ses. 1; 4 = TZBR Ses. 3; 5 = TZBR Syn W; 6 = TZBR Syn Y; 7 = ATP; 8 = Ak 9443 DMRSR; 9 = DMR-LSRW; 10 = Suwan-1 S

Table 3. Comparison of selection cycles from stem borer resistant maize populations evaluated at Egbema, Nigeria – Late Season 1999

Genotype	Grain yield (Kg/ha)	Plant aspect Rating (1 – 9)	Cob damage Rating (1 – 9)
TZBR Eldana 3			
C0	3981.7	4	4
C1	4370.7	3	5
C2	4437.2	3	4
TZBR Sesamia 3			
C0	2279.0	5	6
C1	2459.9	5	5
C2	3092.9	4	5
Mean	3123	4	5
SED	629.2	0.5	0.8
R-SQUARED	0.7	0.5	0.9
CV	28.5	67.1	23.0

A study to estimate progress from selection for stem borer resistance was conducted under artificial selection with Sesamia and/or Eldana and also under natural infestation at a hot spot location – Egbema in southeast Nigeria. Results obtained for example from two of the populations (TZDR Eldana 3 and TZBR Sesamia 3) evaluated at Egbema are presented in Table 3. This result suggests that in general, grain yield increased with newer cycles but plant aspect, a measure of the physical appeal of the genotype and cob damage due to stem borer infestation were rather constant. In effect, the selection index used in identifying superior genotypes with reduced levels of damage and good grain yield has resulted in an increase in tolerance rather than antibiosis. Tolerance as a mechanism of resistance is being promoted in the region because of its desirability in sustainable pest management programs.

9.2.3. Improve levels of resistance to downy mildew in maize

by S.O.A

A study to estimate progress from selection to downy mildew attack in maize was conducted in 1999 at Akure, Nigeria. Result obtained (Table 4) showed that in general, grain yield of the genotypes increased with a concurrent reduction in downy mildew incidence with each cycle of selection. This study and similar studies from previous years also revealed S1 selection to be an effective procedure in decreasing

downy mildew infection in maize with 4 and 5 cycles of selection being highly effective in reducing downy mildew infection to almost non-significant levels.

Table 4. Comparison of selection cycles from downy mildew resistant maize populations evaluated at Akure, Nigeria – Early Season 1999

Genotype	Grain yield (Kg/ha)	DM incidence (%)
TZL Comp4 DMRSR C11	2924.0	38
Ak 95 TZL Comp 4 DMRSR	4088.4	10
Acr.90 DMRLSR-W	3595.5	13
Ak. 93 DMRLSR-W	3017.9	2
Acr. 96 DMRLSR-W	4154.3	4
Ak. 95 DMRESR-W	2543.0	7
Acr. 89 DMRESR-W	1739.3	7
Mean	2448.1	26.7
SED	518.7	6.0
R-SQUARED	0.7	0.9
CV	30.0	31.9

9.2.4 Evaluation of maize inbred lines derived from adapted x exotic backcrosses for resistance to downy mildew

by A.M., K.F.C.

Seven-day-old seedlings of 48 maize inbred lines derived from backcrosses populations between downy mildew resistant and adapted inbred lines, namely KU1414 SR and KU1403, and introduced inbred lines were inoculated with downy mildew suspensions of 1.0×10^5 to 1.2×10^5 conidia ml^{-1}. Inoculated plants were transferred to the screen house and the number of infected plants was counted two weeks later. Significant differences among inbred lines were detected for percent downy mildew infection (Table 5).

Table 5. Mean percent downy mildew incidence of three resistant and three susceptible inbred lines selected from a trial inoculated with spore suspension in the screen house in 1999.

	Percent downy mildew infection	
Selected lines	Screen house	Field
(KU1414SR/SRx1368STR)-1-1-B	0	16
KU1414xFLA2AT98-1xKU1414-4-2 BAG	0	0
KU1414xFLA2AT116-1xKU1414-2-1 BAG	0	11
KU1414SR	100	2
1368STR	100	51
TZMI102	100	74
ACR90 POOL 16 DT (Susceptible Check)	100	90
Mean	86	38
SE	26	18
CV (%)	30	47
Probability of F	0.002	0.000

The disease pressure was so severe that even the inbred line with known resistance to downy mildew, KU1414-SR showed 100% disease incidence. However, three inbred lines derived from backcross populations of KU1414-SR did not show any downy mildew infection (zero infection). The donor parents of two of the three inbred lines are introductions (FLA2AT98, and FLA2AT116-1). These lines can serve as new sources of resistance to enhance durability of resistance to downy mildew in adapted varieties and hybrids.

9.2.5. Evaluating post harvest resistance to maize pests

by W.G.M, R.H.M. – in collaboration with D. Bergvinson, B. Maziya-Dixon

The variety which showed the most resistance to *P. truncatus* development and survivorship in laboratory tests was multiplied in the field, with samples sent to Ibadan for testing against pathogens, and to local farmers, to evaluate their impressions. The variety, which has a very short cycle (less than 90 days), was severely attacked by several diseases in Nigeria, and would not be acceptable in its present form in the African moist savannah. However, farmers in Benin, who did not experience many disease problems this year, appreciated the short cycle and found the maize acceptable in terms of color, hardness and taste. However, it remains to be seen whether the resistance characteristics observed in the lab provide economic benefits. Results from previous field trials and simulation modelling have shown that even relatively strong resistance may only provide temporary protection in field situations. In any case, performance in post-harvest situations is only one factor of many (for example, field resistance to pests, diseases and drought) that farmers consider in their choice of variety, so varietal resistance is best considered as part of an overall strategy against stored product pests, rather than a stand-alone technology.

9.2.6. Development of germplasm with resistance to *Aspergillus flavus*

by A.M., K.F.C. - in collaboration with R.L. Brown, D.G. White

Aspergillus ear and kernel rot of maize is caused by *Aspergillus flavus*. This disease and its associated production of aflatoxin in maize grain are severe in areas and years with drought conditions. Aflatoxins, which are toxic secondary metabolites, are potent carcinogens to humans and domestic animals, because they frequently contaminate the maize grain. Host plant resistance can make major contributions to the control of aflatoxin contamination of maize grain. In our effort to develop cultivars resistant to *A. flavus*, we introduced a breeding population and nine inbred lines exhibiting resistance to aflatoxin contamination in field and laboratory studies in the U.S.A. Backcross populations involving these genetic materials as donors of resistance to *A. flavus* were developed in 1999. Several S1 lines were extracted from three backcross populations for further inbreeding. As part of a collaborative research work with USDA, 76 IITA inbred lines were evaluated for resistance to aflatoxin accumulation, using a laboratory kernel screening assay. At least 18 inbred lines had aflatoxin levels as low as or lower than the most promising resistant genotypes identified by USDA. These lines also showed protein profiles that were not found among inbred lines developed in the US. Six potentially resistant and 4 susceptible inbred lines from the KSA, were selected for further investigation. Using an *A. flavus* genetic transformant containing a GUS reporter gene linked to a $-tubulin gene promoter in conjunction with the KSA, fungal growth and aflatoxins were both quantified and then compared in the selected lines. Generally, kernels of inbreds supporting lower levels of aflatoxins supported lower fungal growth and vice versa. Exceptions to this were inbred #1368 which accumulated moderately low levels of aflatoxin B_1, yet high levels of fungal growth, and inbred #15 with high aflatoxin levels and low fungal growth. Further studies of inbred lines 15 and 1368 may provide information leading to the identification of traits that directly affect the biosynthesis of aflatoxins. Traits previously identified appear to limit aflatoxin production indirectly through fungal growth inhibition.

9.2.7. Breeding for host plant resistance to *Cercospora zeamays*, causal agent of grey leaf spot of maize

by A.M., J.F., K.F.C. - in collaboration with G. Bigirwa, Z. Ngoko

In recent years, grey leaf spot has become the most devastating disease of maize in Eastern and Southern Africa. This disease has also been reported in Cameroon. Consequently, we initiated screening of our elite inbred lines in collaboration with scientist in the national programs to identify lines with good levels of resistance to this disease. Resistant lines will be useful to incorporate in our germplasm base in the event of an outbreak of grey leaf spot in West and Central Africa. A total of 64 elite mid-altitude inbred lines were planted in Uganda and Cameroon for screening against grey leaf spot. The data has not been received from our collaborators for analysis and inclusion in this report.

9.2.8. Evaluation of interaction between maize genotype, *Fusarium*, and stem borers

by S.O.A., F.S., K.F.C.

Old and new cycles of selection of 8 IITA maize genotypes were subjected to a 2x2 factorial experiment design with plants inoculated and non-inoculated with *Fusarium verticillioides* and *Eldana saccharina*. The hypothesis is that genotypes that have some resistance to stem borers, may also be resistant to *F. verticillioides*. From this experiment, it will also be possible to tell if, within the same genotype, cycles

of selection toward greater stem borer resistance are also having an effect on the amount of pathogenicity and asymptomatic endophycity of *F. verticillioides* in the maize stem.

9.3. Biological control and habitat/store management options

Background

Biological control and habitat management provide the options of choice, when levels of host plant resistance are inadequate to protect the crop against pest or disease pressure, since these strategies are usually highly compatible, or even synergistic, with genetic resistance. Indeed, biological control, especially for an introduced pest species like the larger grain borer, can often be implemented much more rapidly than adequate levels of plant resistance can be developed by breeding; thus, in some circumstances, biological control becomes the option of first choice. In the case of maize pests and diseases in Africa, we are faced with organisms of a variety of different origins, including co-evolved species, introduced recently or long-ago from the same area of origin as the crop, African species which have moved from other wild or cultivated cereals, some African species originating from botanically unrelated host plants, and a few species of quite different geographical origin. Before biological control or habitat management options can be developed, it is vitally important to diagnose the source of the pest or disease problem correctly. Especially for biological control of stem borers, collaboration or informal networking with taxonomists and with entomologists working in other regions and crop systems has played a key role in suggesting innovative ways to tackle this long-intractable pest problem.

Habitat management has, in principle, great potential as a strategy to reduce pest populations, either directly (for instance by killing pests surviving between cropping seasons in crop residues or on alternative host plants) or indirectly, by encouraging the action of natural enemies. However, in practice, the usefulness of this approach is constrained not just by our incomplete knowledge of the interspecific relationships involved (which can be addressed by research) but by the difficulty of changing the management of field margins and fallow areas, which normally receive little attention, especially in situations where the availability of labor is often strictly limited. The feasibility of any potentially-useful options must be evaluated very carefully through participatory research and extension exercises.

Bio-competitive niche management is a new approach for reducing the presence of several deleterious fungi associated with maize. There are current working examples of effective displacement of a undesirable target species with either an introduced or enhanced indigenous species that is more acceptable. Examples include hyperparasitic fungi such as *Trichoderma* spp. that can invade the niche of other fungi, such as endophytic *Fusaria* spp or rhizophytic *Rhizoctonia* spp.; and toxigenic *Aspergillus flavus* strain displacement by non-toxigenic strains of the same species.

On-going and future activities

9.3.1. Identification of promising redistribution candidates

by F.S. - in collaboration with W. Overholt, D. Conlong, R. Ndemah, G. Thottappilly

Surveys and on-station trials in various West and East African countries indicate that in many ecologies most indigenous parasitic natural enemies of cereal stem borers are not reliable and important natural control factors. In West Africa and under certain ecological conditions, exceptions are the *Sesamia* egg parasitoids, *T. busseolae* and *T. isis* which reach peak parasitization rates of over 90% before and during the second cropping season when the crop is both most attractive to ovipositing moths and susceptible to stemboring larvae, thereby significantly reducing yield loss. Likewise, recent on-farm studies in the forest zone of Cameroon showed that *Telenomus* spp. egg parasitism the main factor responsible for reduced *B. fusca* attacks on second season maize. Whereas *T. busseolae* has been reported to exist across Africa, *T. isis* has not yet been found in the eastern African region. The same study also showed higher diversity of beneficials on the wild host *Pennisetum purpureum* as compared to maize. Some of the species common in the Cameroon such as the tachinid *Actia? antiqua* and species of the *Tetrastichus atriclavus* complex, were never recovered from any other West African country, and Actia does not exist in South Africa indicating opportunities for the redistribution BC approach. *C. sesamiae*, a common larval parasitoid of *S. calamistis* and *B. fusca* in East and Southern Africa, is exceedingly rare in western Africa. In Cameroon, a few specimens only were obtained from *P. purpureum*. Strains of *C. seasmiae* from the Kenyan coast and Kitale provided by ICIPE were released in Benin and Nigeria but so fare the coastal strain only established in southern Benin. In both countries, the release cages disappear/get stolen as fast as they are set up and the fate of the parasitoids released is mostly unknown. In 2000, releases will therefore only be made on research stations.

Collaboration with the South African Sugar Experiment Station (SASEX), Durban, continued in 1999. Several consignments of *Sturmiopsis parasitica*, a tachinid pupal parasitoid attacking *S. calamistis* and *E. saccharina*, were sent to South Africa, and finally released in sugar cane fields.

In 1999, further consignments of *S. calamistis* pupae parasitized by *Pediobius furvus* were shipped to Brazil to be tested on the sugar cane borer *Diatraea saccharalis*. However, no lab colony could be established yet, for unknown reasons.

9.3.2. Testing the suitability of West African stemborer species for exotic and indigenous natural enemies

by F.S.- in collaboration with S.D. Imeldas, K. Agboka

Suitability tests were continued using five stemborer species- *S. calamistis, S. poephaga, S. botanephaga, B. fusca* and *E. saccharina*- and a coastal and Kitale strain of *Cotesia sesamiae*, and the exotic *C. flavipes* and *C. chilonis*, all provided by ICIPE, Kenya. Acceptability varied significantly with stemborer species and parasitoid, and tended to be lowest with *E. saccharina* followed by *B. fusca*. E. *saccharina* was not suitable to any of the parasitoids, whereas *B. fusca* was unsuitable for *C. chilonis, C.* flavipes and the coastal strain of *C. sesamiae*, and *C. flavipes* did not produce any offspring on *S. botanephaga*. For all species, highest proportion of female parasitoids were produces on *S. calamistis*, except for the Kitale strain for which *B. fusca* was the most suitable host. It is recommended to use the coastal strain of *C. sesamiae* in areas with multiple *Sesamia* species (Ghana) and the Kitale strain in area where *B. fusca* is the predominant species (Cameroon with special reference to the Western Highlands). As already shown in Benin, and earlier work in Ghana and Côte d'Ivoire, the exotic *C. flavipes* and *C. chilonis* because have little chance to get established because of low host specificity and suitability of some common host species.

The suitability of eggs of *S. calamistis, S. botanephaga* and *B. fusca* for the noctuid egg parasitoids *T. busseolae* and *T. isis* was tested in lab experiments. The parasitoids accepted and developed in all three host species. Generally, *T. busseolae* parasitized more eggs (52.0%) than *T. isis* (29.7%). For *T. isis* only, significant differences in parasitism between host species was found, with the highest rate of 40% on *S. calamistis* and 29.7% and 26.5% respectively, on *B. fusca* and *S. botanephaga*. For both species, emergence was highest on *B. fusca* and lowest on *S. botanephaga*. The sex ratio was not influenced by the host species but sex ratio of *T. isis* was always higher than that of *T. busseolae*.

9.3.3. The effect of various soil nutrients on development and survival of stem borers

*by F.S., S.O.A. - in collaboration with S. Hauser, S. Weise, R. Ndemah**

Survey work, lab and field trials conducted in Benin showed that increasing soil nitrogen favors both plant growth and survival and fecundity of stem borers, but had no effect on ear borers such as *M. nigrivenella* and *C. leucotreta*. Silica had a negative effect on survival on young *S. calamistis* larvae. However, differences between treatments were small, probably due to the low silica content of maize as compared with wild grasses and rice. Surveys carried out in southern Benin in 1993, showed negative relationships between *S. calamistis* densities and some soil nutrients. Life table studies of borers on plants subjected to various doses of K showed that for *S. calamistis* fecundity decreased linearly with K, whereas for *E. saccharina* only very low and very high dosages had a negative effect. Similarly, work in the forest benchmark sites in Cameroon yielded negative and positive relationship between K and Mg, respectively, and *B. fusca* densities at harvest. It is theorized that under insular conditions as occurring in forest fields, K could have a long-term negative effect on *B. fusca* populations via reduced fitness.

9.3.4. HPR x soil nutrient interactions

by S.O.A., F.S.

The nutrient status of the soil affects to a large extent the resistance or susceptibility of genotypes to stresses. Preliminary results obtained from a study conducted on the interaction of stem borer resistant or susceptible maize varieties with nitrogen and potassium fertilizer levels showed that grain yield and stem tunneling of the entries due to *Sesamia* infestation increased with nitrogen levels. Potassium had a negative effect on stem tunneling. Both the resistant and the susceptible entries gave their best grain yields at 120 kg N and 30-kg K.

9.3.5. The role of wild hosts as a refuge of natural enemies in the stemborer ecosystem

*by F.S. - in collaboration with S. Gounou, R. Ndemah**

Since maize is not available all year round, biological control by larval and pupal parasitoids takes place in the wild habitat. Thus, they are a refuge for natural enemies during the between and the off-season for maize and thereby stabilize the system. E.g., results from trials in Cameroon showed higher diversity of parasitoids on the wild host *Pennisetum purpureum* than on maize. In addition, results from survey in various countries and from lab studies indicated that many grass species act as trap plants causing immature mortalities of close to 100%.

Trap plant trials were carried out in 1998 and 1999, using *Pennisetum polystachion* only, and *P. polystachion, Panicum maximum* and *Sorghum arundinaceum*, respectively, as border rows. Data from both trials consistently showed that pest incidence (both *S. calamistis* and *E. saccharina*), borer densities and damage levels were significantly higher in pure stands of maize, although no significant differences in egg batch numbers were found between treatments. This was probably due to higher egg parasitism on grasses as compared to maize. Larval parasitoids such as *Cotesia sesamiae, Sturmiopsis parasitica* and *Decampsina sp* were recorded in the course of both experiments, with significantly higher parasitism on grasses. As for pests, proportion of plants showing *Fusarium moniliforme* disease symptoms was significantly higher in pure maize stands. However, all maize plots surrounded by grasses had considerably higher rodent damage, and as a net result, yields were one third-one fourth of that of pure maize fields. It is concluded, that the present planting arrangement, besides not being adoptable, is not an economically feasible option to control stemborers.

9.3.6. Microbial control of stemborers

by K.F.C., F.S. - in collaboration with, A. Cherry, S. Odubiyi, J.O. Bukola,

Stemborer populations crash long before the onset of the dry season. It has been suspected that this may be partly due to diseases that become important at high aggregation of the pests. A project on microbial control of stemborers funded by ODA started in 1996. For further details see Project 7: Biological Control of Pests in the farming systems.

A.o., the feasibility of using *Beauveria bassiana* to control *S. calamistis* and *E. saccharina* is investigated, with special reference to endophytic strains. *B. bassiana* isolates inoculated into the whorl of 30-day-old maize plants were recovered easily from the leaf tissue 30 days later. The fungus was seen to be growing in intercellular spaces and on the leaf surface. Field inoculations of maize stems also yielded recovery of *B. bassiana* above and below the insertion point giving the best indication yet that the fungus is capable of living and spreading endophytically within the plant. The plants with and without *B. bassiana* were also exposed to *Eldana saccharina*. Data on reduction in tunneling is being compiled.

9.3.7. Development and testing of pathogen application techniques against storage pests

by W.G.M., R.H.M. - in collaboration with A. Cherry

Data collected from lab and field experiments, conducted in 1997 to 1998 and involving the development of a biopesticide for grain stores, is being analyzed using simulation modelling. While the strain of Beauveria bassiana used in the field trial was found highly virulent against P. truncatus in the lab, application in a field situation failed to control the pest. By incorporating the observed values on the virulence and persistence of the entomopathogens into a simulation model of P. truncatus, role of the timing of the application and the target stage of the pest (e.g. larval or adult stage) will be examined. The results will also be used to indicate the characteristics to look for in candidate fungal strains and in carriers and application techniques for stored products.

9.3.8. *T. nigrescens* release and monitoring

by W.G.M, R.H.M., C.N. – in collaboration with D. Bergvinson, J. Hirabayashi, G. Hill, F. Nang'ayo

T. nigrescens individuals, collected by workers at CIMMYT, were sent for quarantine to CABI in the UK. No pathogens or parasitoids were found in any of the collected beetles, and the progeny of those beetles were sent to PHMD for lab tests on their tolerance of cool temperatures. Initial results show that the new *T. nigrescens* have similar temperature requirements as those found in southern Benin, suggesting that the poor performance of *T. nigrescens* at mid altitude sites in East Africa is not due merely to cold sensitivity of the strain of *T. nigrescens* released in East Africa, but probably to a complex of other factors.

9.3.9. Soils characterizations for atoxigenic strains of the soil inhabiting fungus *A. flavus*

*by K.F.C. - in collaboration with P.J. Cotty, L. Ayinde, T. Hoffstadt**

Populations of *A. flavus* in agricultural field soils are composed of strains that exhibit a gradient of aflatoxin producing ability. Studies in the U.S.A. have shown that toxigenicity of a strain is not related to the ability of the strain to invade and colonize host tissue. In field experiments in the United States, atoxigenic strains of *A. flavus* have been found to interfere with and displace toxigenic strains and thus reduce preharvest aflatoxin contamination of maize. This is currently being tested on a semi commercial scale in the US as a potential control for contamination of cotton, groundnut, and maize.

A number of atoxigenic isolates have been identified from Benin, for which NIT mutants have been generated, and characterized as to vegetative compatibility group (VCG). The prevalence of these VCGs in the soils of Benin will be studied over the next few years.

A toxic and an atoxigenic isolate of *A. flavus* were tested in the field on maize ears to assess if there is biocompetition between the isolates. Ear silks were inoculated with one or the other strain, and then both strains in one after another to determine if toxin production could be precluded by the atoxigenic strain. The atoxigenic isolate alone produced no toxin in the ear. The mixture of atoxigenic and toxigenic significantly reduced toxin production in the ear when the atoxigenic strain was applied after the toxigenic. The trial is being repeated in 1999.

9.3.10. Biological control of *F. moniliforme* with endophytic hyperparasites.

by K.F.C. - in collaboration with A.C. Odebode, A.A. Shobowole

Fifty two fungi including the pathogen (*F. moniliforme*) were isolated from different parts of the maize plant and it's rhizosphere using acidified potato dextrose agar (APDA) (July - Sept. 1997). One after the other, each of the fungi was tried as a potential antagonist against the pathogen by pairing in-vitro, using three methods of pairing, each of which was done in triplicates (Oct.1997 - May 1998). Fourteen of the potential antagonists (ten *Trichoderma* spp., three *Mucor* spp. and one *Rhizopus* sp.) were successful against the pathogen. Analysis showed *Trichoderma longibrachiatum*, *T. harzianum* (str.3) and *T. polysporum* as the best of all the potential antagonists, and inoculation of the antagonist before the pathogen (AGb4P) as the best pairing method. The fourteen successful antagonists were taken to the screen house and to the field and were either paired with the pathogen (*F. moniliforme*) or inoculated singly into maize stalks. Data on length of pith rot, location of recovery of the antagonist and the pathogen from the stem, and yield were taken. Data analysis is continuing.

9.4. Tools and tested packages for IPM of maize pests and diseases

Background

In the high-input cropping systems for which IPM strategies were originally conceived, reduction of excessive pesticide use, and the compatibility of pesticide use with other IPM options, was often the key issue to be resolved in practical development and testing. However, in most maize systems in Africa pesticide use is not very prevalent and the development of integrated control strategies is a matter of constructively assembling a number of compatible options, especially to enhance plant health and ensure the sustainability of the complete system. For pre-harvest pests and diseases, working with soil fertility may be an especially important component of the system. Once diagnostic research has indicated the real nature of the problem and the form of a possible solution, the key to progress towards IPM implementation lies with the empowerment of farmers. Usually, neither farmers nor extensionists understand the underlying ecological principles of pest and disease regulation and it is only when they have acquired some of this knowledge that they may be prepared to undertake the changes, often requiring extra labor, that are involved in the implementation of IPM. Participatory or collaborative approaches may provide a vital entry point to this process.

Post-harvest losses from insect feeding and losses in quality from fungal contaminants are multivariate problems that usually start in the field and are carried into the store. Often, there are a series of management practices that lead to poor post-harvest storage conditions. To optimize commodity management practices to reduce post-harvest losses in maize, and to understand what costs are involved in doing so, requires IPM component testing with farmers.

On-going and future activities

9.4.1. Farmers participatory deployment of Downy mildew resistant maize

by S.O.A., V.A – in collaboration with World Vision International, B. A. Ogunbodede, E. I. Jolaji, V. Manyong

In continuation of our efforts in 1997 to saturate the Ogbomoso area of Oyo State in Nigeria with DMR maize varieties, the World Vision International (WVI) again provided support in 1998 to the project. For the second year a total of 111 farmers from 34 villages were aided to produce either a late (DMRLSR-W) or an early (DMRESR-W) maize population as preferred. Farmer to farmer diffusion is being used to quickly saturate the area with an improved technology, in this case, a variety. Our model ensures that an already trained farmer backstops a total of four new farmers made up of three farmers from a new village and one from the trained farmer's village, each year. In effect, from a total of 25 farmers from 9 villages that participated in the first year, we expected 100 new farmers and 25 new villages in 1998 thus bringing the total for the year to 125 farmers from 34 villages.

The level of interaction with the project by different categories of farmers was reflected in the grain yield obtained. For example, an average grain yield of 3.7 t/ha was obtained from the old and experienced farmer (farmers that started with the project in the first year) while the average from the new set of farmers was only 2.5 t/ha. Similarly, yield data were obtained from neighboring but non-participating farmers. Average grain yield for the non-participating farmers was 1.9 t/ha while that of the participating farmers was 2.8 t/ha.

9.4.2. Strategic deployment of downy mildew resistant maize

by S.O.A., V.A. - collaboration with V. Manyong, World Vision International- J. Olufowote

With the support of World Vision International, the project on the saturation of a designated area with downy mildew resistant maize varieties was concluded in 1999. For this reporting period, a total of 625 farmers in 159 villages were producing seed of resistant varieties and all had been trained how to produce a healthy crop in field schools run by IITA scientists. Average yields increased by 50% from 1846kg/ha for non-participating farmers to 2763 kg/ha for participating farmers. Downy mildew resistant maize is currently being grown on 45,389ha in Ogo-Oluwa and 240,000ha in Orire, the two local government areas selected for the deployment exercise.

9.4.3. Exclusion of downy mildew from IITA, Ibadan campus

by V.A., K.F.C. - in collaboration with O. Ayinde, D. Onukwu, G. Ogbe

Given the potential for the downy mildew pathogen to be transmitted via seed, spore fall is being monitored and infected maize plants are being rogued to protect the maize breeding program on the IITA, Ibadan campus. Spore fall is being constantly assessed as the total catch on a one cm strip of adhesive tape in a Burkhard spore trap per hour. Exclusion of the disease from the IITA campus is continuing, by treating all maize seed with Apron plus®, and/or using DMR varieties. Campus maize plots were periodically monitored for downy mildew infection and rogued. During the 1996 period, 23% of maize plants in research plots were found to be infected and by 1997 incidence of infected plants on the campus was at .07%. The average spore catch in a Burkhard spore trap in the center of IITA campus dropped from a mean maximum of 5 to around 3 spores/mm^2/hr from 1994 to 1995. In 1996, the maximum mean spore catch in the year was about 1.2 spore/mm^2/hr which indicates a marked decrease in epidemic potential. The highest mean central campus spore trap catch in 1997 was .8 spores/mm^2/hr, indicating an even further decline in epidemic potential on the IITA campus. Nevertheless, a spot survey of farms around the IITA perimeter, revealed that infection in farmers' fields still ranged from 0 to 94% in June, 1997.

In 1998, spore fall and infected plants in and around IITA campus continued to be monitored. In 1998, no single maize plant in IITA research plots was found to be infected. A survey of maize farms outside IITA campus showed that 71% of the total farms surveyed had no infection while the remaining 29% had infection ranging between 0.03 – 27%. The highest mean spore catch in the year was about 1.7 spore/mm2/hr in April, but declined to between 0.7 – 0.8 spore/mm2/hr at the peak of planting. These indicators were a marked reduction from 1997 and may be the result of an unusually dry year.

Continuing the trend started in 1998, during 1999 no downy mildew infected maize plants were found on the IITA campus. The highest hourly spore catch occurred in July and was 0.25 spore/mm2/hr. For the first time since the epidemic started in 1992, for 9 of the 12 months of the year the spore catch was 0.

9.4.4. Testing of integrated post-harvest quality management options

by K.H., K.F.C.

Selected villages were visited with a team of socioeconomists and focus groups assessed the post-harvest management problems encountered by farming families in these areas to identify points of intervention. The Aflatoxin Project collaborates in these villages with field agents working for the PADSA Project (a Danish project working in postharvest research) which supports the Beninese NARES (INRAB) in Benin; and with the GTZ Public health project and the Togolese NARES (ITRA).

The aflatoxin control options that are tested in the villages are:

a) influence of sorting
b) influence of storage structure (traditional vs. storage in polyethylene bags)
c) influence of insect control (with recommended post-harvest insecticides)
d) influence of drying
e) toxin contamination in clay stores

In some villages a combination of the control options is being tested.

Trials were established with farmer groups to evaluate the influence of these management practices on aflatoxin development. At 2 months intervals maize samples are evaluated with the farmers to assess insect infestation, fungal contamination and market price. Samples will be taken to the laboratory to get a clearer picture of the fungal spectrum and determine aflatoxin levels.

9.4.5. IPM of stored product insect pests

by W.G.M., C.N., R.H.M. – in collboration with HELVETAS

Six farmer workshops were held in southern Benin and Togo in collaboration with Helvetas, a Swiss-based NGO. The workshops were attended by Stored Product Pest Management workers from IITA, technicians from Helvetas, and approximately 30 farmers (men and women) at each location. The objectives of the workshops were to identify the most important agricultural problems perceived by farmers, to determine how these problems are currently solved by farmers, and to expose farmers to research being done at agricultural research centers. Post-harvest pests were considered very important, and in visits to grain stores in sites in southern Togo showed high infestations of the larger grain borer. Results from the workshop are being used to design a course for extension workers and farmers on post-harvest pest management.

Five farmers in southwestern, southeastern and northeastern regions of Benin, for a total of 15 farmers, have been involved in the testing of potential IPM strategies for postharvest maize. At each site, usually the farmer's compound, three grain stores were constructed: one store constructed and maintained by the farmer according to his or her own preferences, one store treated with a grain protectant at the time of stocking, and one store untreated. All three stores at each site are sampled once per month. The objective of the work is to determine whether application of the simplified sampling plans can be effective, to evaluate the efficacy of the use of grain protectant on whole ears stored in the husk (as farmers usually do in these areas) and to examine, with the farmer, whether the farmers preferred strategy, often involving the application of field pesticide, is really economical and effective. Several of the stores have been severely infested with larger grain borer. One farmer in each region will be selected to host a course in stored product IPM, to be given by IITA and Helvetas. The selected farmer's stores will be sampled, and group evaluations of the results will be conducted, along with lessons on insect identification, available IPM options, and economics of stored products.

Completed studies

Journal articles and book chapters

Adenle, V.O. & K.F. Cardwell. Seed transmission of maize downy mildew* (Peronosclerospora sorghi) *in Nigeria. Euro J. of Plant Pathol. (in press).

In an area of Nigeria where downy mildew of maize is present, histological assessment of maize seed revealed the presence of mycelium and oospores of *Peronosclerospora sorghi* in the kernels. Seed transmission of downy mildew of maize was demonstrated when grain purchased at local markets gave a mean seedling infection of 14% (untreated seeds) and 11.8% (in metalaxyl treated seeds) within the first 7 days of emergence. When seeds taken from nubbin ears of systemically infected plants from southern Nigeria were planted at 9 days (22% moisture content), and 27 days (10% moisture content) after harvest, 10.0% and 33.3% infected seedlings resulted, respectively. Seeds from northern Nigeria had 13% systemic seedling infection after 9 months of storage at 8% moisture content.

When seeds harvested from maize plants inoculated with *P. sorghi* through silks were examined histologically, hyphae of *P. sorghi* were observed mostly in the scutellum of the embryo. Transmission of disease to seedlings was observed when the silk inoculated seeds (9% moisture content) were planted in pots in a greenhouse, however no disease transmission was observed when such seed was planted in the field.

The epidemiological significance of seed transmission is discussed with particular reference to survival of inoculum, and development of epidemics. Also noteworthy is the overall significance of seed transmission in Nigeria, where the major source of seed is saved by farmers from their grain crop, occasionally supplemented by seed bought from the local market.

Adipala, E., G. Bigirwa, J.P. Esele, & K.F. Cardwell, 1999. Development of sorghum downy mildew on sequential plantings of maize in Uganda. Int. J. of Pest Management 2:147-154.

Agboka, K., F. Schulthess, I. Labo & H. Smith. Intra- and interspecific superparasitism of **Telenomus busseolae** ***Gahan and*** **Telenomus isis** ***Polaszek (Hymenoptera: Scelionidae) two egg parasitoids of the African cereal stemborer*** **Sesamia calamistis** ***Hampson (Lepidoptera: Noctuidae). BioControl (submitted).***

Host discrimination, oviposition behaviour, self-, inter and intra-specific superparasitism by the scelionids *Telenomus busseolae* and *T. isis* were studied at 0, 24 and 48 hours after eggs of the pink stalk borer *Sesamia calamistis* were first parasitized. Three events marked the oviposition behaviour: Antennal drumming, insertion of ovipositor and oviposition, and marking of parasitized eggs. Both *Telenomus* species were able to discern eggs already parasitized. As a result, self-superparasitism was only 37.7% for *T. busseolae* and 27.0% for *T. isis*. Superparasitism was significantly higher when parasitized eggs were offered immediately and after 48h than 24h later. Apparently, the recognition of parasitized eggs after 24h and 48h was based on presence of parasitoid larvae rather than a specific marking substance. Intra-species superparasitism was 32 and 15% respectively for *T. busseolae* and *T. isis* when the parasitized eggs were offered immediately. Inter-species superparasitism after 0 hour was 24.1 and 17.2% when *T. busseolae* and *T. isis*, respectively, was the second species, indicating that both species recognized each other's markings, and emerging offspring were 63.4% *T. busseolae* versus 9.5% *T. isis*, with low mortality. At 24 h, superparasitism was 16.3 and 9.6% when *T. busseolae* and *T. isis*, respectively was the second species. In this case, the first species emerged more often than the second did but the mortalities were >40%.

Ayertey, J.N., W.G. Meikle, C. Borgemeister, M. Camara & R.H. Markham. 1999. Studies on predation of Prostephanus truncatus (Horn) (Col.: Bostrichidae) and Sitophilus zeamais Mots. (Col.: Curculionidae) at different densities on maize by Teretriosoma nigrescens Lewis (Col.: Histeridae). Journal of Applied Entomology 123: 265-271.

Laboratory experiments using whole cobs were conducted to examine the effect of varying densities of the larger grain borer, *P. truncatus* and the maize weevil, *S. zeamais* on rate of population increase by the histerid beetle, *T. nigrescens*, a predator primarily of *P. truncatus*. Densities of all species of insects were determined at the end of the experiment, and an electrophoretic analysis of gut content was conducted on larval and adult *T. nigrescens* sampled during the experiments. Results indicated that *T. nigrescens* has a strong preference for *P. truncatus* and densities of *T. nigrescens* were associated only with densities of *P. truncatus*. Although *T. nigrescens* could complete development on *S. zeamais* the maize weevil played little role as an alternative prey or in interfering with *T. nigrescens* reproduction.

Bigirwa, G., E. Adipala, J.P. Esele & K.F. Cardwell, 1999. Reaction of maize, sorghum and johnson-grass to Peronosclerospora sorghi. Int. J. of Pest Manage. (in press).

Bock, C.H., M.J. Jeger, L.K. Mughogho & K.F. Cardwell, 1999. Effect of dew point temperature and conidium age on germination, germ-tube growth and infection of maize and sorghum by an isolate of Peronosclerospora sorghi from Zimbabwe. Mycol. Res. 103 :859-864.

Bonato, O., F. Schulthess & J.U. Baumgaertner, 1999. A simulation model for carbon and nitrogen allocation and acquisition in maize. Ecological Modelling 124: 11-28.

A common demographic model for maize growth and development driven by temperature, solar radiation, soil water and soil nitrogen is presented. A distributed delay model was used to describe the dynamics of carbohydrates and nitrogen of leaves, roots, stems and grains in the plant. Light (Photosynthesis), water and nitrogen uptakes were simulated with a modified functional response model based on predation theory. Carbohydrates, water and nitrogen supply-demand ratios scale growth of different populations of plant organs (leaf, stem, root, grain). The model was validated with field data from a 95 and a 120-days variety grown at the Research Station of the International Institute of Tropical Agriculture in Calavi, in the south of the Republic of Benin (West Africa). The effects of drought stress, soil nitrogen contents and planting density on maize growth were investigated.

Bonato, O. & F. Schulthess, 1999. Selecting a character for identifying larval instars of the stemborers **Sesamia calamistis** ***Hampson (Noctuidae) and*** **Eldana saccharina** ***Walker (Pyralidae) on maize. Insect Sci. Applic. 2:101-103.***

In experiments to select a character for identifying larval instars in *S. calamistis* and *E. saccharina*, body length, body width and head capsule width were measured in populations reared on artificial diet. Seven instars were

found in *S. calamistis* and 5 in *E. saccharina*. For both species, body length was determined to be the best characteristic to distinguish instars because it was easy to measure and had the smallest error.

Borgemeister, C., K. Schaefer, G. Goergen, S. Awande, M. Sétamou, H.M. Poehling & D. Scholz, 1999. Host-finding behaviour of* Dinoderus bifoveolatus *(Coleoptera: Bostrichidae), and important pest of stored cassava: The role of plant volatiles and odors of conspecifics. Annals of Entomological Society of America, 92:766-771.

In cassava chips, sampled on a local market in Cotonou, *Dinoderus bifoveolatus* Wollaston was the most predominant pest. In olfactometer experiments, cassava chips infested by *D. bifoveolatus* were highly attractive to both sexes of the beetle, suggesting that male *D. bifoveolatus* produce an aggregation pheromone. Female *D. bifoveolatus* showed a significantly stronger response pattern than conspecific males. Sticky traps, baited with cassava chips harboring male *D. bifoveolatus*, set up in 2 regions of southern Benin, caught consistently considerable numbers of conspecifics. Trap catches differed significantly between regions, and for one region also between the sites. The sex ratio of the trapped *D. bifoveolatus* was significantly female-based. Low numbers of 2 other bostrichids, i.e., *Prostephanus truncatus* (Horn) and *Rhyzopertha dominica* (Fabricius), were also recorded in the traps.

Bourassa, C., C. Vincent, C.J. Lomer, C. Borgemeister & Y. Mauffette. Effects of* Beauveria bassiana *(Balsamo) Vuillemin and* Metarhizium anisopliae *(Metschnikoff) Sorokin on the larger grain borer,* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae), and its predator,* Teretriosoma nigrescens *Lewis (Coleoptera: Histeridae). Journal of Invertebrate Pathology (submitted).

Four strains of entomopathogenic fungi, three of *Beauveria bassiana* and one of *Metarhizium anisopliae*, were tested against *Prostephanus truncatus*, a pest of stored maize and cassava introduced into Africa, and against its natural enemy, the predator *Teretriosoma nigrescens*. All strains were pathogenic to adults of the two beetle species. At a concentration of 10^9 spores ml^{-1} mortality rates were nearly twice as high for *P. truncatus* than for its predator (90-95% vs. 42-56%). Mycopesticides could therefore be used in an integrated pest management approach against *P. truncatus*, as a complement to the use of its natural enemy *T. nigrescens*. Applications of formulations containing 10^8 and 10^9 spores ml^{-1} resulted in 100% mortality of *P. truncatus* larvae on the eighth and fourth day, respectively. *P. truncatus* eggs were not affected by the strains and fungi tested. When *B. bassiana* (10^9 spores ml^{-1}) was applied to maize grains and cobs under semi-field conditions, approximately 27% mortality of adult *P. truncatus* was observed. This low rate may be explained by poor contact between the insect and the fungal spores applied on the grain.

Cardwell, K.F, J.G. Kling, B. Maziya-Dixon & N.A. Bosque-Pérez. Relationships among* Fusarium moniliforme *and* Aspergillus flavus *ear rot pathogens, insects and grain quality in four maize genotypes in the lowland tropics of Africa. Phytopathology (in press).

An experiment was designed to compare maize genotypes for ear and grain quality characteristics, interactions with *Aspergillus flavus* and *Fusarium moniliforme* infection, and insect infestation of the ear over two seasons. Mean infection levels by *A. flavus* and *F. moniliforme* were significantly higher in inoculated rows than in the controls and were inverse to each other under the respective inoculation treatments. The *F. moniliforme* inoculated rows had significantly more coleopteran and lepidopteran borers per ear than the controls and *A. flavus* inoculated rows. Genotypes were not different with respect to numbers of insects or % fungal incidence in the ear, but they were for husk extension, % floaters, and grain hardness. Inoculation with either fungus resulted in significantly higher percent of floaters and lighter grain weight than the controls. Grain hardness increased with *F. moniliforme* inoculation, particularly in the soft endosperm populations. Aflatoxin (B1 and B2) in the *A. flavus* inoculated rows averaged 327 ppb the first season and 589 ppb in the second (and dryer) season. Fumonisin levels in *F. moniliforme* inoculated rows did not differ between seasons, with an average of 6.2 ppm across seasons. In the non-inoculated control rows, fumonisin was significantly higher in the first season (5.3 ppm) than in the second (3.1 ppm). Husk extension was reduced across genotypes in the fungal inoculated treatments. General ear rot scoring was significantly correlated with *F. moniliforme*, and grain weight loss, but not with *A. flavus* in the grain.

Cherry, A.J., C.J. Lomer, D. Djegui & F. Schulthess, 1999. Pathogen incidence and their potential as microbial control agents in IPM of maize stem borers in West Africa. BioControl 44: 301-327.

A review of the existing basis for maize stem borer IPM is given and the role of pathogens in the system evaluated. Survey work outlining the major groups of insect pathogens is described; fungi (*Beauveria bassiana* and *Metarhizium anisopliae*), bacteria (*Bacillus thuringiensis* and *Serratia marcesens*), and viruses (granuloviruses and cytoplasmic polyhedroviruses) were identified. The presence of other unidentified protazoans, nematodes, fungi and viruses was noted. The virulence of some of the more promising known insect pathogens was explored in preliminary bioassays. Considering the cryptic habits of the insects, and the low input agriculture practiced by the majority of maize farmers in sub-Saharan Africa, *B. bassiana* isolates possessing the capacity to grow systemically in the maize plant are considered one of the more interesting candidates for development as microbial control agents despite limited control in preliminary trials. Further work should also investigate the potential of pathogens of moderate virulence, such as the protozoans and CPVs.

Cotty, P.J. & K.F. Cardwell, 1999 West African and North American communities of* Aspergillus section flavi *are divergent. Applied and Environmental Microbiology 65:2264-2266.

West African *Aspergillus flavus* S Strain isolates differed from North American isolates. Both produced Aflatoxin B_1. However, in NH_4 medium 40% and in Urea medium 100% of West African isolates also produced aflatoxin G_1. No North American S strain isolate produced Aflatoxin G_1. This geographical divergence may influence aflatoxin management.

Denké, D., F. Schulthess, O. Bonato & H. Smith. Effet de la fumure en potassium sur le développement, la survie et la fécondité de Sesamia calamistis Hampson (Lepidoptera: Noctuidae) et de Eldana saccharina Walker (Lepidoptera: Pyralidae). Insect Sci. Appl. (in press).

L'influence de la teneur en potassium de la fumure appliquée au maïs, sur le développement, la survie, la fécondité, ainsi que sur le poids des larves et des chrysalides de *Sesamia calamistis* et de *Eldana saccharina* a été étudié en laboratoire. Six différents traitements correspondant à des doses de 0, 30, 60, 90, 120 et 150 kg K_2O/ha ont été utilisés. L'augmentation de la dose de potassium n'a pas affecté les durées de développement larvaire et nymphale, ni la longévité des femelles de *S. calamistis*. Les mortalités larvaires les plus élevées ont été enregistrées à 0 et 150 kg K_2O/ha. Concernant les chrysalides les différences ont été beaucoup moins marquées, mais des teneurs élevées en potassium (> 60 kg K_2O/ha) tendent à réduire leur survie. La fécondité a été négativement corrélée à l'augmentation de la dose de potassium. Le poids le plus faible chez les larves et chez les chrysalides a été obtenu à la dose de 150 kg K_2O/ha. Les valeurs du r_m et du R_0 ont été maximales à 60 kg K_2O/ha. Pour *E. saccharina* aucun effet du potassium n'a été noté sur les durées de développement larvaire et nymphal, sur la survie larvaire, ainsi que sur le poids des chrysalides. Les valeurs de survie des chrysalides, de la fécondité, du poids des larves, du r_m et du R_0 ont été maximales à 90 kg K_2O/ha.

Gudrups, I., S. Floyd & N.A. Bosque-Pérez. A comparison of two methods of assessment of maize varietal resistance to the maize weevil,* Sitophilus zeamais *Motschulsky, and the influence of kernel hardness and size on susceptibility. Journal of Stored Products Research (submitted).

Hell, K., K.F. Cardwell, M. Sétamou & H.-M. Poehling. Maize Storage Practices And Their Influence On Aflatoxin Contamination In Stored Grains In Four Agroecological Zones In Benin, West Africa. J. Stored Prod. Res. (in press).

Aflatoxin levels in 300 farmers' stores in four agroecological zones in Benin, a west African coastal country, were determined over a period of 2 years. At sampling a questionnaire helped to evaluate maize storage practices. Farmers were asked what storage structure they used, their storage form, storage period, pest problems in storage and what was done against them. Beninese farmers often changed their storage structures during the storage period. Maize would be transferred from a drying or temporary store to a more durable one. Most of the farmers complained about insects damaging stored maize. Often, storage or cotton insecticides were utilized against these pests. Regression analysis identified those factors that were associated with increased or reduced aflatoxin. Maize samples in the southern Guinea savanna and Sudan savanna were associated with higher aflatoxin levels and the forest/savanna mosaic was related to lower toxin levels. Factors associated with higher aflatoxin were: storage for 3-5 months, insect damage, and use of Khaya senegalensis bark or other local plants as storage protectants. Depending on the agroecological zone, storage structures that had a higher risk of aflatoxin development were the "Ago", the "Secco", the "Ava" or under the roof of the house. Lower aflatoxin levels were related to the use of storage or cotton insecticides, mechanical means or smoke to protect stored grains or cleaning of stores before loading them with the new harvest. Storage structures in which fewer aflatoxins were found were the "Ago" made from bamboo or when bags were used as secondary stores.

Holst, N., R.H. Markham & W.G. Meikle. Integrated pest management of postharvest maize in developing countries. IITA Publications (submitted) [http://www.agrsci.dk/plb/bembi/africa/project.htm.]

A CD ROM was developed containing downloadable simulation models, sampling plans and associated computer programs, and field data, along with a brief introduction to research on the larger grain borer. The weather-driven models include *Prostephanus truncatus*, *Sitophilus zeamais* and *Teretriosoma nigrescens*, and they are linked to grain damage and weight loss. Sequential sampling plans are presented.

Holst, N., W.G. Meikle & R.H. Markham. Grain injury models for* Prostephanus truncatus *(Coleoptera: Bostrichidae) and* Sitophilus zeamais *(Coleoptera: Curculionidae) in rural maize stores in West Africa. Journal of Economic Entomology (in press).

Prostephanus truncatus (Horn) and *Sitophilus zeamais* Motschulsky have been reported as the two most serious pests of stored maize in sub-Saharan Africa and smallholder farmers are in urgent need of guidelines for their proper management. In this paper we investigate the injury rates attributable to these two species in terms of percentage weight loss and percentage grain damage, and we derive functional response models for the two species on maize. The models successfully described the progression of grain injury in an extensive data set compiled from previously published studies, comprising 43 time series of data relating maize injury and insect pest density. The grain injury models can be used, in conjunction with predictive models of pest population

dynamics, to guide the development of integrated management strategies for post-harvest maize pests in West Africa and comparable regions elsewhere.

Meikle, W.G., N. Holst, & R.H. Markham. 1999. A population simulation model of* Sitophilus zeamais *Motschulsky (Coleoptera: Curculionidae) in grain stores in the Republic of Benin. Environmental Entomology 28: 836-844

A distributed-delay, demographic simulation model of *Sitophilus zeamais* Motschulsky populations in rural maize (*Zea mays* L.) stores was developed. Published equations describing the effects of temperature, humidity and density effects on fecundity, juvenile survivorship and development and emigration were used or equations were estimated from published data and from laboratory experiments. Simulation model output was compared to *S. zeamais* density observed in field experiments before and after the introduction of *Prostephanus truncatus* (Horn) to West Africa. The overall phenology of the simulated beetle dynamics reflected that of field data, although the model output tended to overestimate beetle population growth early in the season. The model was modified using published data to simulate dynamics of populations developing on resistant and susceptible maize cultivars. The model is intended as part of a cost-effective tool for evaluating factors influencing population dynamics of stored-product pests and their natural enemies and to provide a framework for assessing different control strategies in an integrated control context.

Meikle, W.G., N. Holst & R.H. Markham. An evaluation of sequential sampling plans for the larger grain borer (Coleoptera: Bostrichidae) and the maize weevil (Coleoptera: Curculionidae) and of visual grain assessment in West Africa. Journal of Economic Entomology (submitted).

Two surveys of rural maize stores in Benin were conducted in order to evaluate published sequential sampling plans for *Prostephanus truncatus* (Horn) (Col.: Bostrichidae) and *Sitophilus zeamais* Motsch. (Col.: Curculionidae). Two sampling plans were evaluated: Iwao's confidence interval plan and Wald's sequential probability ratio test for a Negative Binomial distribution. Wald's plan was chosen as the most appropriate since Iwao's plan required many more ears on average to make a decision. A computer program was used to re-randomize the data and evaluate the effects, in terms of average sample number and error rates, of different sampling plan parameter values. With respect to *P. truncatus*, lower and upper thresholds of 0.2 and 1.0 insects per ear and parameter values of $k=0.5$, $\alpha=\beta=0.1$ were found to be adequate. With respect to *S. zeamais*, lower and upper thresholds of 10 and 20 insects per ear and parameter values of $k=1.0$, $\alpha=0.01$ and $\beta=0.1$ were found to be adequate. Simplified sampling rules were proposed in which 5 ears should be sampled and if no *P. truncatus* are found, the population is low; otherwise the Wald plan should be followed. Owing to the lower per capita rate of damage, simplified sampling rules for *S. zeamais* were difficult to construct. The visual assessment scale was correlated with pest density but not of sufficient precision to substitute for a count-and-weigh procedure.

Nansen, C., S. Korie & W.G. Meikle. CANOCO and SADIE - two software packages used for spatial analysis of pheromone trap catches. Journal of Tropical Forest Resources (in press).

Pheromone trapping of the Larger Grain Borer (*Prostephanus truncatus*), a serious pest on stored maize, and its predator, *Teretriosoma nigrescens* was conducted at 16 sites during 21 weeks in the Lama Forest in the southern Benin. The main purpose was to outline an analytical methodology for examining the distribution pattern of the pest and its predator in the forest environment. Variation in weekly trap catches was analyzed using two different software packages, CANOCO and SADIE. *P. truncatus* trap catches were significantly higher in the north-eastern part of the forest throughout the trapping period. Vegetational variables suggested that high trap catches were significantly associated with the abundance of teak trees (*Tectona grandis*) on trap sites. Examination of the spatial distribution pattern of trap catches revealed that *P. truncatus* catches were significantly aggregated in 16 of the 21 weekly trap catches, while *T. nigrescens* catches were only significantly aggregated in 5 of the 21 weeks. Analysis of the spatial association between trap catches of *P. truncatus* and *T. nigrescens* was not significant for any of the 21 weeks of trapping. The analyses, using CANOCO and SADIE, gave very similar results although based on different mathematical approaches, and in combination these two software packages seem relevant for a broad range of entomological studies.

Nansen, C., A. Tchabi & W.G. Meikle. Phytosociological study of disturbed dry semi-deciduous forest in Benin, West Africa. Journal of Tropical Ecology (submitted).

The southern Benin comprises the Dahomey Gap, and human pressure on forest resources has lead to a dramatic reduction and disturbance of remaining forest patches. The largest remaining forest reserve in the southern Benin is the Lama forest, which is a heterogeneous and a unique genetic forest reserve for many endangered species. As part of the on-going plans for the conservation of this forest patch an analysis of the existing forest types and the vegetative trends was conducted. Three objectives were established: assess the tree species composition by fitting it to a theoretical abundance distribution; ordinate the floristic composition in order to identify forest types; outline the hierarchical association of forest types as levels in a succession sequence. The number of conspecific trees on vegetation plots could be fitted to a geometric series distribution, suggesting that species abundance composition resembled that of a disturbed forest. Five forest types were defined according to their floristic composition and vegetative characteristics like: tree density, number of species, Shannon index of diversity,

basal tree cover, girth at breast height. Geographical variables were also used to examine the spatial distribution of identified forest types. The forest types were interpreted as subsequent levels in a secondary succession sequence, and plantation of the most important tree species in the initial succession sequence levels is recommended in order to improve the natural reforestation.

Ndemah, R., F. Schulthess, M. Poehling & C. Borgemeister. Species composition and seasonal dynamics of lepidopterous stemborers on maize and the elephant grass,* Pennisetum purpureum *(Moench) (Poaceae), at two forest margin sites in Cameroon. African Entomologist (submitted).

Lepidopterous stemborers were monitored on maize and *Pennisetum purpureum* plots during two consecutive cropping season and the off-season at two forest margin locations, Nkolbisson and Minkomeyos, in Cameroon. The noctuids *Busseola fusca* (Fuller) and *Sesamia calamistis* (Hampson), and the pyralid *Eldana saccharina* Walker were found on both hosts. Additionally, the tortricid *Cryptophlebia leucotreta* (Meyrick) and the pyralid *Mussidia nigrivenella* Ragonot were collected from maize and the noctuid *Poeonoma serrata* (Hampson) from elephant grass. *Busseola fusca* was the most abundant species on both host plants. The numbers of eggs per m^2 between plant hosts was not significantly different, whereas numbers of larvae and pupae were three to nine times higher on elephant grass than on maize. Analyzing numbers of *B. fusca* larvae according to size/age classes, all sizes tended to be more abundant on elephant grass than on maize, but significant differences were only found during the second season at Minkomeyos when densities were high. No significant differences were found between plant hosts for diapausing larvae and pupae. The implication of these findings for the possible function of the grass as a trap plant or reservoir for natural enemies in the management of *B. fusca* are discussed.

Ndemah, R., F. Schulthess, M. Poehling & C. Borgemeister. Spatial dynamics of lepidopterous pests on* Zea mays *(Linnaeus) and* Pennisetum purpureum *(Moench) in the forest zone of Cameroon and their implications for sampling schemes. J. Appl. Entomology (submitted).

The most common lepidopterous borers attacking maize and/or the wild host *Pennisetum purpureum* in the forest zone of Cameroon are the noctuids *Busseola fusca* (Fuller), *Sesamia calamistis* (Hampson) and *Poeonoma serrata* (Hampson), the pyralids *Eldana saccharina* (Walker) and *Mussidia nigrivenella* (Ragonot), and the *Cryptophlebia leucotreta* (Tortricidae). The within-plant distribution on maize and elephant grass was studied for the predominant species *B. fusca*, and on maize only for *E. saccharina* to determine the basic sampling unit. On both plant species, *B. fusca* showed a strong oviposition preference for young plant parts. By contrast, *E. saccharina* larvae and pupae on maize were only found on older plant parts indicating that it does not oviposit on young plants. None of the plant strata showed to be a stable sampling unit and it is recommended to do whole plant or whole tiller sampling for maize and grass, respectively. For the development of sampling plans, dispersion was described for all species using Taylor's power law and a non-linear model which gives the relationship between the proportion of infested plants [P(I)] and mean density (m). *B. fusca* egg batches as well as diapausing larvae and pupae on maize showed a random distribution while all the other cases were aggregated, with *B. fusca* egg batches on elephant grass exhibiting the lowest and *M. nigrivenella* on maize the highest aggregation. Optimal sample size/ mean density curves were developed for groups of insects with low and high aggregation.

Ndemah, R., F. Schulthess, M. Poehling & C. Borgemeister. Natural enemies of lepidopterous borers on maize and elephant grass in the forest zone of Cameroon with special reference to* Busseola fusca *(Fuller) (Lepidoptera: Noctuidae) Bull. Ent. Res. (submitted).

The importance, geographic and temporal distributions of parasitoids of lepidopterous borers on maize and elephant grass, *Pennisetum purpureum*, were assessed during surveys in farmers' fields in six villages and two on-station trials in the forest zone in Cameroon, between 1994 and 1996. The borer species encountered were *Busseola fusca, Eldana saccharina, Sesamia calamistis* on both host plants, and *Mussidia nigrivenella* on maize only. *B. fusca* was the predominant host accounting for 96.1% and 43.7-57.3% on elephant grass and maize, respectively, followed by *E. saccharina* on maize with 27.2-39.1%. Fifteen hymenopterous, two dipterous and one fungal species were found on these stem and cobborers. Among those were six pupal, six larval, four egg, one larval-pupal parasitoid and four hyperparasitoids. The scelionid parasitoids *Telenomus busseolae* and *T. isis* were found on *B. fusca* eggs in all locations. During the first season, mean egg parasitism was low and ranged between 3.1% and 26.6% versus 56-87% during the second season. Species belonging to the *Tetrastichus atriclavus* complex were recovered from all four borer species. The majority and most common larval and pupal parasitoid species belonged to the ingress-and-sting guild. Larval and pupal parasitism were very erratic and on more than 50% of the sampling occasions, no parasitoids were recovered. Parasitoid diversity was higher on elephant grass than maize.

Ngoko, Z., K.F. Cardwell, F. Schulthess, W.F.O. Marasas, J.P. Rheeder, G.S. Shephard & M.J. Wingfield. Factors affecting maize grain quality and Fumonisin Content in some villages of the Western Highlands of Cameroon (submitted).

A survey was conducted in three of the Western Highlands (WHL) of the Republic of Cameroon to assess the biological and physical constraints on maize grain quality. Thirty two of the 36 samples analyzed, tested positive with a concentration ranging between 0 and 8.2 ppm. Questionnaires were administered to 36 farmers in 1997. A backward regression analysis revealed that several agricultural practices were associated with the infection of

maize grains by *Fusarium* species and subsequently contamination with fumonisin. Harvesting maize in June (11.1%), sorting right from the field (16.7%), drying maize over the fireplace with husk (19.4) or without husk (33.3%) or in the cribs, were factors that significantly reduced the infection by *F. moniliforme* and the risk of contamination of fumonisin. Yellow maize was less contaminated with fumonisin compared to white maize. The storage weevil, *Sitophilus zeamais*, significantly increased the risk of contamination by fumonisins. Other factors such as harvesting in August, storing in bags, maize as previous crop, and the education level of the farmers were non-significant factors retained by the regression analysis.

Ngoko, Z., K.F. Cardwell, W.F.O. Marasas, M.J. Wingfield, R. Ndemah & F. Schulthess. Biological and Physical Constraints on Maize Production in the Humid Forest and Western Highlands of Cameroon. Plant Dis. (submitted).

A study was carried out to identify biological and physical factors responsible for the reductions in maize production in Cameroon. Two surveys were conducted in 72 fields in two of the five agroecological zones in the country in 1995, 1996, and 1997. The combination of these biological factors (diseases and insects), and the physical parameter soil fertility were responsible for reducing maize yield in these selected benchmarks of Cameroon. In the Humid Forest (HF), *Bipolaris maydis, Stenocarpella macrospora, Puccinia polysora, Rhizoctonia solani* and soil fertility were factors that reduced maize production in 1995 and 1996. In the Western Highlands (WHL), *Cercospora zeae-maydis*, and the interaction between soil fertility and maize variety were the most important constraints to maize production in 1996. In 1997, in addition to *C. zeae-maydis, S. macrospora*, physiological spot and insect damage expressed as the number of holes bored in the stem by *Busseola fusca* were negatively related to ear weight. Average yield reductions were 68.2% due to *B. maydis* and 9.2% due to *S. macrospora*, respectively, in the HF in 1995. In 1996, yield reductions were estimated at 34.3%, 41.4% and 29.6% due to *S. macrospora, P. polysora*, and *R. solani*, respectively, in the HF. In the WHL, *Cercospora zeae-maydis* caused a yield reduction of 78.5% in 1996. The interaction between *C. zeae-maydis* and *B. fusca*, the stem diseases and the physiological spot caused reductions of 37.9%, 33.6% and 39% respectively, in the WHL in 1997. Insects were considered in 1997.

Ngoko, Z., W.F.O. Marasas, J.P. Rheeder, G.S. Shephard, M.J. Wingfield & K.F. Cardwell. Fungal infection and mycotoxin contamination of maize in the Humid Forest and the Western Highlands of Cameroon (submitted).

Maize samples from the first season crop were collected from 72 farmers' stores in 1996 and 1997 in the Humid Forest (HF) and Western Highlands (WHL) of Cameroon. Mycological assays of these samples revealed several fungal species in the kernels. *Nigrospora* spp. were the most prevalent fungi in both the HF (32.1%) and the WHL (30.2%) in 1996. *Fusarium verticillioides (22%)* and *F. graminearum (27%)* were also isolated from the samples. In the WHL in 1996, no significant difference (p>0.05) was found among villages for the incidence of mycotoxic spp. in samples collected two months after harvest, but at four months, percentages in Bamunka and Njinikom were significantly higher. In 1997 the levels of *Fusarium* contamination were not as high as in 1996, with the highest of 7% recorded in Njinikom. The incidence of *Aspergillus* spp. was low, but tended to be higher in samples collected four months than those collected two months after harvest. Analysis with thin layer chromatography did not detect quantifiable levels of aflatoxins in most samples. The *F. verticillioides* mycotoxin fumonisin B_1 (ranging between 300-26,000 ng/g) and the *F. graminearum* metabolites deoxynivalenol (<100 – 1,300ng/g) and zearalenone (<50 -110ng/g) were determined by means of polyclonal antibody (PAb-based) competitive direct enzyme-linked immunosorbent assay. A significant correlation (r=0.72; p=0.0001) was found between the incidence of *F. graminearum* and the contamination with deoxynivalenol. Storage time had a significant positive effect (r=0.39; p=0.013) on the level of fumonisin B_1 in one village, and the levels found between villages were significantly different. This is the first report of the natural occurrence of fumonisins, deoxynivalenol and zearalenone in stored maize in Cameroon.

Olatinwo, R.O. K.F. Cardwell, M.L. Deadman & A.M. Julian, 1999 . Epidemiology of* Stenocarpella macrospora *(Earle) on maize in the mid-altitude zone of Nigeria. J. of Phytopathology 147:347-352.

Disease progress of Stenocarpella macrospora (Earle) Sutton was monitored on selected maize breeding lines over two seasons at three locations. Tagged plants were assessed at 10 day intervals for foliar lesions on a 1-9 scale and for ear rot on a 1-5 scale. Locations with hold-over debris from previous crops had significantly greater infection than locations without. There was a significant negative correlation between the leaf severity score and grain weight. However, no correlation existed between ear rot and leaf disease severity. Spatial disease progress diagrams indicated that S. macrospora was initiated form random foci from which secondary spread occurred.

Olatinwo, R.O. K.F. Cardwell, A. Menkir, M.L. Deadman & A.M. Julian. 1999 Inheritance of resistance to* Stenocarpella macrospora *(Earle) ear rot of maize in the mid-altitude zone of Nigeria. Euro. J. of Plant Pathol. 105:535-543.

Inheritance of resistance to *Stenocarpella macrospora* (Earle) Sutton ear rot of maize was studied among selected maize populations in the mid-altitude (1280m) agro-ecological zone of Nigeria. Diallel analysis among the populations showed significant values for general combining ability (GCA) and specific combining ability (SCA).

Variance components of GCA and SCA on ear rot symptoms were 0.019 and 0.627 respectively, indicating non-additive gene effects. The GCA and SCA effects were relatively dependent on the materials involved in the evaluations. Generation mean analysis was used on five selected parent inbreds (2 resistant and 3 susceptible, crossed to give P1, P2, F1, BC1, BC2 and F2 generations). Estimates of the six parameters on ear rot indicate that dominance gene effects made the major contribution to variation in ear rot in the crosses studied.

Olatinwo, R.O, M.L. Deadman A.M. Julian & K.F. Cardwell. 1999 Survey of the incidence and severity of* Stenocarpella macrospora *(Earle) leaf blight of maize in the mid-altitude zone of Nigeria. Int J. of Pest Management, 45:259-262.

Surveys were conducted on the incidence and severity of Stenocarpella macrospora (Earle) Sutton on maize in the mid-altitude zone of Nigeria in 1995 and 1996. The results indicated a possible link between disease severity and plant density. Fewer symptoms were observed at altitudes below 700m. There was no significant correlation between cropping system and disease incidence or severity.

Oussou, R.D., W.G. Meikle & R.H. Markham, 1999. Factors affecting the survivorship and development rate of larvae of* Teretriosoma nigrescens *Lewis (Coleoptera: Histeridae). Insect Sci. Applic. 18: 53-58.

Laboratory experiments on the role of humidity, and density and species of prey, were conducted in order to better understand the ecology of *Teretriosoma nigrescens*, a predator introduced into West Africa to control the larger grain borer, *Prostephanus truncatus*. Duration of *T. nigrescens* development was very similar among individuals exposed to 30, 40, 70 and 90% relative humidity at 30_C, although survivorship varied. Larvae fed only first instar *S. zeamais* larvae as prey took longer to develop, and weighed less at emergence, than for those larvae raised on first instar *P. truncatus* when both were kept under optimal temperature and humidity conditions. Larvae feeding on *Tribolium castaneum* took longer to develop with only 10% surviving to adult, and no larvae offered *Gnatocerus maxillosus* survived. In an analysis of prey consumption rates, no larvae survived on 1 *P. truncatus* first instar larvae per day, 50% survived on 2 per day, and almost 90% survived on 5 per day. In an analysis of density effects on *T. nigrescens* reproduction and survivorship, no difference in the number of F1 offspring was found among *T. nigrescens*: *P. truncatus* ratios of 15:300, 30:300, 60:300 or 90:300, suggesting that the low density treatment was the most efficient production ratio of the four.

Schaefer, K. G. Goergen & C. Borgemeister. A simplified identification key to distinguish four different species of adult* Dinoderus *(Coleoptera: Bostrichidae), commonly attacking dried cassava chips in West Africa, Journal of Stored Products Research (in press).

Sétamou, M., F. Schulthess, H-M. Poehling & C. Borgemeister. Monitoring and modeling of field infestation and damage by the maize ear borer* Mussidia nigrivenella Ragonot *(Lepidoptera: Pyralidae) In Benin, West Africa. West Africa. Journal of Economic Entomology (in press).

In many countries in West Africa, the pyralid ear borer Mussidia nigrivenella Ragonot occasionally causes severe damage to pre- and post-harvest maize. Between 1992-95, the distribution of and damage caused by M. nigrivenella were studied in Benin using survey data and an on-station field experiment. The borer was distributed across the whole country, and at maturity an average 25% of the ears sampled in maize fields were infested. Damage levels varied with agro-ecological zones and were highest in the Guinea Savannas. However, borer-related yield losses were comparatively low. Three applications of cypermethrin over the growing season did not provide sufficient control in the on-station field experiment. A model was developed to estimate maize losses caused by M. nigrivenella, using the percentage of infested ears, which explained 93% of the variance. Extrapolation of field data indicated a 25% yield loss once a 100% infestation of maize ears was reached. For surveys in maize fields the model is a valid tool for a rapid assessment of crop losses caused by M. nigrivenella.

Sétamou, M., F. Schulthess , H-M. Poehling & C. Borgemeister. Host plants and population dynamics of the cob borer Mussidia nigrivenella Ragonot (Lepidoptera: Pyralidae) in Benin. Journal of Environmental Entomology (submitted).

The maize ear borer, *Mussidia nigrivenella* Ragonot, is a polyphagous insect pest that feeds on various cultivated and wild plants. Surveys in 4 agro-ecological zones of Benin, conducted between 1993 and 1997, revealed about 20 plant species from 11 plant families hosting the borer, but only 13 host plants enable the borer to develop to the pupal stage. Whereas a maize crop usually supports one generation per season, several generations of *M. nigrivenella* were recorded on *Parkia biglobosa* (Jacq.) Benth. and *Gardenia* spp. Agro-ecological variation in the availability of wild host plants was noticed. The high abundance of wild hosts in the Guinea Savannas reflects the diversity of the natural flora in these zones. This abundance of *M. nigrivenella* host plants, coupled with their overlapping fruiting periods may be the main reason for the high pest densities on maize, although only 1 maize crop per year is grown in the Northern Guinea savanna. In a field experiment, the highest infestation levels and densities of *M. nigrivenella* occurred on *Canavalia ensiformis* (L.) DC. and *Mucuna pruriens* DC., 2 popular cover crops in West Africa. Maize and cotton were about equally suitable hosts. Thus, fruiting periods of *C. ensiformis* and *M. pruriens* should not precede that of maize, to avoid emerging *M. nigrivenella* populations shifting from the cover crops to maize.

Sétamou, M., F. Schulthess, N. A. Bosque-Pérez, H-M. Poehling & C. Borgemeister. Effects of different host plants on the bionomics of* Mussidia nigrivenella *Ragonot (Lepidoptera: Pyralidae). Bull. Ent. Res. (in press).

Life table studies on *Mussidia nigrivenella* (Lepidoptera: Pyralidae) fed maize ears, and pods of jackbean, *Canavalia ensiformis*, and velvetbean, *Mucuna pruriens*, showed significant host plant species effect on larval survival and developmental time as well as on adult fecundity. Highest larval survival was recorded on jackbeans, C. ensiformis (36.2%) and lowest on maize (18.4%). Mean larval developmental period was longest on maize (19.8 days) and shortest on C. ensiformis (17.2 days). Pupal survival, weight, and mean developmental time were not significantly affected by the host plants. Oviposition rate was highest for females emerging from larvae fed on C. ensiformis (mean = 176, SE = 13), followed by *M. pruriens* (mean = 143, SE = 11), and lowest on maize (mean = 127, SE = 13). Likewise, longevity of ovipositing females was highest on C. ensiformis whereas sex ratio of did not vary with food source. According to the growth index and life table statistics (r, R0 and G), C. ensiformis was the most suitable host plant followed by M. pruriens. Thus, in mass rearing programs of *M. nigrivenella*, using natural host plants, C. ensiformis should be used which, moreover, requires only one diet replacement throughout larval development. Because of the high suitability of C. ensiformis and *M. pruriens* planting of those cover crops should be timed in a way that the emergence of females moths from mature pods does not coincide with the presence of maize in a stage attractive to ovipositing female moths and suitable for development larvae.

Sétamou, M., F. Schulthess, G. Goergen, H-M Poehling & C. Borgemeister. Natural enemies of the maize cob borer,* Mussidia nigrivenella *Ragonot (Lepidoptera: Pyralidae) in Benin, West Africa. Biocontrol, Science and Technology (submitted).

Surveys conducted in the different agro-ecological zones of Benin during 1994-1997 revealed one egg parasitoid, three larval parasitoids and one pupal parasitoid attacking the pyralid maize cob borer *Mussidia nigrivenella* Ragonot. Egg parasitism was scarce on all host plants sampled and in all agro-ecological zones. Parasitism by larval and pupal parasitoids was usually low (< 10%), and was varied with the different host plant species. Both larval and pupal parasitoids were rare or absent in maize fields. The solitary chalcid pupal parasitoid, *Antrocephalus crassipes* Masi, was the predominant species, contributing to approximately 53% of the observed mortality. Logistic regression analysis suggested that this parasitoid was more prevalent on fruits of *Gardenia* spp. than on the other host plant species, and was abundant between February and September.

Sétamou, M., F. Schulthess, H-M. Poehling & C. Borgemeister. Spatial Distribution Of And Sampling Plans For* Mussidia nigrivenella *Ragonot (Lepidoptera: Pyralidae) On Cultivated And Wild Host Plants In Benin. J. Economic Entomology (submitted).

Spatial distribution of *Mussidia nigrivenella* Ragonot (Lepidoptera: Pyralidae) was studied in maize fields and on 4 major wild host plants in the Republic of Benin, West Africa. Maize ears were sampled at harvest in 1994 and 1995, and fruits of the wild host plants were collected monthly from January 1996 to December 1997 during the fruiting periods of the respective host species. The spatial distribution was analyzed using Southwood's index of dispersion (s^2/m), Iwao's patchiness regression and Taylor's power law (TPL). Iwao's patchiness regression was inappropriate for our data as shown by the non-homogeneity of variance, whereas TPL fitted the data quite well. Based on Southwood's index of dispersion and TPL, *M. nigrivenella* was aggregated on maize ears and fruits of 3 wild hosts, i.e., *Adansonia digitata* L. (Bombacaceae), *Parkia biglobosa* (Jacq.) Benth. (Mimosaceae) *Ximenia americana* L. (Olacaceae). On *Gardenia* spp. (Rubiaceae) however, the distribution was either regular or random according to the season. Density and aggregation of *M. nigrivenella* was strongly positively related with the fruit size of the host plants. The optimal number of minor sampling units needed to estimate *M. nigrivenella* densities on the respective host plants in Benin, varied from 4 fruits on *Gardenia* spp. to 10 pods on *P. biglobosa*. These values were used to calculate the number of maize fields or host plant trees required to estimate *M. nigrivenella* densities in a given area, at a pre-defined precision level and for a certain cost.

Udoh, J.M., K.F. Cardwell & T. Ikotun, 1999. Storage structures and aflatoxin content of maize in five agro-ecological zones of Nigeria. J. Stored Prod. Res. 36 :187-201.

A survey was conducted in 1994 to describe the maize storage systems, quantify the aflatoxin levels in these storage systems, and identify the primary constraints recognized by male and female farmers in five agro-ecological zones in Nigeria. Maize storage in plastic bags was the most common among all farmers. The clay Rhumbu was used in 4 out of 5 agroecological zone by both male and female farmers. The woven Oba was found only in the southern Guinea savanna and was used predominantly by women. Only 13% of the male farmers in the southern Guinea savanna and none in the other zones stored in an improved crib while no female farmers across all the zones used the crib system of storage. Male and female farmers across all the zones identified insect infestation, fungal and rodent attack as primary constraints in their stored maize. Insect infestation was reported by 83% of the female farmers in the southern Guinea savanna zone who stored maize in bags. The highest fungal attack on stored maize was reported by 71% of the male farmers who stored maize in bags in the Humid Forest zone, while 75% of the male farmers, (the highest percentage), who stored in bags in the Sudan Savanna zone complained of rodent attack. Across all zones, farmers of both genders identified insects as the most common storage problem.

Farmers who reported insect problems were significantly more likely to have aflatoxin in their stores. The highest zonal mean aflatoxin level of 125.6 mg/kg was obtained from maize samples provided by male farmers in the Sudan savanna zone who stored maize in bags or in a Rhumbu. Across the storage systems, 33% were contaminated with detectable levels of aflatoxin. No aflatoxin was detected in the storage systems of male or female farmers in the northern Guinea savanna zone in 1994. Storing maize in plastic bags is probably a relatively new practice in Nigeria, having replaced more traditional materials. It apparently is a practice that should be discouraged because of the negative effect on grain quality.

Vowotor, K.A., W.G. Meikle, J.N. Ayertey, C. Borgemeister, C. Adda, B. Djomamou, P. Degbey, K. Azoma, A. Adda & R.H. Markham. 1999. Intra-specific competition between larvae of the larger grain borer,* Prostephanus truncatus *(Horn) (Col.: Bostrichidae) within maize grains. Insect Sci. Applic. 18:171-175.

The effects of egg clutch size on development and survivorship of *Prostephanus truncatus* (Horn) (Col.: Bostrichidae) were measured using single grains of the white maize variety, TZSR-W, at 30oC and 70% rh in the laboratory. The objective of the work was to determine the maximum carrying capacity of a single grain, and to examine the effects of competition in terms of physiological parameters. A maximum number of 6 adults emerged from a single grain. At high densities (>4 per kernel), some *P. truncatus* larvae reduced competition by moving out of the grain (since the grains were single, these larvae died of starvation). The mean number of adults that emerged per grain for initial egg densities of 8 and 16 were 3.3 and 3.5, respectively. Mortality of first instar larvae was high, suggesting that most competition effects manifested themselves very early on. Some emerged adults proceeded to bore into the grain, often killing pre-emerged adults. *P. truncatus* adult weight at emergence was not significantly influenced by initial larval density except in the case of initial egg density of 16. Sex ratio (female: male) of emerged adults was unaffected by competition, and was 1:1. First instar larvae fed mainly on the floury endosperm tissue whereas the second and third instar larvae fed on the germ tissue. Complete developmental period within grains was between 28 and 32 days. The implications of intra-specific competition under storage conditions

are discussed.

Conference papers, workshop proceedings, newsletters, thesis abstracts

Brown, R.L., Z-Y. Chen, T.E. Cleveland, A. Menkir, K.F. Cardwell, J.G. Kling, & D.G. White, 1999. Resistance to aflatoxin accumulation in maize inbreds selected for ear rot resistance in west and central Africa. USDA ARS Aflatoxin elimination workshop. Oct 20-22. Atlanta.

Cardwell., K.F., 1999. Mycotoxins in foods in Africa — Antinutritional factors. In: Improving Human Nutrition Through Agriculture. IFPRI. Oct. 5-7, 1999 Los Baños, Philippines. www.cgiar.org/ifpri/themes/

Mycotoxins come under regulatory limits in foods and feeds because they are carcinogens. In addition to tumorigenic properties, many mycotoxins are anti-nutritional factors causing unthrifty growth and immune suppression in young animals. In the developed world, human exposure, and particularly exposure of children, to dietary mycotoxins is virtually non-existent because of regulatory standards. In developing countries, particularly in sub-Saharan Africa, monitoring and enforcement of standards is rare and mycotoxin susceptible foods are often the primary staples in rather undiversified diets. People are being exposed to unsafe levels of various mycotoxins, often in mixtures, and the consequences in terms of public health burden have been ignored. This paper presents information on the health effects that have been attributed to mycotoxin exposure from medical research literature; data on existing mycotoxin levels in maize in west and central Africa; and nutritional indicators on Béninese children. There is co-incidental appearance of growth faltering and increased illness (symptoms associated with sub-acute mycotoxin exposure) with the weaning of children onto solid foods with a high risk of significant mycotoxin contamination. The International Institute of Tropical Agriculture, in it's maize IPM project, has recognized mycotoxins as one of the most important constraints to the goal of improving human health and well being through agriculture. An overview of various research and development activities at the institute is given.

Cardwell, K.F., K. Hell, J. Udoh-Mafon, & Z. Ngoko, 1999. Factors associated with contamination of maize with mycotoxigenic fungi in small-scale traditional farming systems in Bénin, Nigeria and Cameroon. FAO/ WHO Mycotoxin meeting, Feb. 1999, Tunis www.fao.org-/waicent/faoinfo/economic/esn/mycoto

Degbey, P., R. Oussou, W.G. Meikle & R.H. Markham. 1999. Des outils de prise de décision efficace dans la gestion des stocks. Presented at the African Association of Insect Scientists, Ouagadougou, Burkina Faso, 14-21 July 1999.

A decision-support tool, consisting of simulation models and sampling plans, was presented. The objectives of the decision-support tools are to reduce prophylactic pesticide use on stored grain, and to permit a market-oriented approach to pest management, by allowing farmers to use information (on pest density) to exploit economic opportunities.

Meikle, W.G., N. Holst, C. Nansen, J.N. Ayertey, B. Boateng & R.H. Markham. 1999. Developing decision-support tools for post-harvest pest management in grain stores in West Africa. p. 145-155 In: Borgemeister, C., O. Mueck and A. Bell (eds.) From biological control to a systems approach in post-harvest. Proceedings of the workshop on integrated control on insect pests in rural maize stores, with particular reference to the larger

grain borer* Prostephanus truncatus *(Horn) (Col.: Bostrichidae), and the future development of the post-harvest sector in sub-Saharan Africa. 13-15 October, 1997, Calavi, Benin. Organized by IITA and GTZ.

Models simulating the interaction between stored grain, insect pests, biocontrol agents and measures of farmer intervention are a valuable tool to organize scientific research and to predict the outcome of various Integrated Pest Management (IPM) strategies. In combination with Geographic Information Systems (GIS) and general agro-climatological data, different IPM scenarios can be visualized on regional or continental scale and thus used to help direct IPM resources to where they are most needed and are expected to work most efficiently. A farmer may use IPM strategies to achieve different goals: One goal of an effective IPM strategy could be simply to diminish the loss of stored grain, and another could involve maximizing the economic outcome. Decision rules to opt for one strategy or the other can be derived from simulation models that are integrated with maize market price dynamics. Simple sampling plans must be developed which farmers can use to gauge the current pest status, as well as to make decisions about pest management. In this presentation we review our efforts with regards to (1) modeling the grain store ecosystem, (2) modeling grain store value through time and (3) developing sampling plans for insect pests.

Meikle, W.G., P. Degbey, R. Oussou, N. Holst, C. Nansen and R.H. Markham. 1999. Pesticide use in grain stores: An evaluation based on survey data from Benin. P. 5-9 in PhAction News, the Newsletter for the Global Post-harvest Forum (published jointly by IITA, GTZ, NRI and CIRAD), edited by S. Ferris and J. van S. Graver. October 1999, No.1 [see http://www.cgiar.org/iita].

Rather than present pest population dynamics and grain losses as inexorable and inevitable processes, the goal of the Stored Product Pest Management group is to offer the farmers and extension agents an understanding of the management options available, along with an idea of their costs and benefits. Important questions must first be addressed: "Is there a need for such information?" and "Can the information be used to reduce losses or improve living standards?" To answer these questions, surveys were conducted of maize stores in Benin Republic. The first survey, from January to March 1997, involved 39 grain stores in the Mono and Zou provinces and the second survey, from October 1997 to July 1998, involved 63 grain stores in all the provinces in Benin. Up to 60 cobs were sampled from each store once per month for up to 7 months. Farmers were interviewed to establish their choice of pest management strategy. This information was used to a simple extension message:

1) Store the maize as usual, but do not apply pesticides.

2) Sample the store for insect pests after the maize has had a chance to dry, about 3 or 4 months into the storage season. Depending on the outcome of the sampling, and on the economic situation of the farmer:

3a) Pest densities were found to be low enough to ignore. Farmer will have saved on pesticides and has the option to keep the maize longer, and wait for higher prices, without a high risk of large losses.

3b) Pest densities were found high enough to worry about, and farmer anticipates serious losses in grain value before the end of the season. Shell the maize and consume it, sell it, or treat it and store it longer. The farmer has avoided the use of pesticides, and albeit with some losses (usually minor at this point of the season, even if *P. truncatus* is present) would now have the maize in a form that could keep for several more months, while prices go up. Farmers should be urged not to treat their grain stores with potentially dangerous pesticides intended for field crops.1) Store the maize as usual, but do not apply pesticides.

Ndemah, R., 1999.Towards developing a sustainable pest management strategy for the African stalk borer,* Busseola fusca *(Fuller) (Lepidoptera: Noctuidae) in maize systems in Cameroon. PhD thesis, University of Hannover, Germany, 135pp.

This study attempts to produce baseline data on importance and geographic distribution of stem borers and identify key interactions among and between abiotic (soil nutrients) and biotic (different life stages of pests, beneficials, host plants, vegetation indices, intercrops) factors in the stemborer ecosystem in Cameroon, which is a prerequisite for the development of environmentally sound IPM-technologies. From 1993 to 1997, 297 farmers' maize fields in six benchmarks in the forest zone and three benchmarks in the mid-altitude were visited periodically. In the forest zone only, the benchmarks were grouped into three blocks representing gradients in human population density and, thus, in length of fallow period.

Five borer species were found on maize (Busseola fusca, Eldana saccharina, Sesamia calamistis, Mussidia nigrivenella and Cryptophlebia leucotreta) and four (B. fusca, E. saccharina, S. calamistis, Poeonoma serrata) on elephant grass, the most common wild host. Larvae and pupae per m^2 of B. fusca were three to nine times higher on P. purpureum than on maize, whereas for E. saccharina the situation was the reverse. It was concluded that P. purpureum is not a good trap plant because larval mortalities were too low.

Enumerative sampling procedures, based on Taylor's power law, were developed for the most common pest species in order to make estimation of pest densities as cost-efficient as possible without losing accuracy.

For any of the variables measured, there were no significant block effects in the forest zone; within field variability was highest and between field variation contributed more to total variability than location, emphasizing the insular character of forest fields. In the forest zone, *B. fusca* was the predominant species during the first and *E.*

saccharina during the second season. In the mid-altitude, *B. fusca* was predominant during both seasons whereas *E. saccharina* was not found in any of the fields. In both zones, negative relations could be found between cob weight and stem or ear damage, with *B. fusca* the most damaging species. *B. fusca* numbers at harvest increased with egg infestation but was negatively related to egg parasitism or parasitoid sex ratio earlier in the season. Soil Mg had a negative effect on yield by increasing *B. fusca* densities whereas egg parasitism had a significant positive effect. Increasing density of cassava in the system had a negative effect on *B. fusca* densities, probably because of increased mortality of migrating first instar larvae.

Fifteen hymenopterous, two dipterous parasitoids and one fungal species were found. The scelionid egg parasitoids *Telenomus busseolae* and *T. isis* were the most common parasitoids and found in all locations in the forest zone. Most larval and pupal parasitoids belonged to the ingress-and-sting or planidial ingress guild. *Cotesia sesamiae*, the most common larval parasitoid of noctuid stem borers in eastern Africa was very scarce.

Recommendations are given for further research into habitat management (management of soil nutrients, trap plants and intercropping with non-hosts), biological control options ('redistribution' approach, microbial control using viruses) and on how to increase uniformity of field infestations for host plant resistance screening.

Schulthess F. & S.O. Ajala, 1999. 'Recent advances in the control of stemborers West and Central Africa' in Strategy for sustainable maize production in West and Central Africa, Proceedings of a Regional Maize Workshop, Cotonou, RB, 21-25 April, 1997, 35-52.

The major field pests of maize in West and Central Africa are the lepidopteran stemborer species *Sesamia calamistis*, *Eldana saccharina*, *Busseola fusca* and the earborer *Mussidia nigrivenella*. IITA's first approach to combat stemborer problems was host plant resistance. IITA identified sources of moderate levels of resistance to *S. calamistis* and *E. saccharina* whereas CIMMYT and ICIPE have developed genotypes with strong antibiosis to whorl feeding species such as *B. fusca*, *Diatrea* spp. and *Chilo* spp. Levels of cross resistance among borer species are continuously determined through germplasm exchange between centers. This approach has led to the development of broad based genotypes with resistance to *S. calamistis* and *E. saccharina*. Concomitantly, IITA is looking for other means of control, including biological control and habitat management. In a first step, the ecosystem of stemborers is being analyzed and compared across countries within a region and between regions via surveys, followed by multitrophic level studies on-farm at selected sites, or on-station, in the laboratory or green house. The aim of this system analysis is first, to delineate the area of problem and to identify key components in the system that could be manipulated to reduce stemborer infestations on maize. Because of the complexity of the pest problem and the size and ecological diversity of the maize growing area in Africa, this required a high level of involvement of NARES, other IARCs and advanced laboratories in Africa and overseas. The target ecozones for stemborer work identified via these surveys were the zones south of the southern Guinea Savanna, the mid-altitudes and highlands. The ecosystem analysis yielded several control options such as forms of biological control [new associations (i.e., the use of non-coevolved natural enemies), redistribution (i.e., expanding the geographic range of natural enemy species and strains) and biocidal control] as well as habitat management solutions (e.g., trap plants and management of soil nutrients). They are being developed and tested in collaboration with various NARES and IARCs.

Schulthess, F. & K.F. Cardwell, 1999. Effect of **Fusarium verticillioides** ***infection in maize on infestations of stem and ear borers. Phytopathology 89:70.***

In field trials at the International Institute of Tropical Agriculture, Ibadan, Nigeria, maize cobs artificially inoculated with *Fusarium moniliforme* had double the number of lepidopteran and four times the number of coleopteran pests than the non-inoculated controls. Surveys in Benin revealed *F. moniliforme* was present in 73% of plants with stem borer damage compared to 43% in stems without borers. Field and greenhouse trials were designed to explore the relationship between the fungus and lepidoptera in maize stem. In the field, a significant gradient of *F. moniliforme* infection was induced by a) stem inoculation with *F. moniliforme* (81% infection), b.) natural incidence (22%), and c.) hot water seed treatment and soil fungicide (3.6% infection). Numbers of *Eldana saccharina* larvae were significantly higher in the inoculated plots. Oviposition and life table studies showed that plants with high *F. moniliforme* had significantly larger *E. saccharina* egg batches and higher numbers of larvae. It is concluded that reducing *F. moniliforme* incidence in stems and ears would also significantly reduce pest infestations.

Project 10

INTEGRATED MANAGEMENT OF CASSAVA PESTS

by A. Cherry, S.K. Dara, A.G.O. Dixon, G. Goergen, R. Hanna (Project Coordinator,) J.d'A. Hughes, B.D. James, J.P. Legg, W. Meikle, P. Neuenschwander, P.R. Speijer, J.M. Teri, M. Toko, J. Whyte, K. Wydra

assisted by L. Afouda, M. Ahounou, H. Baïmey, A. Fanou, B. Gbaguidi, D. Gnanvossou, F. Hountoundji A. Kalyebi, A. Nkakwa, A. Onzo, G. Paraiso, I. Zannou, V. Zinsou

Project Rationale

Cassava is among the most common crops in Sub-Saharan Africa, where it is an increasingly important food source for rapidly expanding rural and urban populations. Numerous widely distributed pests and diseases, as well as poor agronomic practices are causing large cassava crop losses, which can lead to severe economic hardship to more than 200 million people, including some of the poorest on the African continent who rely on cassava as a source of carbohydrates. The most widely distributed and important cassava pests include the cassava green mite *Mononychellus tanajoa* (Bondar), the cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr (under successful biological control), *Bemisia tabaci* (Genn.) vector of cassava mosaic viruses the causal agents of cassava mosaic disease (CMD); cassava bacterial blight caused (CBB) by *Xanthomonas campestris p.v. manihotis*, cassava anthracnose disease (CAD) caused by *Colletotrichum gloeosporiodes f. sp. manihotis*, cassava brown streak virus, and various root and stem rot pathogens. Less widely distributed pests include the spiraling whitefly *Aleurodicus dispersus* Russel, the stored product beetles *Prostephanus truncatus* (Horn) and *Dinoderus bifoveolatus* Wollaston, cassava root scale *Stictococcus vayssierei* Richard, root knot nematodes *Meloidogyne* spp., variegated grasshopper, *Zonocerus variegatus* (L.), and various species of termites and vertebrates.

The overall goal of project 6 is to "increase and sustain cassava productivity in SSA by reducing cassava crop losses due to pests", thus contributing to the attainment of CGIAR's mission of reducing hunger and poverty by enhancing agricultural production, while conserving natural resources. To this effect, the project conducts diagnostic surveys and yield loss assessments to determine the incidence and severity of pests, and carries out fundamental research to characterize and understand the nature of multitrophic interactions affecting the biology and population dynamics of cassava pests and their associated antagonists. The project devotes the largest proportion of its resources to the development of sustainable IPM tools and technologies with emphasis on biological control, host plant resistance and cultural methods. To facilitate the implementation and adoption of IPM technologies, the project develops training materials and decision support systems, provides training and technical support to national programs, and encourages participatory evaluations of IPM technologies.

In 1999, the project's highest priority was the continuation of the Africa-wide implementation of cassava green mite biological control by exotic phytoseiid predators. The exotic phytoseiid predator *Typhlodromalus aripo* (DeLeon)(Acari., Phytoseiidae) was first released in late 1993, and by end of 1999 it has been reported established in 21 African countries, with the greatest spread occurring in Benin, Cameroon, Cote d'Ivoire, Ghana, Guinea Conakry, Kenya, Nigeria, Republic of Congo, Tanzania, Togo, and Uganda. Limited spread has been reported from Democratic Republic of Congo, Kenya and Tanzania, and recent establishment has been reported from Malawi, Mozambique, and Zambia. Establishment of *T. aripo* was reported also from Burundi, Liberia, Rwanda, and Sierra Leone, but country-wide survey in these countries have to determine the extent of *T. aripo* spread have not been conducted because of security problems. *T. aripo* now covers over a million km2 with most of the area covered occurring in West Africa, East and Central Africa. In West and Central Africa *T. aripo* has reduced cassava green mite populations by two thirds and increased cassava yields by an average of a third. In dollar terms, cassava green mite biological control has resulted in farmer benefits of up to $195 per hectare. Research also continued in testing and releasing exotic virulent isolates of the mite fungal pathogen *Neozygites floridana*, which is now established in southern Benin. Surveys in the Republic of Congo, Tanzania, and Uganda confirmed that biological control is still keeping cassava mealybug under control. In addition, several parasitoids associated with *B. tabaci* were identified on cassava, and severe infestations of the African Root and Tuber Scale (ARTS) *Stictococcus vayssierei* in the forest zone of Cameroon appear to be associated with *Chromolaena* follows.

In plant pathology, work continued with using and refining PCR techniques to map the distribution of geminiviruses and detect mixed geminivirus infections in the CMD pandemic in East Africa, and to investigate the mechanisms of apparent geminivirus cross-protection in cassava. The hybrid virus

associated with the spread of severe CMD in East Africa, and known to be present in the Great Lakes region, was recently found in a CMD-outbreak area in the central plateau of the Congo (Brazzaville), and a new cassava mosaic geminivirus variant was found in Zimbabwe. The project also conducted farmer participatory evaluations of multiple pest and disease resistant cassava varieties, and developed quality management protocols for cassava multiplication. Several cultural practices were developed to reduce crop losses caused by CBB by mixed cropping, burying infected plants, pruning infected leaves, and hot water or hot air treatments to destroy CBB inoculum in cassava seeds. These practices are presently being tested in Togo with farmer participation. Eight cassava varieties were tested for resistance to CBB in Togo, and among five fungal species causing cassava root rot, the fungus *Botryodiplodia theobromae* was identified as highly virulent. Biochemical techniques were developed for quick and easy detection of CBB. Sources of resistance were also identified against CBB, CAD and CMD from local clones and breeding lines in Benin and Nigeria. Moderate populations of root-knot nematode caused substantial reductions in cassava sprouting. In addition to research and implementation, the project trained 72 NARS staff on various aspects of integrated management of cassava pests and diseases, and with the participation of numerous NARS staff and farmers conducted in field evaluations of cassava germplasm for resistance to pests and diseases in several countries. The publication of four cassava IPM guides was completed and the placement of the ESCaPP database on CD ROM was initiated.

In 2000, priority will be given to the continuation of the Africa-wide biological control of cassava green mite, and management of CMD and *S. vayssierei* with a combination of biological control, host plant resistance and cultural controls. CBB and nematology activities will be eliminated due to loss of project staff. For the first time, the project will initiate considerable level of research on postharvest IPM of cassava in West Africa, and later in parts of East Africa. Cassava green mite efforts shift to impact assessment, enhancement of biocontrol through cultural practices, and persistence of CGM biocontrol in the lowland humid tropics of West Africa and mid-altitude humid tropics of East and Central Africa. Releases of two strains of *T. aripo* will continue in southern Africa including Angola. Efforts will continue to determine the mechanism of cultivar preference by *T. aripo* for its eventual incorporation in cassava breeding programs. The project will also initiate efforts to determine the trade-offs between cassava resistance to CMD resistance and suitability to *T. aripo* and biological control of CGM. Efforts will continue to establish virulent exotic strains of the mite fungus *N. floridana* to enhance cassava green mite control and to monitor the spread of the present establishment of the fungus in southern Benin. Research on *S. vayssierei* will expand to DRC and Centre Afrique where the project will look for sources or cassava plant resistance, and identify the factors associated with severe *S. vayssierei* infestations. The project will continue its efforts in monitoring the CMD pandemic expansion in East Africa, intensifying farmer participatory evaluations of multiple pest and disease resistant varieties, conducting CMD regional epidemiology studies, and determine the efficiency of aphelinid parasitoids associated with the whitefly *B. tabaci*. Identification of sources of resistance CGM, CBB, CAD and root rots will continue as part of Project 6. The project will devote considerable amounts of human and material resources to training and supporting national programs through participatory evaluations of IPM technologies, conducting on-site IPM training courses, establishing farmer training programs, and developing training materials and decision support systems to enhance the implementation and adoption of sustainable IPM technologies. All project activities have been prioritized by agroecozones to reflect the zonal needs in cassava plant protection. In 2000, 39% of project activities will be in the mid-altitude zone, while 44% and 17% of activities will be in the savannas and humid forest zones, respectively.

Outputs

10.1. Assessment of incidence, abundance, severity and diversity of pests and associated yield loss

Background

An understanding of a pest's distribution and impact provides the basis for assessing the importance and generating background information needed to design and execute appropriate intervention technologies. Evaluating farmers' constraints as influenced by biotic, abiotic and socio-economic factors within agroecosystem in collaboration with the clients assures the relevance and focus of proposed R&D activities. Regional surveys on incidence and severity help define the extent of pest and disease constraints. Yield loss trials in specific ecozones complement survey data in assessing economic importance. Identification and characterization of insects and pathogens with molecular, genetic,

biochemical and physiological methods help quantify their diversity and provide additional information needed to develop control strategies.

On-going and future activities

10.1.1. Distribution and abundance of *Stictococcus vayssierei* in the forest zone benchmark area of Cameroon

by R.H., M.Ti. G.G., P.N. - in collaboration with A. Nkakwa, N. Ntonifor

A first phase African root and tuber scale *Stictococcus vayssierei* survey was initiated in 1999 and completed in January 2000 in the Yaoundé, Mbalmayo and Ebolowa blocks of the forest margin benchmark area of Cameroon. *S. vayssierei* distribution, abundance, host-plant and ant associations were determined in 24 mixed food crops fields. Overall scale incidence level across fields was 56% with a mean density of 172.75 scales per cassava plant. Ebolowa was the most affected block showing a scale incidence level of 87.5%, followed by Mbalmayo with 76%. Yaoundé block was the least affected with a scale incidence level of 5%. In general, cassava planted after *Chromolaena* fallow showed a 2-fold higher *S. vayssierei* infestation compared with cassava planted after a secondary forest. Additional research is underway to determine the role of *Chromolaena* fallow in severity of *S. vayssierei* infestations.

10.1.2. Diagnosis and monitoring of viruses associated with the cassava mosaic virus disease pandemic in East Africa.

by J.P.L. – in collaboration with J. Ndunguru, S. Jeremiah, J. Kamau

Continued expansion of the CMD pandemic was documented into north-western Tanzania (Kagera region) and its status was monitored in western Kenya. Changes in Kagera in terms of CMD incidence, severity and the abundance of *B. tabaci* were described in addition to an expansion in the range of the hybrid virus, UgV/EACMV-Ug, and results published. Areas newly affected by the CMD pandemic in 1999 included Karagwe and Muleba districts of Kagera region, north-west Tanzania, and the Homa Bay area of southern Nyanza Province, western Kenya. In each of these areas, there were significant increases in the incidence and severity of CMD and in the abundance of *B. tabaci*, and UgV/EACMV-Ug was detected.

10.1.3. Diagnosis and characterization of whitefly and whitefly-born virus constraints of cassava and sweet potato production.

by J.P.L. – in collaboration with G. Banks, P. Markham, A. Cudjoe, S. Saizonou T.N.C. Echendu, N. Ntonifor, G. Otim-Nape, R. Kapinga, M. Theu, J. Kamau, S. Ranomenjanahary

Whitefly IPM Project diagnostic surveys were completed for Malawi and data entered and database analyzed for previously completed surveys done in eight other countries in sub-Saharan Africa. The final summary report was completed for submission to the donor, DANIDA. In collaboration with Project partners, 15 draft chapters were prepared for a book to be published in 2000 relating to outputs of IITA's sub-project 4. Cassava mosaic geminiviruses (CMGs) occurring in sampled countries were characterized. The occurrence of a novel CMG similar to South African cassava mosaic virus (SACMV) was recorded from Zimbabwe. Both EACMV and ACMV were recorded from Madagascar. The Uganda Variant form of EACMV (UgV/EACMV-Ug) was only recorded from the Lake Victoria zone of East Africa, and mixed infections were only recorded from Uganda (UgV/EACMV+ACMV), Kenya and Tanzania (EACMV+ACMV). Biotypes of the whitefly vector of CMGs, *B. tabaci*, were identified based on sequences from the cytochrome oxidase gene (CoI) of mitochondrial DNA and these were related to biotypes occurring in other regions of the world. It was confirmed that no 'B' biotype *B. tabaci* were recorded from cassava in any of the nine countries sampled and that the cassava biotype was similar to biotype 'S' previously recorded from *Ipomoea* in Spain. There was no evidence for the occurrence of a CMD epidemic-associated biotype from East Africa. A new species of parasitoid was identified parasitizing *B. tabaci* on cassava and sweet potato and the geographical distribution and relative importance were described for the two principal parasitoids of *B. tabaci* on cassava, namely: *Encarsia transvena* and *Eretmocerus* sp.

10.1.4. Cassava mosaic virus outbreak in the Republic of Congo

by P.N., J.H.

IITA was asked by FAO on behalf of the Government of the Congo to send an evaluation mission to investigate phytosanitary problems on cassava. The main problem, as it turned out, was an outbreak of

CMD, whereby cassava of entire villages was almost totally destroyed by early stunting of the plants. A DNA analysis (through PCR) of infested leaves, stored in alcohol, resulted in the discovery of ACMV, EACM, the Uganda variant (UgV; a hybrid of the two) and a second recombinant form. This is the first time that UgV, a specially virulent form of CMD, has been reported outside South-East Africa. It is likely that the 'pandemic' can now spread into West Africa. The second recombinant form detected could indicate a separate recombination event in the Congo; alternatively UgV might have been brought into the Congo by the numerous fugitives from Rwanda, who were settled in central Congo.

10.1.5. Pathogenic and genetic diversity of *Xanthomonas campestris* pv. *manihotis* strains from Togo, O virulence of fungal pathogens causing root rot from Togo, Benin and Nigeria

by K.W., A.G.O.D. - in collaboration with K. Kpèmoua, V. Verdier, A. Banito, J. Onyeka

From leaf samples with symptoms of cassava bacterial blight and root and stem samples with rot collected in four ecozones in Togo, 50 strains of *X. campestris* pv. *manihotis* and 34 fungal strains, respectively, were isolated and characterized for virulence. Most of the strains were highly virulent after stem inoculation in a susceptible variety. Further 80 strains collected from 2 fields in 2 ecozones were isolated for genetic characterization of the *Xcm* population in an individual field. In the year 2000, another collection from the same fields is planned to study genetic shifts in the population. For genetic studies of pathogen diversity, DNA and AFLP (amplified fragment length polymorphism) techniques were developed and tested with *Xcm* strains. The root rot causing fungi collected in Togo belonged mainly to the species *Botryodiploidia theobromae, Sclerotium sp., Fusarium sp. Pythium sp.* and *Diaporthe sp.*, while in Nigeria mainly *B. theobromae* and *Sphaerostilbe repens* were isolated. Strains of *B. theobromae* were highly virulent after stem inoculation, while the strains of other species were lowly virulent.

10.2. Evaluation of multitrophic interactions of key cassava pests

Background

The first step in developing integrated management practices is to gain an understanding of the dynamics and key interactions between (plant-pest-antagonist) and across trophic levels (e.g. crop-alternative host plants) within the ecosystem, and the biotic potential of both plant and pests in the farm setting. Knowledge of pest survival, host range and preference, vectors and transmission helps to understand the problem and target the solution. Strategic and tactical models can be used to identify critical interactions, and evaluate the potential impact of tested technologies. It is also a practical way to characterize complex interactions found in an agroecosystem with data from different disciplines.

On-going and future activities

10.2.1. Multitrophic interactions between cassava, *M. tanajoa* and exotic predators-

by R.H, M.T. - in collaboration with D. Ojo, D. Gnanvossou, A. Onzo, G. Paraiso

The exotic phytoseiid predator *T. aripo* inhabits the apex of cassava shoots during much of day and forages on cassava leaves during the evening and night hours. Cassava provides shelter, prey as well as non-prey food such as exudates for the maintenance of *T. aripo* populations. In field surveys throughout the areas where *T. aripo* has been established, we have observed at times large differences in *T. aripo* abundance among cassava cultivars that differed in the level of shoot apex 'hairiness'. In an initial attempt to understand the relationship between cassava cultivars and *T. aripo*, we set up a common experiment with 6 cassava cultivars, 3 with 'hairy' apices (Agric, Oko Iyawo, and TMS 91/0326), and 3 with 'glabrous' apices (TMS 30572, Amala, and Odongbo). Mite abundance and several cassava apex characteristics were evaluated on 4 occasions over a 12-months period. Abundance of both *M. tanajoa* and phytoseiid predators varied considerably between sampling periods, as expected, and among cultivars. 'Hairy' cultivars had significantly higher hair density and hair length on the midrib, vein, and venule of immature leaf tissue in the cassava shoot apex. *Mononychellus tanajoa* densities were higher during the dry season on 'glabrous' compared with 'hairy' cultivars. Moreover, *T. aripo* abundance was positively correlated with hair density on the midrib, veins and venules of immature leaf tissue in the cassava shoot apex, despite lower abundance of *M. tanajoa* on the 'hairy' cultivars.

10.2.2. Long-term population dynamics of exotic phytoseiids and cassava green mite

by R..H., M.T. – in collaboration with Y.S. Gogovor, A. Onzo, J. Ogwang, T. Hangy, N. Ntonifor, B. Pallangyo, C. Kariuki

Continuous, long-term observations of population dynamics of cassava green mite and exotic phytoseiid predators provide evidence over-time of the stability of biocontrol. We have established several long-term population dynamics sites in Benin (transition forest, moist savanna and dry savanna), Cameroon, (rainforest), Togo (coastal savanna lowland humid), Uganda (transition forest mid-altitude humid), Democratic Republic of Congo (humid forest), Kenya (moist savanna lowland humid), and Tanzania (moist savanna lowland humid). In general, the population dynamics *M tanajoa* and *T. aripo* show seasonal patterns influenced by rainfall regime. Peak *M. tanajoa* densities correspond to the beginning and the end of the dry season. A positive correlation is generally found between *T. aripo* and *M. tanajoa* densities. The analysis of the distribution of both *M. tanajoa* and *T. aripo* based on Taylor's power law and the Iwao regression model showed that their distribution is aggregated. Highly significant differences were observed in the distributions of both *M. tanajoa* and *T. aripo* among plants and among dates. There were no differences in the within field distributions.

10.2.3. Diurnal within- and between plant distribution of cassava green mite and exotic phytoseiid predators

by R.H. – in collaboration with A. Onzo, M. Sabelis

Understanding within- and between-plant distribution and diurnal movement of CGM and associated predators can help us further our understanding of the interactions between predators and prey and develop sampling programs for population estimation and monitoring. The within-plant movement of cassava green mite *M. tanajoa* and its two most efficient exotic phytoseiid predators *Typhlodromalus manihoti* and *T. aripo* released and established in Africa was monitored in two field sites in Benin every 3 months from August 98 to June 99. During a sampling day, whole plant sampling was conducted at 4 hour-interval over a 24-hour period starting from 12 o'clock to 8 o'clock the following morning. Analysis of the data showed that the within-plant distribution of *M. tanajoa* did not follow a diurnal pattern but fewer *M. tanajoa* were found in the upper part of the foliage compared to its normal distribution in the absence of efficient predators. The exotic predator *T. manihoti* also did not show any diurnal pattern in its distribution within cassava plants. It was confined on cassava leaves especially on young leaves but was never found in cassava tips. But the exotic phytoseiid predator species *T. aripo* showed a diurnal pattern in its within-plant distribution. Samplings at 12 noon, 4pm and 8 am, revealed presence of *T. aripo* almost exclusively in the cassava tips; while at 8pm, only 36% and 18% of *T. aripo* remained in the tips for the two field sites respectively. At midnight, 36% and 40% of *T. aripo* remained in the tips; while at 4am, 65% and 53% of *T. aripo* were found in the tips. During these hours, individuals of the predator were found foraging on leaves and other plant parts. The mechanisms that prompt *T. aripo* to forage only at a given period of the night to hide in the tips before sunrise is still unknown. All mobile stages of the predator could be found on leaves and other plant parts during their foraging hours.

10.2.4. Impact of multiple predator introductions on cassava green mite biocontrol

by R.H. – in collaboration with A. Onzo, M. Sabelis, I. Zannou

The exotic phytoseiids, *T. manihoti* and *T. aripo*, can be found associated on cassava plants in some areas of Benin, Ghana and Nigeria. Interspecific interactions between these two species may have considerable effects on the stability of cassava green mite biocontrol. The extent of these interactions, however, are not known. We initiated screen house and field experiments in collaboration with the University of Amsterdam, Netherlands, to determine the level of interspecific interactions between the two exotic phytoseiids. Available data indicates that the addition of *T. manihoti* reduces the variation in CGM densities across sites, but populations of this predator may be negatively affected by the endemic phytoseiid *Euseius fustis*. On-going greenhouse studies will determine the level and nature of interactions among exotic and endemic phytoseiids.

10.2.5. Prey location behavior by *T. manihoti* and *T. aripo*: Response to *M. tanajoa* and *Oligonychus gossypii*

by R.H. – in collaboration with D. Gnanvossou, M. Dicke

While searching for prey, *T. manihoti* and *T. aripo* use volatiles emitted by the host plant-spider mite complex. The attraction of the two predatory mites to the volatile cues emitted from infested cassava

leaves and prey preference, were investigated with an Y-tube olfactometer in the laboratory. Females of *T. manihoti* and *T. aripo* significantly preferred the odors from the *M. tanajoa*-infested cassava leaves to that from the uninfested leaves when they were starved for either 2, 6 or 10 hours. Satiated *T. manihoti* has a weak attraction whereas satiated *T. aripo* was significantly attracted to infested cassava leaves. No significant difference was found between predator species regardless of starvation period. The two predators were not attracted to odors from females of *M. tanajoa* removed from a plant or to odors from mechanically wounded leaves. When *M. tanajoa*-infested leaves and *O. gossypii*-infested leaves were offered simultaneously, 2h-starved *T. manihoti* and *T. aripo* preferred odors from *M. tanajoa*-infested leaves over *O. gossypii*-infested leaves. In addition, 2hr-starved *T. manihoti* and *T. aripo* were attracted to mixed odors of *M. tanajoa-O. gossypii* infesting either the same or two sets of leaves vs. uninfested leaves. The attraction of *T. manihoti* and *T. aripo* to *M. tanajoa*-infested leaves and *O. gossypii*-infested leaves offered simultaneously is a good indicator that the two predators can selectively feed on the target prey when the two prey species colonize either the same or different patches on cassava plants. However, when the two prey species are together in the same patch, the presence of *M. tanajoa* may enhance predation on the inferior prey *O. gossypii*.

10.2.6. Life table studies of field and laboratory populations of *T. manihoti* and *T. aripo*

by R.H. – in collaboration with D. Gnanvossou, K. Neglou

Life table studies of field and lab populations of *T. manihoti* fed *M. tanajoa* were studied at three constant temperatures 20, 25 and 30°C; L12: D12 photoperiod and 70-90% r.h. Overall, the laboratory population had shorter developmental time, age-specific fecundity, net reproductive rate and intrinsic rate of increase compared with the field population. It is too early at this point to make any broad generalizations. Similar studies are being conducted on three populations other phytoseiid species. What is clear from the available data, however, is that the source of populations and the condition under which the populations are maintained could have substantial effects on life history parameters of phytoseiid predators. One likely effect is on models that utilize life table parameters to model population growth and dynamics.

10.2.7. Spore production potential of Brazilian and Beninese isolates of *Neozygites floridana*

by R.H., A.C., C.L. - in collaboration with F. Hountondji

Virulence bioassays conducted during 1996-1997 indicated that Brazilian isolates were generally more virulent than the Beninese isolate of *Neozygites floridana*. The release conducted in 1999 showed higher infection levels among the exotic isolates. Some trials were conducted to better understand the spore production potential of isolates of *N. floridana*. Brazilian isolates were found to produce more infective spores (capilliconidia) than the local isolate. A very few resting spores were produced, but conditions for this production are not yet well known.

10.2.8. Effect of population density on reproduction and emigration of *Dinoderus bifoveolatus*, a pest of stored cassava.

by W.M. - in collaboration with C. Nansen, Y. Magnon

The study quantified the relationship between density and reproduction of *Dinoderus bifoveolatus* (as measured by the number of adult offspring per initial parent) and emigration. The relationship between initial density (of 80, 200, 400, 2000 and 4000 insects per kg) was a curve similar in form to that described for *Prostephanus truncatus*. No particular relationship was observed between density and rate (% of population) of emigration, which was unexpected. Both *P. truncatus* and *Sitophilus zeamais*, also serious pests of stored cassava, showed increasing rates of emigration with increasing density. Perhaps much higher densities of *D. bifoveolatus* are needed prior to large scale dispersal can occur.

10.2.9. Interactions between cassava green mite and cassava mosaic virus disease

by J.P.L. - in collaboration with J. Whyte, B. Khizzah, J. Ogwang

CGM/CMD interaction studies in the field and screen house were completed. In screen house studies, the effect of CGM infestation on CMD-free, mildly CMD-diseased and severely CMD-diseased cassava plants was investigated. The effects of CGM and CMD were assessed in terms of their impact on a series of plant growth characteristics including: plant height, leaf length, petiole length, leaf number and proportion of dropped leaves. Some evidence was obtained for a positive interaction between CGM and CMD from leaf length data. CGM infestation had no effect of the pattern of increase in average cassava leaf length between 3 and 7 months after planting for CMD-free or mildly CMD-

diseased plants. For severely CMD-diseased plants, however, CGM infestation led to a significant reduction in average leaf length in comparison with the uninfested control. Follow-up studies will examine the effect of different viruses and virus combinations on interactions between CGM and CMD. Studies to assess the effect of CMD on the activity of the CGM predatory mite, *T. aripo* were initiated in collaboration with IITA's CGM Biocontrol Project.

10.2.10. Description and characterization of interactions between cassava mosaic geminiviruses (CMGs)

by J.P.L.

Pure cultures of ACMV, UgV/EACMV-Ug, and mixed ACMV + UgV/EACMV-Ug infected plants of the standard susceptible cultivar 'Ebwanateraka' were established under screen-house conditions. These were used to initiate whitefly transmission studies that will investigate virus-virus interactions and putative cross protection. Field trials were established to investigate the possible inhibitive effect of infection by ACMV on subsequent super-infection by UgV/EACMV-Ug. Experimental plots comprised 30% plants infected by ACMV through the cutting, which were dispersed at random amongst 70% CMD-free plants. PCR-based virus diagnostics using specific primer pairs for ACMV and for UgV/EACMV-Ug were used to follow the progress of virus infection within the trial plots. By the end of the experiment at eight months after planting, all plants had dual ACMV+UgV/EACMV-Ug infections, suggesting that ACMV had no inhibitive effect on UgV/EACMV/Ug super-infection.

10.2.11. Interaction between CMD severity and yield loss and changes in symptomology over repeated cropping cycles

by J.P.L.

Long-term severity vs. yield loss experiments were maintained at Serere, north-eastern Uganda. Experiments were planted at Serere to investigate the effects of CMD severity on yield and changes in the relative proportions of CMD symptom types over repeated cropping cycles resulting from the selection for replanting of the most vigorous stems at the end of each cropping cycle. The first generation of the experiment comprised a randomly mixed square block of 300 CMD-free, 300 mildly CMD-diseased and 300 severely CMD-diseased plants of the local CMD-susceptible cultivar 'Ebwanateraka', planted in 1997. At the end of 12 months, stems were selected from the most vigorously growing plants for replanting and 900 cuttings obtained from these stems were replanted. The third generation of the experiment was constituted and replanted in the same way in 1999. Preliminary data for the second generation trial indicate that the yield of initially mildly diseased plants was more than twice that of those either initially healthy or initially severely diseased. The relative proportion of the mildly diseased plants also increased from the initial 33% to 42% in the second generation and 64% in the third generation. This increase in the proportion of mildly diseased plants mirrors the change occurring in farmers' fields in post CMD epidemic areas of Uganda.

10.2.12. Role of insects as vectors of cassava bacterial blight

by K.W. - in collaboration with P. LeGall, C. Borgemeister, M. Zandjanakou

Studies on *Zonocerus variegatus* as vector of *X. campestris* pv. *manihotis* were continued. Additionally, other insect species were collected from cassava fields and their contamination with *X. campestris* pv. *manihotis* studied. All the insects were found to carry *Xcm*. It was demonstrated that *Z. variegatus* fed with *Xcm*-infected leaves transferred the pathogen to healthy plants. Further studies to localize the pathogen in the insect using immunefluorescence and to quantify the survival of *Xcm* in the insect are planned.

10.3. Development, testing and integrating IPM components

Background

Host plant resistance, biological control and cultural practices form the basis of an ecologically sound and sustainable plant health management. Technologies are being developed to screen varieties in the laboratory, greenhouse and the field for resistance mechanisms. Quantifying symptoms in relation to inoculum or population pressure is needed to select varieties with desirable resistance mechanisms. Cultural practices begin with the cutting material, include soil management, continue with intercrops and other interactions the cropping system until harvest. Biological control opportunities including the use of entomopathogens and pathogen antagonists exist for both pests and pathogens.

On-going and future activities

10.3.1. Culture of exotic phytoseiids

by R.H., M.T. - in collaboration with D. Gnanvossou, G. Paraiso

The maintenance of mother cultures continued at an acceptable level of production for 3 species and a total of 8 colonies. The exotic species still in culture include *Neoseiulus idaeus* (two Brazilian populations including one from a release field in Benin), *T. aripo* (three Brazilian populations), and *T. manihoti* (two Brazilian populations from release fields in Benin only). The pathogenic fungus *N. floridana* from Brazil is also being maintained in culture. No new exotic phytoseiids *N. floridana* are expected in 2000.

10.3.2. Improving cassava green mite biocontrol with cultural practices

by R.H., M.T.- in collaboration with D. Ojo, A. Onzo

Numerous field observations have shown that *T. aripo* presence on cassava can be variety dependent. We have initiated studies in Benin and Nigeria to determine if cassava green mite biocontrol on non-preferred varieties could be improved by interplanting *T. aripo* preferred and non-preferred varieties. Varying ratios of preferred and non-preferred varieties are used to determine the optimum interplanting ratio. Results of two trials showed that *T. aripo* abundance on a non-preferred cultivar could be increased by several folds when interplanted with a preferred cultivar at a minimum interplanting density of 3:1 non-preferred to preferred cultivars. In addition to interplanting cassava varieties, we conducted a survey in 60 cassava fields in south-eastern Togo to determine the effect second season cassava-maize intercropping (a very common cropping system in West Africa) on CGM and phytoseiid densities. The survey data has not been fully analyzed, but it appears that second season cassava-maize intercropping resulted in enhancement of local phytoseiids (which do not have much of an impact on CGM densities) and had little effect on *T. aripo* densities. CGM densities, however, were about 20% higher in the cassava-maize intercrop than in cassava monocrop, probably due to greater nutrient and water stress caused by the addition of maize to the system, although other biotic and/or abiotic factors may be involved. The survey will be conducted again in 2000 for first season cassava-maize intercrop.

10.3.3. Release of *Neozygites floridana* for the control of the cassava green mite

by R.H., A.C., C.L. - in collaboration with F. Hountondji

A release procedure using live infected mites was developed and tested in the field in Adjohoun, in 1998. Following the recovery of the inoculum and the multiplication of the fungus on the inoculated plants in some fields, the procedure was improved and promising isolates of *N. floridana* released in the same area early 1999. The monitoring conducted throughout the year showed the multiplication and persistence of the fungus in the field, although at low levels, until December when higher infections were recorded. The highest infections (20-35%) were observed in fields inoculated with the brazilian isolates whereas the highest infection observed with the local isolate was less than 5%. A method to differentiate between the isolates and the dispersal of the fungus are to be studied. A release was initiated and also conducted on-station at Ina (North Benin), late this year.

10.3.4. Persistence of the biological control of cassava mealybug

by P.N.

In 1999, two purported outbreaks of cassava mealybug were investigated and one country, Tanzania, was investigated in the framework of. a long series of surveys. In Soroti, Uganda, the *Phenacoccus manihoti* outbreak proved to be a minor, short-term peak and almost no living mealybugs were encountered anymore. The presence of *Apoanagyrus lopezi* could be ascertained. In central Congo-Brazzaville, *P. manihoti*, despite claims to the contrary, was infrequent. One heavily infested field could be sampled, which confirmed previous studies. The outbreak occurred on extremely bad, unmulched soil, while neighboring fields with slightly better management were not attacked. *A. lopezi* was present. In Tanzania, a country-wide survey was conducted in June 1999, to document the status of cassava mealybug 11 years after the first release of *A. lopezi*. Several surveys, during which the pest and its natural enemies, but also the leaf and tuber production of cassava had been quantified, had preceded this survey during the last 10 years. The results, though not yet fully evaluated, were supported by farmers' interviews and showed that cassava production had improved and cassava mealybug was no longer a problem.

10.3.5. Investigation of the mechanisms for apparent geminivirus cross-protection in cassava

by J.P.L – in collaboration with W. Sserubombwe

Recent evidence indicates that cassava mosaic geminivirus variants occur in Uganda and furthermore that these give rise to the expression of consistent and different symptoms. Most notably, it appears that there are both mild and severe forms of UgV. Preliminary results from the severity/yield loss trial further suggest that the mild form of UgV may provide some 'cross-protection' against super-infection by the severe form of UgV. Two small experiments were planted in October 1998 to provide quantitative information on super-infection and putative cross protection. PCR diagnostics were used to identify cassava plants infected by either ACMV or the mild form of UgV and these were planted together with disease-free plants in order to compare the relative ease of infection/super-infection and symptom progression for ACMV-infected, mild UgV-infected and CMD-free plants. Results showed that the rate of infection/super-infection with UgV/EACMV of plants initially infected with ACMV did not differ from the rate of infection with UgV/EACMV-Ug of initially CMD-free plants.

10.3.6. Quick screening of varieties for resistance /tolerance to root and stem rots

by K.W., A.G.O.D. - in collaboration with P.-L. Amoussou, L. Afouda, J. Onyeka**

Several methods for the quick evaluation of symptom development of fungal isolates were tested. An optimal method was identified used for the screening of varieties for their resistance against root rot pathogens: the inoculation of cuttings and symptom evaluation after 5 days was selected for further experiments to inoculate varieties with rot pathogens of high virulence and from different locations. Tuber inoculation methods were optimized. Cuttings and tubers were inoculated with strains of different species. The influence of stem/tuber age and stem/tuber size on symptom development was determined. Varieties TMS 30572 and 92/0057 were most resistant.

10.3.7. Screening of varieties for resistance to bacterial blight, elucidation of some mechanisms of resistance, pathogen-genotype interaction in different ecozones and identification of possible existence of races of Xcm

by K.W. - in collaboration with A. Fanou, V. Zinsou**

Varieties identified as tolerant or resistant after the field screening were inoculated with highly virulent strains from various geographic regions in glasshouse experiments. Highly virulent strains from different geographic origin were inoculated on a selected set of six varieties to identify the possible existence of races. These experiments were conducted in the glasshouse under containment conditions. The cassava varieties were selected after evaluation and analysis of a field trial with 423 varieties inoculated with *Xcm*. The inoculation method was stem puncture and leaf infiltration with different concentrations of inoculum. Differential reactions indicating the existence of races after stem injection could not be confirmed with leaf infiltration. The multiplication of *Xcm* in cassava leaves, petioles and stems of 5 cultivars was determined using antibiotics resistant strains. Inoculation of abaxial and adaxial leaf surfaces should give insight into the major ways of entrance of the bacteria and the possible influence of stomatal distribution in different varieties on their resistance. Trials are ongoing. Epiphytic *Xcm* populations were lower in some of the more resistant varieties.

10.3.8. Development of screening methods for resistance or tolerance to root-knot nematodes

by P.R.S. - in collaboration with N.N. Makumbi-Kidza, R.A. Sikora

Nematodes are among the biotic factors that constrain cassava productivity. Severe damage of cassava due to root-knot nematodes (*Meloidogyne* spp.) has been reported from western Uganda and southern Mozambique. Using the differential host technique the biological race of a root-knot nematode population implicated with causing severe damage in farmers fields in Masindi District in Uganda was established as race 2 of *Meloidogyne incognita*. The performance of 25 cassava genotypes infected with the root-knot nematode population from Masindi was evaluated in a field experiment. A relatively low initial nematode pressure was able to cause significant ($P<0.05$) production losses of as much as 25% after 12 months in 16% of lines tested. The validity of screening for nematode tolerance using short-term pot trials was investigated by relating the results of early- (3 months), medium- (6 months), and long-term (9 months) pot experiments to the results of the 12 month field performance evaluation. The effect of root-knot nematodes on cassava sprouting was also tested for the two cultivars SS4 and Migyera (TMS 30572) at two nematode infestation levels. Sprouting of the cultivar Migyera was delayed and reduced at the higher infestation level. Cuttings pre-sprouted in polyethylene bags were less sensitive to nematode infestation in the establishment phase. These results indicate that cassava

response to root-knot nematodes is cultivar dependent. Root-knot nematodes adversely affect cassava productivity in three ways: (1) by reducing plant establishment, (2) by decreasing the number of storage-roots formed, and (3) by reducing the size of the storage roots formed.

10.3.9. Mechanisms of resistance and host-pathogen interactions in the system cassava / bacterial blight: Analysis of plant and bacterial polymers and of low molecular inhibitory substances

by K.W. - in collaboration with V. Zinsou, A. Banito, K. Kpèmoua, B. Ahohuendo, K. Rudolph, R. Cooper, F. Witt, B. Kemp

To study host-pathogen interactions, characterization of bacterial surface structures and of plant cell wall polymers and their interaction are planned. It is supposed that these molecules are decisive factors in the recognition reaction and thus involved in the first steps of development of a compatible or incompatible interaction. The identification of resistance factors of cassava can lead to a quick screening method for the resistance of varieties and thus support breeding programs. Lipopolysaccharides (LPS) of *Xanthomonas campestris* pv. *manihotis* and of *X.c.* pv. *cassavae* - causal agent of bacterial necrosis, for comparison - were extracted after large-scale production of bacterial cultures in fermenters (100l). LPS of *Xcc* was chemically analyzed. Various methods for extraction of cassava pectins were compared and pectins extracted from a susceptible (Ben 86025) and a resistant (TMS 30572) variety from glasshouse plants. Leaves for pectin extraction were collected from the field in different ecozones, pectin extraction is ongoing. The rheometer was adapted and calibrated to investigate the interactions of LPS and pectins.

Suspension cell cultures of cassava were challenged with a range of elicitors, and resistance-related components were produced: alkalinisation and oxidative burst, PAL, proteins, lysozyme, protease, glucanase and chitinase. Methods for extraction and detection of bacteria inhibiting substances, phytoalexins, were tested using cassava leaves. Phytoalexin detection: A constitutive antibacterial compound was extracted from leaves. It was active against all the *Xcm* strains tested. Lysozyme, protease, glucanase and chitinase were detected in cassava latex.

10.3.10. Determination of infection rate, multiplication of *Xcm* and determination of stomatal distribution and number in resistant and susceptible cassava plants

by K.W. - in collaboration with E. Agbicode, V. Zinsou, R. Cooper, K. Rudolph, B. Kemp, F. Witt

Leaf infiltration of the abaxial surface of leaves with three inoculum concentrations resulted in a lower number of spots in the resistant than in the susceptible variety, while after leaf spraying with three concentrations no spot was observed. The inoculum concentration of 10^6 cfu/ml was determined as optimal concentration to differentiate varieties for resistance by symptom development In susceptible varieties the multiplication of *Xcm* in the leaves, petioles and stems was higher than in the resistant variety. The migration of bacteria into the stem was lower in the resistant variety TMS 30572. This may be due to a resistance factor on stem level. The number of spots on leaves was higher in the susceptible variety, as well as the number of stomata on the adaxial leaf surface. In further more detailed studies, a resistant cultivar under field conditions had significantly fewer stomata at the leaf base than a susceptible one. This may indicate that the number of stomata plays a role as mechanisms of resistance.

10.3.11. Reaction of local and improved varieties to highly virulent strains of *Xcm* from different geographic origin

by K.W. - in collaboration with K. Kpèmoua, B. Ahohuendo, A. Banito, V. Zinsou

Twenty-four local and improved varieties from Togo were stem-inoculated with 4 highly virulent *Xcm* strains from various geographic origin. The local variety Gbazekoute and the improved varieties CTM4, TMS 920057, TMS 91/02316, TMS4(2)1425 and TMOA378 showed resistance/tolerance to the inoculated strains. Several varieties are being tested by leaf inoculation with the 10 most virulent strains. Inoculating nineteen local and improved varieties from Benin/Nigeria by stem puncture and leaf infiltration with *Xcm* strains from various origin, races of *Xcm* could not be identified. Experiments with the backcross (BC1) of TMS30572 x CM2177-2 (Latin American origin) population are ongoing.

10.3.12. Characterization of symptom development and determination of yield loss due to bacterial blight infection of local and improved cassava varieties in ecozones in Benin and Togo

by K.W., A.G.O.D. - in collaboration with K. Kpèmoua, B. Ahohuendo, A. Banito, V. Zinsou

In Togo, 24 cassava varieties collected from farmers' fields and from the National Cassava Collection

were planted in 2 ecozones in 1998 and in 3 ecozones (littoral, forest and wet savanna) in 1999. Symptoms of CBB and CMD were evaluated. In harvests after 6 and 12 months root, stem and leaf weight and number of leaves and of fallen leaves was determined in the inoculated treatment and the control. The local variety Nakoko was resistant in the field, but susceptible to inoculation with virulent strains of other geographic origin. In Benin, thirty local varieties were tested for resistance in the forest savanna transition, the wet and the dry savanna zones. Trials are presently repeated for a second year.

10.3.13. Combination of crop management practices for control of cassava bacterial blight in five ecozones

by K.W. - in collaboration with K. Kpèmoua, B. Ahohuendo, A. Banito, V. Zinsou

Trials combining cultural control measures and varietal resistance were installed in the forest zone, forest-savanna transition zone, highland (littoral in Togo), wet savanna and dry savanna in Benin and Togo. Different components were: variation of planting date, two densities of cassava, intercropping with maize, sorghum, cowpea and cocoyam, four levels of fertilizer (Kcl: 0, 60, 80, 120 kg/h) and mulching with *Cassia siamea*. Trials are presently being repeated for a second year.

10.3.14. Screening of cassava varieties for resistance to root rots

by K.W., A.G.O.D - in collaboration with K. Kpèmoua, B. Ahohuendo, A. Banito, V. Zinsou, J. Onyeka

Cassava varieties with resistance/tolerance to CBB were selected for inoculation with root rot pathogens. Highly virulent pathogens collected in Togo, Benin and Nigeria were selected. Trials are performed in pot experiments under controlled conditions using soil inoculation.

10.4. Development and dissemination of information resources for sustainable cassava pest control

Background

Information resources are needed to facilitate processing, summarization, interpretation and communication of the large and diverse databases. Large multi-disciplinary databases are best exploited by a systems approach specifically designed to update, manage and interpret dynamic data. Work already initiated along these lines includes development of text references, taxonomic resources, digitized interactive information resources and decision support systems. An effort will be made to identify and compile into a database the national root crop plant protection gray literature in each country which is often difficult to find, e.g. theses, dissertations, project documents, annual reports, etc. Other relevant databases already compiled will be updated including databases on cassava research personnel worldwide, cassava projects in Africa, and a comprehensive bibliography of cassava literature.

On-going and future activities

10.4.1. Extension/farmer training materials

by B.D.J., J.S.Y., W.M., K.W., J.P.L., P.N., M.T., in close collaboration with J.A. Tumanteh, N.G. Maroya; A.R. Cudjoe, T.N.C. Echendu

Four previously field tested cassava IPM field guides for extension are in the final stage of printing. These guides will be distributed to NARS staff and other interested parties. A source book for extension trainers in cassava IPM is being finalized.

10.4.2. Interactive information media

by R.H., J.S.Y., B.D.J., M.T. – in collaboration with F. Fulorunmi, B. Gbaguidi, A. Kagbahinto

A cassava plant protection information CD-ROM developed by ESCaPP with the University of Florida is being improved, updated and placed in a web site. The information resource will consist of a cassava plant protection directory of personnel, projects and institutions, full text of important cassava management documents, photographic quality color images of major production constraints and natural enemies, bibliographies, and a series of databases including cassava mites of Africa, ESCaPP protection, production and socio-economic diagnosis, collaborative study of cassava in Africa, and long-term African meteorological data.

10.4.3. Use of diagnostic survey results to forecast the expansion of the CMD pandemic in East Africa

by J.P.L. - in collaboration with J. Ndunguru, S. Jeremiah, J. Kamau

Survey results were used to develop GIS maps of the epidemiological characteristics of the CMD pandemic in the Lake Victoria zone of East Africa. These maps have been used to forecast areas likely to be affected by the pandemic within a 1-3 year period. During 1999, one of the zones identified as being threatened by the pandemic, was widely affected (Kagera region, Tanzania), and was officially gazetted by the Tanzanian Government, with restrictions were placed on the replanting of diseased stems and the movement of material out of the region. Increases in CMD incidence and the new occurrence of UgV/EACMV-Ug were also reported and published for the threatened zone in western Kenya.

10.4.4. Workshop manual: Integrated management of cassava bacterial blight

by K.W

Results of a 6-years project to develop and test methods for „Integrated management of bacterial diseases and root and stem rots of cassava and cowpea" were specified in detail in a workshop manual with the above title. The manual includes exercises for field and glasshouse screening for resistance of varieties against bacterial diseases and root and stem rots as well as laboratory methods describing the detection and isolation of pathogens from plants, seeds, soil and debris, the characterization and inoculation of pathogens and evaluation of symptoms. Epidemiological studies on the role of vectors are part of the proposal. For the control of diseases, exercises on biological control, physical treatment of seeds and the evaluation of resistance and mechanisms of resistance are described. In an annex, culture media for bacterial and fungal pathogens and for antagonists are listed, as well as evaluation sheets for virulence tests and symptom evaluation in the glasshouse and the field.

10.5. Enhancing the capacity of NARES and farmers to evaluate, disseminate and implement intervention technologies

Background

Intervention technology is of little value until it is locally adapted, disseminated and implemented. Getting this technology to the farmer is the last, but often the most difficult step, to take. This is where NARES and farmers have an important role, but often lack the experience and training needed to achieve the objective. Developing technology in collaboration with end users and those most closely associated with adoption is a good way to start. Collaborative evaluation, dissemination and implementation activities provide NARES much needed technical training and practical experience. Training for farmers and extension agents concerning technology transfer should improve the evaluation process, enhance dissemination and accelerate implementation.

On-going and future activities

10.5.1. Experimental releases and follow-ups of exotic phytoseiids

by R.H., M.T..- in collaboration with D. Gnanvossou, D. Ojo, A. Onzo, G. Paraiso, I. Zannou, B. Pallangyo, W. N'gunda, C. Kariuki, J. Ogwang, A. Jone, E. Mambo, G. Phiri, M. Mebelo, T. Hangy, N. Ntonifor, O.S. Bah, L. Traore, T. Cudjoe, Y.S. Gogóvor, T.N.C. Echendu, C. Asanzi

A total of 72,240 actives of Piritiba and MGS strains of *T. aripo* were shipped from IITA for experimental releases in Angola, Democratic Republic of Congo (DRC), Malawi, Mozambique, Tanzania, and Zambia, in 1999. Follow-up surveys indicated successful establishment and substantial spread in several sites in Bas-Congo of DRC and Nkhata Bay in Malawi; and limited spread in Luapula Province in Zambia and Nampula province in Mozambique. Establishment in Angola is yet to be confirmed. In Benin, Cameroon, Ghana, Guinea Conakry, and Nigeria, *T. aripo* was recovered in all previous release fields, has persisted for over 5 years, is now found up to the edge of the dry savanna. *T. aripo* was found similarly distributed with similar levels Cote d'Ivoire, and Togo, where this predator was never intentionally released. *T. aripo* was has also spread extensively in Uganda (up to the northern dry regions, throughout the cassava growing areas of Kenya, and much of Tanzania (except in the Mara region and area between southern tip of Lake Tanganyika and northern tip of Lake Nyssa where releases have been made but follow-ups have not been conducted). In the Republic of Congo, *T. aripo* was found up to 300 km from a single release conducted in 1997. The predator has been reported from Liberia, Rwanda and Burundi but the extent of spread in those countries is not yet known. Overall, *T.*

aripo spread currently cover over a million km^2 where it reduces *M. tanajoa* populations by 30 to 60%. The establishment, dispersal, persistence and population dynamics of *T. aripo* will continue to be monitored in 2000 in at least 12 countries.

10.5.2. Support to national programs

by R.H., M.T. - in collaboration with D. Gnanvossou, D. Ojo, A. Onzo, G. Paraiso and I. Zannou

IITA's support to national biological control programs continues in the form of specific training in acarology and associated release techniques, technical assistance with country-wide surveys, identifying mite specimens, preparing appropriate work plans, preparing proposals for bilateral donor support, data analysis, and supplying natural enemies for experimental releases. Support activities were carried out in Benin, Cameroon, Ghana, Guinea, Kenya, Mozambique, Nigeria, Uganda, Zambia, Malawi, Democratic Republic of Congo, Rwanda, Tanzania, and Côte d'Ivoire. Eight trainees from 6 national programs visited the cassava green mite group in Cotonou for an average of one week of personalized bench training during the year.

10.5.3. Impact assessment of exotic predatory mites

by R.H., M.T. - in collaboration with D. Gnanvossou, D. Ojo, A. Onzo, G. Paraiso, I. Zannou, N. Ntonifor, T.N.C. Echendu, Y.S. Gogovor, J. Ogwang, S. Challa, R. Tocloe

Seven on-farm trials were initiated in 1998 and were harvested in 1999 to determine the impact of the exotic phytoseiid *T. aripo* on population dynamics of *M. tanajoa* and the production cassava root yield. These trials were conducted in two ecozones in each of Nigeria and northern Benin, and one ecozone in each of Cameroon, Togo, and Uganda. *M. tanajoa* and phytoseiids were monitored monthly in each site, while plant samples were taken and evaluated for dry matter content at the time of harvest. Except in the northern Benin trial, exotic phytoseiids continued to reduce CGM densities between 30 and 60% and increase cassava yield by an average of 30%. In the northern Benin trials, *T.* aripo had no impact on CGM densities and cassava root yield, because the predators disappeared from cassava four months after the initiation of the trials, probably due to poor cassava shoot tip quality caused by low rainfall during much of 1998.

10.5.4. Participatory evaluation trials for the assessment of 'new' CMD-resistant cassava varieties in technology transfer centers in Uganda.

by J.P.L. - in collaboration with A. Bua, G. Acola, T. Alicai

Recently released and advanced breeding cassava materials were evaluated with farmers at four technology transfer centers (TTCs) in Uganda. CMD remained the major constraint. Of the seven clones evaluated, SS4 and 92/MG11 were least affected by CMD, with incidences after 4 months of 7.5% and 1.7% respectively. Farmers ranked CMD resistance as the most important varietal attribute followed by general plant vigor at the 4-month stage. Training was provided to 48 farmers in pest and disease management. During final harvest-based evaluations successfully completed at three of the four TTCs, assessments of varieties were made together with farmers, and pre-harvest, after-harvest and after cooking evaluations were conducted. Varieties were categorized as either selected or not selected at each of the evaluation stages. Three of the tested varieties were selected at all three evaluation stages at the Kamuli site (TMS 82/0942, 92/MG-11 and 95/NA-2-TC1), two varieties at the Masindi site (TMS 82/0942 and the local 'Nyaraboke') and two at the Mpigi site (95/NA-2-TC1 and MH 95/0161). There was a poor relationship between CMD incidence and final yield, and similarly between yield and farmer selection. Palatability appeared to be a key determinant of farmer selection, suggesting that greater attention needs to be directed to quality characteristics in future breeding work. Evaluations were expanded to four sites in each of the technology transfer centers during November/December 1999.

10.5.5. Evaluation of CMD-resistant cassava varieties in Kenya and Tanzania.

by J.P.L. - in collaboration with J. Ndunguru, S. Jeremiah, R. Kapinga, J. Kamau

More than 25 'improved' cassava varieties were evaluated in collaboration with Tanzanian NARS and responses to CMD described. Only three of the varieties had less than 60% CMD incidence at the highest inoculum pressure location and were therefore considered for incorporation within the multiplication scheme. These were TMS 30572(6). TMS 81983 and TMS 30337. Through the OFDA CMD Project, support was also provided for the performance evaluation of more than 150 clones at

Alupe, western Kenya, and the evaluation and multiplication of 14 clones targeted for 'fast-tracking' through the evaluation, multi-locational testing and multiplication process.

10.5.6. Targeted multiplication of CMD resistant varieties in the zones affected by the pandemic of severe CMD in East Africa.

by J.P.L - in collaboration with J. Ndunguru, S. Jeremiah, R. Kapinga, Tanzania, H. Obiero, J. Kamau, M. Onim, A. Bua, R. Mayiga

The OFDA CMD Project contributed to the multiplication of more than 300,000 stems of CMD resistant varieties in each of Uganda and Tanzania and more than 60,000 stems in Tanzania. Principal CMD resistant varieties multiplied included SS4 in Uganda, TMS 30572 and SS4 in Kenya and TMS 4(2)1425, TMS 30337, TMS 60142, TMS 90057 and TMS 30572(6) in Tanzania. Multiplication plots were established during the first one-year phase of this Project, which will provide for the production of much greater quantities of planting material in the second one-year phase initiated during the final quarter of 1999.

10.5.7. Support for germplasm exchange in East Africa

by J.P.L.- in collaboration with P. Njoroge, O. Opolot, J. Ndunguru, R. Kapinga, R. Mohamed

Within the framework of the OFDA CMD Project, a study tour was made with plant quarantine officers from Uganda, Tanzania and Kenya to assess the potential for the extension of the open quarantine system currently being used in western Kenya to access cassava germplasm from Tanzania. Partly as a result of this, permission was granted by the Plant Protection Department of Tanzania to establish a 5ha open quarantine site at Maruku Research Institute, Bukoba, Tanzania. In November 1999, stems for 5ha of variety SS4 and smaller quantities of 500 clones from the EARRNET regional germplasm programme were transported from Uganda to Tanzania and established at Maruku. 10,000 tissue culture plantlets of CMD-resistant varieties were also supplied to Tanzania in May 1999 to tackle the CMD pandemic in Bukoba.

10.5.8. Cassava pest and disease training

by R.H., M.T., J.P.L, K.W., J.W., B.K.

Several training courses in CMD, and general cassava pest and disease control, and cassava production and 'utilization were held in 1999. The training included (1) a CMD awareness workshop for District Agricultural Officers, western Kenya, March 1999; (2) a cassava multiplication and planning workshop, Rakai and Masaka districts, Uganda, September 1999; (3) training of trainers course on cassava production, pest/disease management and post-harvest utilization, western Kenya, June 1999; and (4) training of village leaders in CMD management, rapid multiplication and processing, Bukoba District, Tanzania, May 1999. Three additional types of training were organized in 1999. In one training course, NARS staff from several countries spent two weeks at IITA-Cotonou, where they received in-depth training in cassava green mite management. In a second training course, fourteen plant pathologists from NARS from 9 countries in West and East Africa received in-depth training at IITA-Cotonou in integrated management of bacterial diseases and root rots of cassava, and in classical and modern phytopathological methods. The third type of training involved in-country training of NARS extension, NGOs and farmers representatives from Bunda, Kahama, Mugumu, Musoma and Tarime districts in Tanzania (4-7 October), and from Mukono (October '99) and Rakai (November '99) districts in Uganda. Participants in the in-country training represented 22,000 families/groups in Mara, 22,000 in Mukono and 15,000 in Rakai who could/would be trained on CGM activities. In addition to courses, on-site and bench training, two PhD and one MSc students completed their degrees, and several PhD and MSc students from various African countries are continuing their research on CBB (2), root rot pathogens (1), root-knot nematode (1), and cassava green mite (7).

10.5.9. Stakeholder workshop on the implementation of cassava green mite biocontrol in eastern and southern Africa

by R.H., M.T., J.P.L. - in collaboration with C. Kariuki, E. Musonda, J. Ogwang, B. Pallangyo, G. Phiri.

A five-day stakeholder workshop, sponsored by IFAD, was held in Kampala, Uganda from 19-23 April, 1999 to develop a comprehensive and broad-based approach to the implementation of CGM biocontrol in Kenya, Malawi, Tanzania, Uganda, and Zambia. Representatives from IITA, donor agencies, NARS, and NGOs from each of the targeted countries (1) identified the needs of the participating

countries and determined ways to respond to those needs, (2) established a collaborative network among NARS, NGOs, and IITA to implement CGM activities and promote cassava IPM, and (3) developed and finalized workplans and budgets for 1999, and work agreements for the life of the project.

10.5.10. Collaborative research programs on bacterial diseases
by K.W

The project on development, integration and dissemination of control methods for bacterial diseases and root rots of cassava and cowpea ended in June 1999 after 6 years. Five PhD thesis (4 African, 1 Asian students) at the University of Göttingen, and 9 Diploma/MSc thesis at local universities were conducted and finalized in the framework of the project. In training courses, more than 100 NARES' scientists had been trained in IPM methods for bacterial diseases. The EC-funded project on the integration and adoption of integrated methods for cassava bacterial blight continued. Two PhD students from Benin and Togo were trained at the University of Göttingen and in Wageningen, Netherlands, in bacteriological, mycological and biochemical methods. Scientist exchange: an EC-project meeting was held in January in Göttingen, and the NARS collaborator from Togo participated as resource person in a workshop at IITA Benin. The PhD student from University of Bath visited Benin and Togo for field studies.

Completed Studies

Journal articles and book chapters

Ambe, J.T., N.N. Ntonifor, E.T. Awah, & J.S. Yaninek, 1999. The effect of planting dates on the incidence and population dynamics of the cassava root scale,* Stictococcus vayssierei*, in Cameroon. International Journal of Pest Management 45: 125-130.

A study on the influence of planting dates on the incidence of the cassava root scale, *Stictococcus vayssierei*, was conducted using an improved and a popular cassava variety from each of two participating villages in the rain forest of Cameroon. Monthly planting of each variety from April to October of 1995 and *S. vayssierei* sampling from 1 month after each planting until 12 months after planting was done. *S. vayssierei* attacked both cassava varieties in each village. The pest usually occurred in clusters or aggregations on the subterranean parts of the plants. The highest root scale densities were about 75 and 51 individuals per plant during the long dry sand rainy season, respectively. Generally, higher *S. vayssierei* densities were recorded during the dry season irrespective of the village. Planting in August-September predisposes the early bulking stages of the crop to high root scale pressures in the dry season, which can have serious repercussions on cassava storage root yield. The onset of the main rainy season (April/May) was the most appropriate period for planting cassava to enable the more susceptible early growth stages of the crop to avoid the period of high root scale infestations. These results highlight the possibility of using cultural practices in managing *S. vayssierei*.

Aritua, V., J.P. Legg, N.E.J.M. Smit & R.W. Gibson, 1999. Effect of local inoculum on the spread of sweet potato virus disease: limited infection of susceptible cultivars following widespread cultivation of a resistant sweet potato cultivar. Plant Pathology 48:655-661.

Borgemeister, C., K. Schaefer, G. Goergen, S. Awande, M. Sétamou, H. Poeling & D. Scholz, 1999. Host-Finding Behavior of* Dinoderus bifoveolatus *(Coleoptera: Bostrichidae), an Important Pest of Stored Cassava: the Role of Plant Volatiles and Odors of Conspecifics Annals of the Entomological Society of America 92:766-771.

In cassava chips sampled on a local market in Cotonou, Republic of Benin, West Africa, *Dinoderus bifoveolatus* Wollaston was the predominant pest. In olfactometer experiments, cassava chips infested by male *D. bifoveolatus* were highly attractive to both sexes of the beetle, suggesting that male *D. bifoveolatus* produce an aggregation pheromone. Female *D. bifoveolatus* showed a significantly stronger response pattern than conspecific males. Sticky traps, baited with cassava chips harboring male *D. bifoveolatus*, set up in 2 regions of southern Benin, consistently caught considerable numbers of conspecifics. Trap catches differed significantly between the regions, and for 1region also between the sites. The sex ratio of the trapped *D. bifoveolatus* was significantly female biased. Low numbers of 2 other bostrichids [i.e., *Prostephanus truncatus* (Horn) and *Rhyzopertha dominica* (F.)] were also recorded in the traps. Fessehaie, A., K. Wydra & K. Rudolph, 1999. Development of a new semiselective medium for isolating *Xanthomonas campestris* pv. *manihotis* from plant material and soil. Phytopathology 89: 591-597.

Gutierrez, A. P., J. S. Yaninek, P. Neuenschwander & C. K. Ellis, 1999. A physiologically based tritrophic metapopulation model of the African cassava food web. Ecological Modelling, 123: 225-242.

The metapopulation dynamics of the African cassava food web is explored using a physiologically based tritrophic model. The interacting species are cassava mealybug and its natural enemies (two parasitoids, a coccinellid predator and a fungal pathogen) and the cassava green mite and its natural enemies (two predators and a fungal pathogen).

The metapopulation model is based on a single patch age-structure population dynamics model reported before. The same model simulates the mass number dynamics of each plant or animal species in each patch and the movement of animals between patches. Movement is based on species specific supply-demand relations. The pathogen mortality rate is a simple function of rainfall intensity. The within-patch species composition, their initial densities, and initial values of edaphic variables may be assigned stochastically. Sensitivity, graphical and multiple linear regression analyses are use to summarize the effects of spatial and resource heterogeneity on species dynamics. Important plant level effects on higher trophic levels are demonstrated, and recommendations are made as to the appropriate model for different ecological studies.

Hountondji, F. C. C., J.S. Yaninek, G.J. de Moraes & Oduor G.I. Lack of infection by the mite pathogen Neozygites floridana in non-target arthropods of the cassava agroecosystem. BioControl (in press).

Tests were conducted on the host specificity of a Brazilian isolate of the fungus *Neozygites floridana*, a potential biological control agent for the cassava green mite, *Mononychellus tanajoa*, in Africa. Six insect and two mite species commonly found on cassava including two ecologically vulnerable indicator species were evaluated for susceptibility to *N. floridana*, namely *Euseius concordis*, *E. citrifolius*, *Phenacoccus herreni*, *Stethorus* sp., *Aleurothrixus aepim*, *Apoanagyrus diversicornis*, *Bombyx mori* and *Apis mellifera*. Individuals of each species were exposed to capilliconidia (the infective stage of the fungus), on either cassava leaf discs, coverslips, or pieces of overhead transparencies for periods of time ranging from a few minutes to two days, depending on the species. After exposure, individuals were incubated for 5 to 10 days in the laboratory at ca. 25°C and 70% RH. None of the tested individuals was found with hyphal bodies (the invading vegetative stage of the fungus), whereas more than 75% of the cassava green mites in the controls became infected. Non-germinated capilliconidia were, however, found attached to several individuals in most species. Some germinated capilliconidia were found attached to the exuviae of *Stethorus* sp., *B. mori*, and *A. aepim* nymphs but these did not develop further to form hyphal bodies in the body of the individuals attacked. This *N. floridana* isolate appears to be specific to *M. tanajoa*. Further evaluation of its performance against this pest in Africa is therefore desirable.

Legg, J.P., 1999. Emergence, spread and strategies for controlling the pandemic of cassava mosaic virus disease in east and central Africa. Crop Protection 18:627-637.

Conference papers, workshop proceedings, abstracts, newsletters

Assigbétsé, K., V. Verdier, K. Wydra, K. Rudolph & J.P. Geiger, 1999. Genetic variation of the cassava bacterial blight pathogen, **Xanthomonas campestris** ***pv.*** **manihotis,** ***originating from different ecoregions in Africa. In: Mahadevan, A. (ed.), Plant Pathogenic Bacteria, Proceed. 9th Internation. Conf., Centre for Advanced Study in Botany, University of Madras, India, pp. 223-229.***

Borgemeister, C., K. Shaefer, T. Tolasch, W. Francke, C. Nansen, R. Hanna & G. Goergen, 1999. Host finding behaviour of **Dinoderus bifoveolatus** ***(Col.: Bostrichidae), a pest of stored cassava in West Africa. Ten minute presentation at the annual meeting of the Entomological Society of America, Atlanta, Georgia, 12-16 December 1999.***

In cassava chips, sampled on a local market in Cotonou, Republic of Benin, West Africa, *Dinoderus bifoveolatus* Wollaston was the predominant pest. In olfactometer experiments, cassava chips infested by male *D. bifoveolatus* were highly attractive to both sexes of the beetle, suggesting that male *D. bifoveolatus* produce an aggregation pheromone. Female *D. bifoveolatus* showed a significantly stronger response pattern than conspecific males. Sticky traps, baited with cassava chips harboring male *D. bifoveolatus*, set up in 2 regions of southern Benin, consistently caught considerable numbers of conspecifics. Trap catches differed significantly between the regions, and for one region also between the sites. Low numbers of 2 other bostrichids, i.e., *Prostephanus truncatus* (Horn) and *Rhyzopertha dominica* (Fabricius), were also recorded in the traps. In ongoing studies, we are trying to identify and synthesize the assumed male-produced pheromone of *D. bifoveolatus* and test the response of male and female conspecifics in olfactometer and flight trap experiments. Moreover, in ongoing olfactometer experiments we are investigating the response pattern of *P. truncatus* and *R. dominica* to odors produced by male *D. bifoveolatus* on cassava chips.

Briddon, R.W., J.A. Farquhar, C. Roussot, G.K. Banks, I.D. Bedford, J.P. Legg & P.G. Markham, 1999. Geminiviruses and whiteflies across Africa. Proceedings of the VIIth International Plant Virus Epidemiology Symposium, Aguadulce (Almeria), Spain, April 11-16, 1999. Abstract. 75-76.

Fanou, A., 1999. Epidemiological studies on the role of weeds, plant debris and vector transmission in survival and spread of **Xanthomonas campestris** ***pv.*** **manihotis,** ***causal agent of cassava bacterial blight. MSc thesis. University of Göttingen, Germany. pp.53.***

Fanou, A. 1999. Epidemiological and ecological investigations on cassava bacterial blight and development of integrated methods for its control in Africa. PhD dissertaion. University of Göttingen, Germany. pp. 199.

Ferris, S., J.P. Legg, G.W. Otim-Nape & J.A.B. Whyte, 1999. Dissemination and Utilisation of Mosaic-Resistant Cassava. Fifth technical report for the ACDI PL 480 Cassava Project.

Ferris, S., J.P. Legg, A. Bua & J.A.B. Whyte, 1999. Dissemination and Utilisation of Mosaic-Resistant Cassava. Sixth technical report for the ACDI PL 480 Cassava Project.

Fessehaie, A., K. Wydra & K. Rudolph, 1999. Cefazolin-Trehalose agar medium, a semi-selective medium for **Xanthomonas campestris** *pv.* **manihotis** *(Xcm), the incitant of cassava bactertial blight. In: Mahadevan, A. (ed.), Plant Pathogenic Bacteria, Proceed. 9th Internation. Conf., Centre for Advanced Study in Botany, University of Madras, India, pp. 100-106.*

Hanna, R., M. Toko & J.S. Yaninek, 1999. Crrent status of cassava green mite biological control in Africa with reference to Tanzania. A key note paper presented at the Fourth Scientific Conference and Annual General Meeting 28-30 September 1999 Tropical Pesticides Research Institute, Arusha, Tanzania.

The cassava green mite *Mononychellus tanajoa*, an introduced pest of cassava in Africa, has been the target of a major classical biological control campaign by the International Institute of Tropical Agriculture. After numerous introduction attempts, three predatory mite species in the family Phytoseiidae were established in several countries, but only *Typhlodromalus aripo* has shown the ability to readily establish and quickly spread on a continental scale. Since its introduction in Benin in 1993, *T. aripo* has established populations in 16 countries; and in the initial establishment areas of Southern Benin and Southwestern Nigeria, it has reduced cassava green mite densities by nearly 50%, with a corresponding 35% increase in cassava root yield. Efforts are now directed toward (1) implementing cassava green mite biological control in Central, Eastern, and Southern Africa; (2) understanding the nature of plant-predator-prey interactions that affect the efficiency of biological control in various agroecozones; (3) determining predator preference to hundreds of cassava varieties and breeding lines; (4) intercropping predator-preferred varieties to enhance biological control on non-predator-preferred varieties; and (5) training scientists, extension agents and farmers

Legg, J.P., R. Kapinga, J. Teri & J.B.A. Whyte, 1999. The pandemic of cassava mosaic virus disease in East Africa: control strategies and regional partnerships. Roots 6(1): 10-19.

Legg, J.P., 1999. Fighting cassava mosaic pandemic: networking critical. Agriforum 7, p1 and p12.

Legg, J.P., P. Sseruwagi, J. Kamau, S. Ajanga, S.C. Jeremiah, V. Aritua, G.W. Otim-Nape, A. Muimba-Kankolongo, R.W. Gibson, & J. Thresh, 1999. The pandemic of severe cassava mosaic disease in East Africa: current status and future threats. Proceedings of the scientific workshop of the Southern African Root Crops Research Network (SARRNET), Lusaka, Zambia, 17-19 August 1998. Eds. Akoroda M.O. and Teri, J.M. pp 236-251.

Legg, J.P. & Okao-Okuja, 1999. Progress in the diagnosis and epidemiological characterization of cassava mosaic geminiviruses in East Africa. Proceedings of the VIIth International Plant Virus Epidemiology Symposium, Aguadulce (Almeria), Spain, April 11-16, 1999. Abstract. 74-75.

Makumbi-Kidza, N.N., P. Speijer, & R.A. Sikora, 1999. The influence of root-knot nematodes on plant growth and tuber formation of cassava at different stages of development. In: Abstracts 14th Symposium of the Nematological Society of Southern Africa, held in Dikohololo South Africa, 30 May – 3 June 1999:24.

Mebelo, M. 1999. Screening phytoseiids for the control of cassava green mites in Zambia. Ph.D. dissertation. University of London-Imperial College, United Kingdom. pp. 186.

A survey was conducted in 23 municipalities in central and southern Brazil to identify suitable sites for the collection of phytoseiid mites to be released in Zambia, as biological control agents against the cassava green mite *Mononychellus tanajoa* Bondar. The distribution and abundance of both predatory and phytophagous mites and other arthropods on cassava and surrounding vegetation were assessed. Interspecific associations between the various assemblages of predatory mites, their phytophagous prey and plant hosts were determined. *Typhlodromalus aripo* DeLeon and *Euseius concordis* Chant were the most common predatory species on cassava, while *Mononychellus* spp. were the predominant phytophagous mite species. Other arthropods included cassava thrips *Scirtothrips manihoti*, whiteflies *Bemisia sp.* and plant bugs *Vatiga illudens*. Different types of food were tested for their suitability as alternate food sources, for *E. concordis* and *T. aripo*. *Euseius concordis* laid the highest number of eggs when fed pollen. *Typhlodromalus aripo* laid more eggs when given thrips larvae than when it was offered M. *tanajoa*, but it consumed higher numbers of cassava green mites than did *E. concordis*. The biology of two populations of T *aripo* from. João Pinheiro (Minas Gerais state) and Rio Verde (Goias state) was studied in the laboratory at four levels of temperature, 15 'C, 20 'C, 25 'C, and 30 'C, and 12L: 12D photoperiod. Using linear regression models, the minimum temperatures required for development and the thermal constant (K) were estimated. Survival rates, sex ratios and fecundity were also determined. Using values obtained above the net reproductive rate (Ro), intrinsic rate of increase (rn,), generation time (G), doubling time (DT) and the finite rate of population increase (k), were also established. The eggs of the two populations were tested for tolerance to different levels of vapour pressure deficit (VPD). The vapour pressure deficit at which only 50% of the eggs hatched (VPD50) was calculated using the logit/response model.

Muimba-Kankolongo, A., N.M. Mahungu, J. P. Legg, M.P. Theu, M.D. Raya, A. Chalwe, P.A. Muondo, A.A. Abu & G. Kaitisha, 1999. Importance of cassava mosaic disease and intervention strategies to overcome its spread in the Southern African Development Community region. Proceedings of the scientific workshop of the Southern African Root Crops Research Network (SARRNET), Lusaka, Zambia, 17-19 August 1998. Eds. Akoroda M.O. and Teri, J.M.

Sseruwagi, P., L.P. Legg & G.W. Otim-Nape, 1999. An overview of the incidence of cassava mosaic disease in East Africa, 1998 update. Proceedings of the VIIth International Plant Virus Epidemiology Symposium, Aguadulce (Almeria), Spain, April 11-16, 1999. Abstract. 87-88.

Wydra, K. & K. Rudolph, 1999. Integrated control of bacterial diseases and root rots of cassava and cowpea in West Africa: report on a collaborative project. DPG AK Plant Protection in the Tropics and Subtropics. Phytomedizin 29:35-36.

The goal of the collaborative project of the International Institute of Tropical Agriculture (IITA), Benin, and the Institute for Plant Pathology and Plant Protection, University of Göttingen, together with national agricultural research systems (NARS) in Benin, Togo, Ghana, Niger, Nigeria and Cameroon, from 1994 to 1999 was to develop, test and adapt integrated methods to reduce losses caused by major diseases of cassava and cowpea in West Africa. Surveys on the economic importance of major diseases revealed as major problems on cassava bacterial blight (CBB) caused by *Xanthomonas campestris pv. manihotis* (*Xcm*) and root rots in the savanna zones and the rainforest, respectively. Exact yield loss trials in different ecozones revealed losses due to CBB up to 50%. Cowpea bacterial blight (CoBB) cause by *X. campestris pv. vignicola* (*Xcv*) was an important constraint in the transition forest and savanna zones, and charcoal rot of cowpea, caused by *Macrophomina* phaseolina ((Mp) in the dry savanna zone, with CoBB causing seed weight losses up to 64%. Strains of *Xcm* and *Xcv* and Mp were characterized pathologically, biochemically, physiologically and genetically. Races of *Xcv* and *Xcm* were not found. Immunological and genetic (for *Xcm*) detection methods as well as semi-selective media (for *Xcm* and *Xcv*) were developed for CBB, CoBB and Mp and used in epidemiological studies on disease vectors, survival in soil and on weeds, which resulted in recommendations for disease control, as (i) weeding and control of grasshoppers to reduce inoculum potential and distribution of *Xcm* and *Xcv*, (ii) burying of infected plant debris especially in the savanna zones to destroy inoculum of CBB and CoBB and (iii) avoiding to grow cowpea in rotation in the same field in the long and short rainy season in the wet savanna zone. Developed control methods comprised also cultural and agronomic measures adapted to ecozones, seed treatments, crop sanitation, biological control for Mp, and plant resistance. The following technologies and recommendations were elaborated and tested: (iv) hot water treatment of cassava and cowpea seeds at 60 °C for 30 min, hot air treatment of cassava seeds at 65 °C for 96 h and cowpea seeds at 65 °C for 120 h or at 75 °C for 48 h, (v) resistant/tolerant cassava (7 against CBB) and cowpea varieties (32 against CoBB and one against Mp), (vi) association of cassava and maize to reduce CBB - root yield is not significantly different compared to cassava monocropping, (vii) association of cowpea with maize or cassava reduces CoBB; loss in cowpea yield is compensated by the yield of the associated crop, (viii) planting at a later date to avoid the peak time of infection of CBB in the forest savanna transition zone, (ix) sowing at a later date to avoid late infection of CoBB in the forest savanna transition zone, and sowing early to avoid an early infection with CoBB in the forest savanna transition while in the dry savanna zone later sowing reduces disease severity but also yield, (viii) pruning of infected leaves and late harvest of infected fields in the dry savanna zone to reduce disease severity of CBB and increase yield, and (ix) no pre-soaking of cowpea seeds in water before sowing to avoid contamination with the CoBB pathogen. Biological control of Mp was successful in pot experiments and has to be validated under field conditions

Wydra, K., V. Zinsou & A. Fanou, 1999. The expression of resistance against* Xanthomonas campestris *pv.* manihotis*, incitant of cassava bacterial blight, in a resistant cassava variety compared to a susceptible variety. In: Mahadevan, A. (ed.). Plant Pathogenic Bacteria. Proc. IX Int. Conf., Madras, India, pp. 583-592.

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Yaninek, S.J. & R. Hanna, 1999. Indirect host defences and the biological control of cassava green mite in Africa. Invited symposium presentation at the annual meeting of the Entomological Society of America, Atlanta, Georgia, 12-16 December, 1999.

Selecting effective natural enemies remains a challenge in biological control. Ten phytoseiids with different capacities for population increase and predation were introduced into Africa against the exotic cassava green mite (CGM) in a continent-wide experiment. Typhlodromalus aripo, the least efficient in terms of food conversion, was most effective at establishing (14 countries), spreading (900,000 km2 in 4 years), reducing CGM densities (52%), and increasing yields (35%). Plant-provided food and shelter, plus modest prey exploitation prompted larger foothold populations and generated more dispersers which increased predator-prey ratios elsewhere. This implicates plant-predator interactions and prey exploitation strategies in natural enemy selection

Plant protection related activities of Project 1

CONSERVATION AND GENETIC ENHANCEMENT OF PLANT BIODIVERSITY

by M. Ayodele, J.d'A. Hughes, N.Q. Ng (project coordinator), S.Y.C. Ng,

Project rationale

The goal of this project is to enhance the availability and efficient utilization of plant genetic resources for increasing food production in a sustainable manner.

Outputs

1.5. Strengthening diagnostic capacities for safe movement of germplasm

On-going and future activities

1.5.1. Development of routine techniques for detection and identification of pathogens in germplasm *by J.d'A.H., M.A.*

a) Use of selective media for the isolation and identification of plant pathogenic bacteria on cassava.

Selective media have been standardized for the isolation and identification of plant pathogenic bacteria (*Xanthomonas manihotis*, *X. cassavae* and *Pseudomonas cassava*) infecting cassava germplasm material intended for international distribution.

For the rapid identification of these bacteria, the cassava leaves, stems and tender shoots were first surface sterilized in 10% aqueous sodium hypochlorite for 3 minutes. Excess sodium hypochlorite was drained and the plant parts plated on nutrient broth yeast agar (NBY) media and the plates incubated at 28°C for 48hrs. The different bacterial colonies obtained were re-plated on fresh NBY to obtain pure cultures. Two pure colony types (yellow and cream) were found to be gram negative. Each colony type were transferred to modified sucrose peptone agar (MSP) selective medium and M71 medium and incubated at 28°C for 24 hours. Colonies of *X. manihotis*, which were cream on NBY medium, remained cream on MSP medium but produced red wine-colored colonies on M71 medium. The second cream colored gram negative bacteria, identified as *P. cassava*, when plated on MSP medium turned the medium yellow, producing fluidal/colloidal colonies while on M71 the bacterium produced colonies with dull purple-red centers surrounded with cream ring. *X. cassavae* gram negative bacteria, which produced yellow colonies on NBY, when cultured on MSP medium produced cream colonies and on M71 medium small, raised, cream-centered colonies were observed after 24 hours incubation.

To test for pathogenicity, tender cassava stems were inoculated with each of the bacterial colonies and incubated at 28°C for 48 hours. It was observed that *X. manihotis* was the only bacterium that caused darkening of the cassava stem tissue with bacterial ooze produced at the point of inoculation. *X. cassavae* produced lesions on leaves and *P. cassava* produced water soaked spots only on leaves without any stem infection occurring. Infection of cassava germplasm by *X. manihotis* is not as common as previously reported while *P. cassava* has been found to be widely spread on several improved cassava clones. More selective media are being developed and standardized for the isolation and identification of other *Xanthomonas* spp., *X. campestris* pathovars, and *Erwinia* spp. which have been isolated from yam tubers and cassava stems.

b) Development of routine techniques for the isolation of pathogens on germplasm

The following protocol has been developed for the detection and identification of plant pathogens in germplasm:

- Surface disinfect seeds / vegetative propagules using 10% aqueous sodium hypochlorite for 3 minutes.
- Rinse the seeds / vegetative propagules in sterile distilled water and blot off excess.
- Plate the material on NBY agar medium and incubate at 28°C for 4 days.
- Examine plate under stereo microscope; make microscope slides of fungal fruiting bodies.
- Examine under compound microscope to identify the fungal fruiting bodies and spores isolated from the mycelium.

- If bacterial colonies were observed around plated infected seed / vegetative propagules, pick up the bacterial smear and streak on fresh NBY plates, incubate at 28°C for 24 hours.
- Purify bacteria by transferring individual colonies onto fresh NBY plates and incubate for another 24 hours.
- Determine whether gram positive or gram negative using KOH.
- Transfer pure cultures onto selective media to identify the bacterium.
- Hypersensitivity and pathogenicity tests can be conducted for confirmation.

c) Developing an agar plate assay for the isolation and identification of *Stenocarpella maydis*

The International Seed Health Initiative (ISHI) Steering Committee, during their meeting in Iowa in 1999, identified some crops and pathogens that should be considered priorities for the standardization of diagnostic protocols. Maize was selected as a priority crop and the pathogen *Stenocarpella maydis*, an important quarantine pest, was considered a priority pathogen for which a protocol for isolation and identification should be developed without delay. Five scientists were nominated from Canada, France, Germany, UK, USA, Zimbabwe and IITA to develop an agar plate assay method that could be used internationally. Diagnostic tests have been hampered by difficulties in inducing this fungus to sporulate in culture. A diagnostic procedure is being developed at IITA. At present the procedure is:

- Seeds are surface-sterilized in 1%, 5% or 10% aqueous sodium hypochlorite for 10, 5, and 3 minutes respectively.
- The seeds are rinsed in sterile distilled water and excess water removed by blotting.
- Five different agar media [nutrient broth yeast agar (NBY); potato dextrose agar (PDA) full strength; PDA 1/4 strength; corn meal agar (CMA), lima bean agar (LBA); malt extract agar (MEA)] are being used for the tests.
- Five seeds are placed on each agar medium with 5 replicates.
- Plates are incubated at 28°C for 7 days.
- Examination for pycnidia production commences after 4 days incubation.
- Pycnidia observed on the 5th day are picked and placed on microscopic slides and examined under the compound microscope for conidia.

d) Rapid serological diagnostics for viruses

Correct diagnosis of the causal agent of a disease is an essential step in plant disease management. Diagnostic tests should ideally be rapid, economic and sufficiently sensitive and specific. Serological assays (immunoassay) rely on the reactions between antibodies and antigens and are used to detect and identify plant pathogens. The enzyme-linked immunosorbent assay (ELISA) is often the method of choice for screening plant samples and have been used extensively in the tropics for diagnosis of virus diseases. While ELISA is economic, the incubation periods mean that the tests usually take two working days to complete. Attempts have been made to shorten the ELISA incubation periods substantially in order to shorten the test period.

For triple antibody-sandwich (TAS-) ELISA, the incubation periods have been shortened considerably as shown below in the ELISA protocol that has been developed for *Rice yellow mottle virus* (RYMV), genus *Sobemovirus*.

In addition to shortening the time required for the ELISA procedure from two working days, to about two hours, to just over one hour, it may be possible to increase sensitivity by varying the buffer concentrations and making modifications to the solid phase of the assays. These are now under investigation.

e) Local lesion indicators for diagnosis of cowpea viruses

The ability to identify viruses is a pre-requisite in understanding their epidemiology and effecting control. Many national programs that do not have appropriate laboratory facilities and that cannot index for the viruses serologically still have a need to identify the viruses in their germplasm.

Many cowpea varieties and breeding lines are susceptible to one or more viruses and may react either by producing symptoms of mosaic, vein-clearing and other systemic symptoms or they may exhibit a hypersensitive reaction where a lesion is formed at the point of inoculation. A selection of cowpea lines and varieties have been screened for a clear hypersensitive reaction to mechanically inoculated viruses in order to develop a set of cowpea differentials for identifying cowpea viruses.

One hundred and ten cowpea breeding lines were mechanically inoculated seven days after planting with five different cowpea viruses. The viruses used were SBMV, *Cowpea mottle virus* (CPMoV), genus (?) *Carmovirus*, *Cowpea mosaic virus* (CPMV), genus *Comovirus*, *Cowpea aphid-borne mosaic virus* (CABMV), genus *Potyvirus* and *Bean common mosaic virus - blackeye strain* (BCMV-BlC), genus *Potyvirus*. The inoculated seedlings were observed for development of lesions on the inoculated leaves.

Two lines were found that developed chlorotic lesions when inoculated with SBMV. Forty-one lines developed pinpoint lesions when inoculated with CPMV, seven developed larger necrotic lesions and one line developed larger chlorotic lesions. Four cowpea lines developed pinpoint local lesions when inoculated with CPMoV, four developed the larger chlorotic lesions and 37 developed necrotic lesions. BCMV-BlC induced lesions on 16 lines. No cowpea line out of the 110 developed lesions after inoculation with CABMV-Monguno, however *Phaseolus vulgaris* is a possible alternative as it developed lesions after inoculation. Selection of the most appropriate lines for the differential series, based on conspicuous symptom expression and consistent results, is in progress.

1.5.2 Detect and/or eliminate virus(es) and other pathogens in germplasm

by M.A., J.d'A.H., S.Y.C.N.

a) A total of 23, 19 field and 5 screenhouse, active growth health inspections were conducted. The field and screenhouse inspections and assessments conducted for the different crops as follows:

Ibadan	*Dioscorea* spp.	338 clones	field
	Vigna unguiculata	174 lines	field
	Zea mays	48 lines	field
	Herbaceous legumes	80 accessions	field
	Manihot esculenta	271 genotypes	screenhouse
	Dioscorea spp.	61 genotypes	screenhouse
Ubiaja	*Dioscorea* spp.	1606 clones	field
	Manihot esculenta	930 families	field
Ikenne	*Dioscorea* spp.	97 clones	field
	V. unguiculata	182 lines	field
Mokwa	*Dioscorea* spp.	212 clones	field
	Glycine max	34 lines	field
Zaria/Kano	*G. max*	81 lines	field
	Herbaceous legumes	14 genotypes	field
Abuja	*Dioscorea* spp.	36 clones	field
	G. max	2 lines	field
Egbema*Z. mays*		36 lines	field

These crop species were multiplied in the field at various locations or in the screen houses to produce seeds and / or vegetative propagules free from diseases in order that the germplasm can be made available to NARS and international collaborators. The various lines/clones/varieties/accessions were assessed visually before flowering / vegetative phase for symptoms of seed-borne viral, bacterial and fungal disease during active growth. Where necessary, samples were taken for laboratory diagnosis.

b) Yams (*Dioscorea* spp.), an important tuber crop in West Africa, have recently been observed to be infected by pathogens causing dry soft rot. This dry soft rot of seed yam tubers has been observed and reported on field harvested and stored tubers in Nigeria and Benin Republic. The disease starts as small brown spot on tubers, extending gradually until the whole tuber rots. The flesh of the tuber turns into a dark brown spongy mass. The pathogens causing dry soft rot present a potential threat to yam production in West Africa. Losses are observed in the field and in storage. Losses due to these pathogens has always been underestimated since rotted tubers which are not even fit for animal feed and thrown away without records on quantity discarded. Three pathogenic bacteria were isolated from 200 clones of seed yams grown in several locations in Benin Republic and Nigeria. These bacterial isolates were subjected to several diagnostic tests for identification. One of the bacteria, identified as *Erwinia carotovora*, produced red colonies on NBY, MSP and M71 selective media while the second bacterium identified as *Pseudomonas* sp. changed the MSP medium to yellow 24 hours after incubation.

The third bacteria, which has not been identified, produced fluorescing and dirty-grayish colonies that diffuse on NBY agar, while on M71 agar medium, large maroon shrunken colonies with irregular edges and surrounded by intense dark/back diffusable pigments were produced. No growth was observed on MSP agar medium. Pathogenicity studies confirmed that the three bacteria were responsible for the dry rot disease of yam tuber.

c) Germplasm health tests, using agar tests, were carried out on 174 cowpea lines, 54 herbaceous legume accessions, 1258 cassava clones, 930 cassava families, 271 cassava plantlets, 53 yam plantlets, 1627 *Dioscorea* clones, 48 maize lines, 64 soybean lines, 5 *Mucuna pruriens* varieties and *Canavalia ensiformis* harvested from 32 farms in 11 locations in the Atacora and Borgou provinces in the Republic of Benin. Those lines observed with viruses were not recommended for international distribution except in cases where the collaborator insisted on obtaining the lines despite the reported presence of pathogens of quarantine importance. Those found with fungal pathogens were recommended for seed treatment prior to distribution. Two hundred lines of soybean germplasm accessions from the Germplasm Resources Unit were grown in the screen house for export certification. Thirty-two lines (11 lines virus infected and 22 loss of viability) were not certified for international distribution.

d) During the year 10 crop genotypes, dried leaf and soil samples were imported by various scientists. The seeds were health tested and interceptions were made on the different crop types. The pathogens isolated from the germplasm were as follows:

Cowpea breeding lines: seed health tests conducted on five imported lines (EAR - 2KVX 745-17, EAR-KVX 745 - 17K; EAR - 2KVX 745 - 11K, EAR 2KVX 745-17P from Burkina Faso and IN 92E - 3 - Niger Republic) were found to be infected with *Macrophomina phaseolina, Fusarium oxysporum, F. equisety, F. solani* and *Colletotrichum truncatum.* It was recommended that these seeds be planted in the screenhouse to avoid spread of the pathogens. The consignments, although accompanied by import permits, were impounded by the PQS for lack of phytosanitary certificates from the exporting country. All efforts to obtain the certificates from the collaborators failed. The consignment was released with the understanding that a follow up will be effected by PQS.

e) Maize: one variety of hybrid corn for trial for ecology adaptation was seed health tested. The pathogens isolated were *Fusarium moniliforme,* causal agent of ear and stalk rot, and *Bipolaris maydis* (blight). The seeds were further planted on the field for symptom observations. During active growth, health inspections were conducted at 3, 4, 6 & 8 weeks intervals. The symptoms observed were yellow chlorotic streaks on the leaves and stunting. The maize was found to be highly susceptible to the maize streak virus. The severe infection prevented the plants from producing cobs.

Three lines of *Z. mays* (Sine 98 98 SYNWECCO; FE 98B EV DT97 STRCO and FE 98 B TZE - WPOP, X 1368 STRCO) imported from Côte d'Ivoire were seed health tested. *Fusarium moniliforme* and *Colletotrichum grammicola,* pathogens of quarantine importance, were isolated from the three lines. *F. moniliforme,* a cosmopolitan fungus and very difficult to eradicate from seed lots, still presents a problem in maize seed certification programs. It is recommended that efforts be made to explore possibilities of obtaining a very effective fungicidal treatment that can control this pathogen that is world wide in distribution.

f) One hundred and twenty-one cassava plantlets intended for international distribution were assessed for presence of cassava mosaic geminiviruses. Of all, 1.6% were found to be positive while the others tested negative by ELISA. Yam, banana and cassava samples were indexed throughout the year for the presence of viruses. Most of the indexing was by ELISA, although for banana viruses, immunosorbent electron microscopy was used for the final diagnosis of *Banana streak virus* (BSV), genus *Badnavirus*.

1.5.3. Study the effects of seedborne pathogens on seed longevity in germplasm collections of cowpea
by M.A., N.Q.N.

During the year, 356 cowpea germplasm accessions that were inspected during active growth were further submitted for testing for the presence of seed-borne pathogens. Seed-borne pathogens isolated were *Colletotrichum lindemuthianum, C. truncatum, Fusarium oxysporum, F. equiseti, F. solani, Cercospora cruenta, Macrophomina phaseolina, Pseudomonas syringae pv phaseolicola, Xanthomonas campestris* pv *phaseoli* and viruses. The seeds were stored and will be re-tested this year to determine the effect of these seed-borne pathogens on the longevity of seed in storage.

1.5.4. Quantify seed transmission of *Cercospora sojina* and seed-borne nature of red leaf blotch in soybean

by M.A.

A total of 52 lines of soybean were inspected during active growth and seed health tested in the laboratory for certification for freedom from seed-borne pathogens. *Cercospora sojina*, causal agent of frogeye disease of soybean, was only isolated from line M-351. Frogeye symptoms were only observed on two plants of soybean line M-351. Out of the 400 seeds plated and incubated, the fungus was observed only on two incubated seeds. No plants with red blotch symptoms caused by *Pyrenochaete sojae* were observed during active growth field inspections. The insignificant occurrence of field symptoms and low percentage infection of these fungi in the field, and on the germplasm submitted for health testing during the year, did not necessitate further tests to be conducted in order to quantify the rate of seed transmission. This activity could be carried out in future if significant occurrences of field symptoms and a high rate of seed infection of germplasm lines meant for export are observed.

1.5.5. Creating databases of pathogens found in germplasm tests and field evaluation of accessions in IITA gene-bank, which link with other germplasm databases at IITA

by M.A., N.Q.N.

Active field inspection and subsequent laboratory health testing of 930 families and 1250 clones of cassava tubers, stems and leaves was conducted during the year. The pathogens isolated were cassava mosaic geminiviruses and *Colletotrichum gloeosporioides*, the causal agent of anthracnose. *Pseudomonas cassavae* was isolated from the clones showing symptoms of bacterial blight. Very few clones were infected with *Xanthomonas manihotis*. Occasionally, *Xanthomonas cassavae* and *Erwinia* sp. were isolated from some clones. Previously, all bacterial blighted leaves have been attributed to *X. manihotis* infection. This is contrary to the results obtained during laboratory diagnosis of 1250 clones of cassava where *P. cassavae* infection was more prevalent than *Xanthomonas* sp. infection. It was also observed that cassava clones grown in screen houses were also infected with *X. manihotis* and *C. gloeosporioides*.

During January to December 1999 41 import permits covering 10 crop genotypes consisting of 789 line/clones/varieties of seeds, one soil and 11 dried leaf samples were obtained from the Nigerian Plant Quarantine Service for use by various scientists for the importation of germplasm material. A total of 808 phytosanitary certificates were also obtained from the Nigerian Plant Quarantine Service to cover 689 genotypes for germplasm exchange and transfer.

The Germplasm Health Unit has established a collection of pure cultures of identified fungus and bacterium species isolated from the IITA's mandate crops multiplied in various locations in Nigeria. The microorganisms are maintained at 4°C. Establishing a system under the Genetic Microbial Resource Database, will provide a framework for the development of centralized IITA long term microbial pathogen storage collection and database. The present collection includes samples from IITA mandate crops and those intercepted from imported germplasm material. Samples held will be released for research to NARS, other CGIAR centers, students and interested scientists. The isolates in the collection will be available for cross referencing and will act as aid to identification.

1.5.6. Introduction and evaluation of unadapted and improved germplasm of IITA's mandate crop

by J.d'A.H., M.A.

Two hundred and five cowpea accessions were screened for resistance to virus infection. The viruses against which the accessions were screened were CABMV, BCMV-BIC and CPMV. 102 lines (50.2%) were resistant to CPMV, 12 lines (5.9%) to BCMV-BIC and 151 lines (75.5%) to CABMV. Segregation was observed among the lines with the highest rate of segregation occurring in response to BCMV-BIC (44.3%) and lowest (22.5%) with CABMV while segregation of cowpeas inoculated with CPMV was 26.1%.

Hypersensitivity reactions were observed in the breeders' lines. 46.3% of the lines reacted with hypersensitivity and production of lesions at the point of inoculation to CPMV, out of which 6.4 % showed chlorotic lesions only and 3.4% had both necrotic and chlorotic lesions. The rate of hypersensitive reaction to BCMV-BIC was 35.5% and none to CABMV.

These breeders' lines were infected singly with the above-mentioned viruses and were rated for symptoms after two weeks. Ten cowpea accessions (4.9%) were resistant to the three viruses, 9 lines (4.4%) were resistant to both CPMV and BCMV-BIC, 79 lines (39.5%) to CPMV and CABMV and 10 lines (4.9%) to CABMV and BCMV-BIC.

1.5.7. Development of monoclonal antibodies and molecular diagnostics for geminiviruses, yam and *Musa* viruses

by J.d'A.H. - in collaboration with G.I. Atiri, L.N. Dongo, S Shoyinka, A. Oladiran, B. Odu, O. Okorie, A. Ala

Monoclonal antibody production against plant viruses infecting IITA's mandate crops is in progress with the aim of providing a continuous source of antibodies from the 'immortal' hybridoma cell lines. The monoclonal antibodies will be used for diagnostics within IITA, for distribution to NARS collaborators and researchers from advanced laboratories.

Monoclonal antibodies have been raised against *Dioscorea mottle virus* (DMoV), genus (?) *Carmovirus*. This virus, originally designated yam virus 121, was isolated from a leaf of *D. alata*, showing symptoms of mild chlorosis, collected from Nassarawa State. The virus was multiplied in, and purified from, *Vigna unguiculata*. Only a single hybridoma cell line (DMoV S121) was found to produce antibodies specific to the virus. The antibodies were able to detect DMoV in sap of infected *V. unguiculata* using triple antibody-sandwich (TAS-) enzyme-linked immunosorbent assay (ELISA) using a polyclonal trapping antiserum raised in rabbits.

Four other viruses are being used to prepare monoclonal antibodies: Banana die-back virus (BDBV), genus (?) Nepovirus, African cassava mosaic virus (ACMV), genus Bigeminivirus, Maize streak virus (MSV), genus Monogeminivirus and Dioscorea alata virus (DaBV), genus Badnavirus. Preliminary attempts to raise monoclonal antibodies against Dioscorea alata virus (DaV), genus Potyvirus failed to produce any antibody-secreting lines specific to the virus. Production will again be attempted in 2000. BDBV was isolated from banana (cv. Valery) by mechanical inoculation to *Nicotiana occidentalis* from which it was purified for antibody production. An attempt was made to produce monoclonal antibodies but the fusion product was not specific to the virus. A second attempt will be made early in 2000. The other viruses have been purified from their hosts and cryo-preserved for injection into mice early in 2000. ACMV was multiplied and purified from *N. benthamiana*, MSV was purified from Zea mays and DaBV was purified from naturally-infected *D. alata*.

1.5.8. Maintenance and rejuvenation of available hybridoma cell lines

by J.d'A.H.

Eleven cell lines are maintained in liquid nitrogen in a cryo-storage vessel, frozen down at their log phase of growth. One cell line (YMV-24) secretes antibodies against *Yam mosaic virus* (YMV), genus *Potyvirus* and two (BSV F9 and BSV D9) secrete antibodies against *Banana streak virus* (BSV), genus *Badnavirus*. The three cell lines were rejuvenated during the year and again cryo-preserved.

Replacement cell lines for the detection of cassava mosaic bigeminiviruses were obtained from the Scottish Crops Research Institute (SCRI), UK. These were rejuvenated at IITA and antibodies produced before the cells were frozen for long term storage. The six cell lines were:

- SCRI 17 (detects *African cassava mosaic virus* (ACMV), genus *Bigeminivirus/East African cassava mosaic virus* (EACMV), genus *Bigeminivirus*)
- SCRI 20 (detects ACMV/EACMV)
- SCRI 23 (detects ACMV/EACMV)
- SCRI 33 (detects EACMV)
- SCRI 58 (detects *Ugandan cassava mosaic virus* (UCMV), genus *Bigeminivirus*)
- SCRI 60 (detects *Indian cassava mosaic virus* (ICMV), genus *Bigeminivirus*).

Two myeloma cell lines, Fox NY and P3-X63-Ag8.653 (from the International Livestock Research Institute (ILRI), Nairobi), are also cryo-preserved and are routinely used for hybridoma production. The viability of P3-X63-Ag8.653 is higher than Fox NY and is therefore preferred for production of antibody-secreting hybridoma cell lines.

1.5.9. Refinement of diagnostic protocols for banana streak virus

by J.d'A.H. – in collaboration with H.D. Mignouna, A.O. Uwaifo, B. Agindotan

Routine diagnostic protocols and procedures for BSV have only been modified slightly in 1999. The earlier procedure used by IITA involved 'hardening' the tissue culture plants, after potting, in the

screenhouse for about eight weeks before the plants were transferred to a controlled temperature room at 22-24°C. After this the plants were indexed twice over a period of six months. The indexing was by ELISA using the rabbit polyclonal antibody cocktail (PMX) developed by at the University of Minnesota or using a chicken polyclonal antibody developed at IITA. Additionally, immunosorbent electron microscopy (ISEM) using the PMX cocktail antiserum was used as a final confirmatory step. The modified procedure no longer utilizes the controlled-temperature room, as it is likely that the stress of the transition between the screenhouse ambient temperature and that of the controlled-temperature room may be sufficient to induce transcription and production of episomal virus from the integrated sequences. The plants are now tested over a six-month period while being grown in the screenhouse in ambient conditions. Testing is initially by TAS-ELISA using the monoclonal antibodies to BSV raised at IITA. Although the strain specificity of the antibodies is not known and the test is not fully validated throughout the countries of West Africa, the TAS-ELISA is useful as a preliminary screening method. Subsequent screening of putative virus-'free' germplasm is by further ELISA using the chicken polyclonal antibody and finally by ISEM using the PMX antiserum.

1.5.10. Production and distribution of antibodies to NARS

by J.d'A.H. – in collaboration with H.D. Mignouna, G. Pietersen, J. Thomas, E. Frison, S.A. Shoyinka, O. Okorie, A. Ala, G.I. Atiri, L. Dongo, B. Agindotan.

A rabbit polyclonal antiserum is being raised against a virus isolated from *Centrosema pubescens* tentatively named *Centrosema mosaic virus* (CenMoV), genus (?) *Potyvirus*. The virus was purified from mechanically inoculated *G. max* cv Samsoy-2. The virus is serologically related to *Bean common mosaic virus - blackeye strain* (BCMV-BlC), genus *Potyvirus* but not to *Cowpea aphid-borne mosaic virus* (CABMV), genus *Potyvirus*. The antibodies available to BCMV-BlC can be used to detect CenMoV in the herbaceous indicator plant *G. max* cv Samsoy-2, but not in *C. pubescens*.

A polyclonal antiserum has been raised against *Dioscorea alata bacilliform virus* (DaBV), genus *Badnavirus*. The virus was purified from *D. alata*, purified and the antiserum raised in mice. The first and second test bleeds were taken four and seven weeks after the first injection. The first test bleed had a titer of only 1/64 (determined by PAS-ELISA) while the second bleed had a titer of 1/1024.

Polyclonal antibodies were raised in rabbits against *Dioscorea alata virus* (DaV), genus *Potyvirus*. A test bleed, eight days after the third booster injection, was taken from the rabbit and was found by PAS-ELISA to have a titer of 1/1000. This dilution was also used as the working dilution.

Three partially characterized virus strains were isolated from *D. alata* in Nigeria. Two test bleeds were collected from the injected rabbit eight days after the first and third injections of *Dioscorea mottle virus - mild mottle strain* (DMoV-MM), genus (?) *Carmovirus*. DMoV-MM was found to be highly antigenic. A test bleed taken after the first injection had a titer of 1/6024, while the one taken after six weeks had a titer of 1/12,048. The titer of the antibodies raised against DMoV-MC (mild chlorosis strain) was also high (1/8000) after six weeks. The rabbit injected with DMoV-N (necrosis strain) developed an antibody titer of only 1/1000 after six weeks.

An antiserum was raised against *Tobacco mosaic virus* (TMV), genus *Tobamovirus* isolated from *Mucuna* sp. grown at IITA as a cover crop. This antiserum, with a titer of 1/8000 is useful for detecting TMV in other crop species *e.g.* pepper (*Capsicum annuum*).

Polyclonal antibodies have been raised in rabbits and mice against *Banana die-back virus* (BDBV), genus (?) *Nepovirus*. Although a mouse polyclonal antiserum (antiserum BDBV M1) was raised initially, this had been prepared using a virus preparation contaminated with host plant antigens. A second mouse polyclonal (antiserum BDBV M2) was prepared by intra-peritoneal injection of purified BDBV into a Balb-C mouse as the initial stage of the production of the monoclonal antibodies. This mouse polyclonal antiserum had a titer of 1:8000. Intra-muscular injections for the production of BDBV rabbit polyclonal antiserum have been completed and the final bleed will be taken at the end of January 2000.

A new polyclonal antiserum has been raised in rabbits against *African cassava mosaic virus* (ACMV), genus *Bigeminivirus*. This antibody will be used as part of the diagnostic 'kits' to be supplied to NARS with the monoclonal antibodies produced from the monoclonal cell lines supplied by the Scottish Crops Research Institute (SCRI), UK. A new polyclonal antiserum has also been raised against *Yam mosaic virus* (YMV), genus *Potyvirus*. It has a titer of 1:64,000 and can be used at a working dilution of 1:10,000.

Monoclonal antibodies against cassava mosaic bigeminiviruses were produced from the SCRI hybridoma cell lines. The antibodies all reacf well in TAS-ELISA at a working dilution of 1/1000.

The stocks available at the end of 1999 are SCRI 17 (80 ml), SCRI 20 (50 ml), SCRI 23 (50 ml), SCRI 33 (50 ml), SCRI 58 (40 ml) and SCRI 60 (40 ml).

1.5.11. Training in germplasm management, disease diagnostics and tissue culture
by J.d'A.H., M.A.

A training workshop on seed health testing methods for the isolation and identification of pathogens of quarantine importance was organized for seven Quarantine Officers from the Republic of Benin at the Germplasm Health Unit in Ibadan. The officers were taught how to plate using the agar assay and blotter methods and to examine incubated seeds/vegetative propagules under the stereo microscope. They were also taught the preparation of slide for spore identification under the compound microscope. The officers were also exposed to the diversity of virus symptoms that may occur in IITA's mandate crops.

Completed studies

Journal articles and book chapters

Hughes, J.d'A. & S.A. Tarawali, 1999. Viruses of herbaceous legumes in the moist savannah of West Africa. **Tropical Science** ***39: 70-76.***

Schilder, A.M.C., D.A. Florini, D.K. Berner, J.d'A. Hughes, S.Y.C. Ng, N.Q. Ng, G Thottappilly & T.W. Haug, 1999. **Containment facilities and safeguards at the International Institute of Tropical Agriculture.** ***In: R.P. Kahn & S.B. Mathur (eds.) Exclusion of pests and pathogens: Containment facilities and safeguards.. APS Press.***

Conference papers, workshop proceedings, abstracts, newsletters

Moody, J.O, V.A. Roberts & J.d'A. Hughes,1999. Antiviral activities of selected medicinal plants II. Effect of extractives of **Diospyros bateri, Diospyros monbutensis** ***and*** **Sphencentrum jollyanum** ***on cowpea mosaic viruses. Proceedings of the 1st International Workshop on Herbal Medicinal Products, University of Ibadan, November 22-24, 1998.***

Plant protection related activities of Project 2

IMPROVING PLANTAIN- AND BANANA-BASED SYSTEMS

by G. Blomme, J. Crouch, G. Dahal, C. Dochez, T. Dubois, S. Ferris, C. Gold, K. Green, J. Hartman, S. Hauser, J. d'A. Hughes, B. Niere, C. Nolte, S. Okech, M. Pillay, P. Ragama, P.R.. Speijer, H. Talwana, A. Tenkouano, M. Tshiunza, R. Vermeulen D. Vuylsteke (project coordinator)

assisted by T.A. Adeniji, S. Adjei-Nsiah, R. Apanisile, B. Dumpe, B. Egwuchukwu, J. Ikea, C. Kajumba, H. Kisingo, G. Kigezi, D. Makumbi, P. Nemeye, G. Night J. Okoro, L. Oragwa, F. Ssango, R. Ssendege, D. Talengera,

Project rationale

The highland cooking banana is the key staple for the Great Lakes region of Eastern Africa, while plantain is an important food crop in much of Central and Western Africa. An estimated 70 million people receive more than 10% of their dietary carbohydrates from banana or plantain. As perennial crops with the capacity to reproduce vegetatively, banana plots may remain in production for 30 years or more without any need for land preparation. Stable banana production can thus greatly contribute to soil conservation and sustainable systems of agriculture. Unfortunately, serious yield declines, attributable to soil exhaustion, worsening banana weevil, nematode and leaf disease problems, have been observed in recent years. Moreover, longevity of plantain stands in parts of West Africa has been reduced to 2 to 3 years, while in East Africa highland banana longevity has been reduced to less than 5 years. Therefore, the objective of this project is to determine banana pest and disease distribution and status, contribute to the understanding of the biology of these pests and to develop and test intervention strategies for their control.

Important pests and diseases of banana and plantain in Africa include banana weevil *Cosmopolites sordidus* Germar (Col., Curculionidae), nematodes *Pratylenchus goodeyi* Sher and Allen, *Helicotylenchus multicinctus* (Cobb) Golden and *Radopholus similis* (Cobb) Thorne, black sigatoka (*Mycosphaerella fijiensis*), Fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*, banana streak virus and banana bunchy top disease.

Banana weevil and nematodes are soil-borne pests which affect the root system and rhizome. Their composite damage weakens plant anchorage and interferes with nutrient and water uptake. Weevil and nematode attack may kill young plants, cause snapping and toppling, delay maturation, reduce bunch size and decrease plantation life. They may also provide entry points for root and rhizome pathogens and reduce tolerance to foliar diseases and other stresses. Damage increases over time such that effects are more pronounced in ratoon crops. Attack on mother plants may also affect the vigor and productivity of followers. In on-station trials, yield losses to weevil and nematodes reached 30-50% An integrated strategy, drawing on cultural and biological controls and cultivar selection, appears to be the most suitable approach in controlling these pests.

Outputs

2.1. Establishment of geo-referenced data bases

Background

Weevils, nematodes and pathogens are pervasive among highland banana and plantain systems: application of GIS techniques across regions should provide insight into pest and disease distribution and status. This activity aimed, therefore, at developing maps of pests and disease constraints, determination of pest status and providing base line data for control strategies and impact monitoring. Intensive collaboration with NARS and training of its staff will strengthen their capability.

On-going and future activities

2.1.1. Diagnostic surveys of pest and disease constraints to highland banana production in Uganda.

by C.S.G., S.H.O., P.R.. - In collaboration with J. Ssennyonga, F. Bagamba, A. Katwijukye, J. Ngoya, W. Tinzaara, C. Nankinga, W.K. Tushemereirwe*

Data analysis of country-wide surveys on banana production constraints was largely achieved through the completion of an M.Sc. thesis. Statistical analyses were carried out on the survey data of 120 banana farms from 24 representative banana growing sites in Uganda. In total six visits were made to

each site to collect data on pest incidence assessment, damage due to weevils, nematodes and leaf spot. In additional, data on banana varieties, genome group and genome sub-group, management levels; monthly rainfall, altitude, soil parameters, e.g., pH, N, K, Na, Mg, sand, clay and silt were collected.

Mixed model procedures were employed to examine the extent of pests and diseases damage on banana plants, with environmental factors and management practices as co-variates or factors. Restricted maximum likelihood analyses took site and farm effects as random effects, while environmental factors and management practices were considered as fixed effects.

Using both principal component and cluster analyses, the results show that weevil infestation was inversely related to elevation. There was also an inverse relationship between weevil damage and rainfall levels the month prior to sampling, although the nature of this relationship varied among cultivars. Although there was some concern over the precision of local soil laboratories, the data suggest that weevil damage was positively related to calcium content in the soil and negatively related to soil sodium and nitrogen.

Multivariate analyses of variance (MANOVA) showed that elevation, rainfall and cultivar type were major factors in weevil infestation. Correspondence analysis showed that the exotic clones Kisubi (AB), Kayinja (ABB) and Ndiizi (AB) were highly resistant to weevil and leaf spot infestation while Salalugazi, Kibuzi and Nakyetengu (all AAA-EA) were most susceptible to weevil and leaf spot attack. The variable "total weevil cross section damage" (averaging damage to the central cylinder and outer cortex for two cross sections) could well be used as a principal measure of weevil damage infestation.

The cultivars Nakitembe, Namwezi and Esenyi (all AAA-EA) were susceptible to root knot nematode while Salalugazi (AAA-EA) and Ndiizi (AB) were resistant to the attack. Nematode activity increased with an increases in elevation, total rainfall and rainfall in the month prior to sampling. Damage varied across cultivars and was shown to decrease with soil pH and potassium content of the soil.

Current survey activities for banana pests and diseases in Uganda are restricted to collection of georeferenced baseline data at benchmark sites. This includes an initial survey at the onset of activities in each site and baseline data for on-farm activities. Supplementary data is taken through continued on-farm assessment to establish weevil status for on-farm research. For example, an initial survey was taken in Ntungamo district in 1996. A second survey was undertaken in 1998/1999 to determine weevil levels on farms to be used in sanitation studies. Similarly, a baseline survey was taken in Masaka district in 1998, while additional farms were sampled in 1999 for treatment allocation in pheromone trials.

2.1.2. Participatory pest assessment in benchmark study sites in Uganda.

by C.S.G., S.H.O., P.R.S. - in collaboration with B. McIntyre, H. Ssali, J. Ssennyonga, W. Tushemereirwe, W. Tinzaara, C. Nankinga

In collaboration with the Uganda National Banana Research Program (NBRP), 4 benchmark sites have been selected for in-depth studies and farmer participatory research. Sites include Bushenyi/Mbarara (area of commercial banana production and high, relatively stable yields yet first signs of decline); Ntungamo (an area of land use intensification, declining soil fertility, increasing pest problems, modest yields and early stages yield decline); Masaka (area of expanding commercial banana production and early to intermediate stages of yield decline); and Luwero (traditional banana growing area with advanced yield decline resulting in shifts away from cooking banana). The Ntungamo locale also served as a satellite site for the first two phases of the African Highland Initiative (1995-1998).

Research in Ntungamo was initiated in late 1995, in Masaka in mid-1997, in Luwero in early 1998, while work in Bushenyi/Mbarara will now commence in late 2000. Site protocols include a participatory rural appraisal, baseline socio-economic and pest surveys, and on-farm and farmer participatory research.

On-going research on banana weevil control is addressing the use of crop sanitation (i.e. management of residues) in Ntungamo district Research to develop economic delivery systems for entomopathogens and the use of semiochemical enhanced trapping techniques to increase trap efficiency and reduce labor investment will be undertaken in Masaka and Luwero districts.

2.2. *Knowledge of pests and diseases enhanced*

Background

Awareness of pest biology or disease epidemiology provides a critical foundation for understanding pest/disease status in different environments and for developing control strategies. For example, it

remains unclear what factors govern banana weevil distribution and why some farms are more subject to attack than others. Similarly, the weevil's population dynamics are poorly understood and information is wanting on their impact on host plant growth and yield formation.

On-going and future activities

2.2.1. Identification and characterization of viruses

by J.d'A.H. - in collaboration with J.E. Thomas, G. Pietersen, E. Frison

Leaf samples from plants in the IITA *Musa* field plot where *Banana die-back virus* (BDBV), genus (?) *Nepovirus* was found were tested by protein A sandwich (PAS) enzyme-linked immunosorbent assay (ELISA) using mouse polyclonal antiserum (antiserum BDBV M1) raised against BDBV. Both plants that were showing the typical symptoms of stunting and die-back as well as apparently healthy plants were tested. The PAS-ELISA revealed much non-specific reaction to host plant proteins using antiserum BDBV M1. In spite of re-testing on several occasions over a two-month period, only three plants were confirmed to be positive using a cut-off of x2 the OD_{405nm} of the healthy control. These were plants that showed typical symptoms of stunting and die-back. The results were confirmed by immunosorbent electron microscopy; virus particles were observed. The absence of *Cucumber mosaic virus* (CMV), genus *Cucumovirus* was confirmed. The other plants that were 'borderline positive' for BDBV also exhibited symptoms but these were less severe.

One plant infected with BDBV is being grown in the screenhouse. The plant was also infected with *Banana streak virus* (BSV), genus *Badnavirus*. The symptoms are not however those normally associated with BSV.

A range of herbaceous indicator plants were inoculated with purified or partially-purified virus preparations diluted with inoculation buffer (0.1M phosphate buffer containing 0.01M ethylene diaminetetraacetic acid and 0.01M L-cysteine pH7.0 or pH7.7). Carborundum was first dusted on the leaves as an abrasive. The results are shown in Table 1.

Although a mouse polyclonal antiserum (antiserum BDBV M1) was produced, this had been prepared using a virus preparation contaminated with host plant antigens. A second mouse polyclonal (antiserum BDBV M2) was prepared by intra-peritoneal injection of purified BDBV into a Balb-C mouse as the initial stage of the production of the monoclonal antibodies. This mouse polyclonal antiserum had a titer of 1:4000. Intra-muscular injections for the production of BDBV rabbit polyclonal antiserum have been completed and the final bleed will be taken at the end of January 2000. Monoclonal antibody production is in progress using Balb-C mice. The hybridoma cell lines will be ready for screening for production of BDBV-specific antibodies by the end of March 2000.

2.2.2. BSV epidemiology and genotype response

by J.d'A.H.

BSV epidemiology is little understood. Except for a single published report on the transmission of the virus by *Planococcus citri*, there is only circumstantial evidence on possible spread of the virus. Recent thought has been that the virus is transmitted largely through the dissemination of infected tissue culture plantlets or suckers.

To test the hypothesis that the virus does not spread readily in the field, a plot of 54 Cavendish cv Williams was planted adjacent to BSV-infected plots at IITA, Ibadan. Cavendish cv Williams has been nominated as one of the few banana or plantain cultivars that does not appear to develop BSV infection from transcription and recombination of integrated BSV-like sequences. The plants that were put into the field plot were multiplied through tissue culture and set of the same plants was grown in the insect-proof screenhouse as controls.

Indexing was initially done on a monthly basis on both the field plants and the plants kept in the screenhouse. The indexing was by immunosorbent electron microscopy (ISEM). All plants tested negative before they were planted in the field. After one month, 44% of the plants tested positive by ISEM, after two months 50% while after six months, 70% of the plants tested positive for BSV. The 10 plants grown in the screenhouse tested negative for BSV by ISEM at each monthly indexing over six months.

Table 1. Host range of banana die-back virus after mechanical inoculation of herbaceous indicator plants with purified or partially purified virus.

Herbaceous indicator plant species	Symptoms reported from work done January to May 1999	Results after immunosorbent electron microscopy using antiserum raised against banana die-back virus (January to May 1999)	Symptoms recorded June to December 1999	Results after immunosorbent electron microscopy using antiserum raised against banana die-back virus (June to December 1999)	Tested by protein A-sandwich enzyme-linked immuno-sorbent assay
Capsella bursa-pastoris	Stunting	No virus particles seen	Not tested	Not tested	Not tested
Capsicum annuum	None	No virus particles seen	None	No virus particles seen	Not tested
Chenopodium					
amaranticolor	Not tested	Not tested	None	Not tested	Negative
C. quinoa	Curled, distorted leaves	No virus particles seen	None	No virus particles seen	Negative
Datura stramonium	None	No virus particles seen	None	No virus particles seen	Not tested
Desmodium heterocarpum	None	No virus particles seen	None	No virus particles seen	Not tested
D. heterophyllum	Chlorotic spots	No virus particles seen	Not tested	Not tested	Not tested
Dolichos trifolium	None	Not tested	None	Not tested	Not tested
Glycine max	None	Virus particles observed	None	Virus particles observed	Not tested
Ipomoea coccinea	Chlorosis	No virus particles seen	None	No virus particles seen	Not tested
I. trichocarpa	None	No virus particles seen	None	No virus particles seen	Not tested
Nicanda physais	None	No virus particles seen	None	No virus particles seen	Not tested
Nicotiana affinis	None	No virus particles seen	Not tested	Not tested	Not tested
N. benthamiana	Stunting	Virus particles observed	None	No virus particles seen	Negative
N. glutinosa	None	Not tested	None	No virus particles seen	Not tested
N. occidentalis	None	No virus particles seen	None	Virus particles observed	Positive
N. rustica	None	No virus particles seen	None	No virus particles seen	Negative
N. tabacum	None	Not tested	None	No virus particles seen	Negative
Petunia compacta	None	Not tested	None	Not tested	Not tested
Physalis edulis	None	Not tested	None	Not tested	Not tested
Vigna unguiculata TVu 2657	Not tested	Not tested	None	Not tested	Negative
V. unguiculata 84S-2114	Not tested	Not tested	None	Not tested	Negative
V. unguiculata IT82E-32	Not tested	Not tested	None	Not tested	Negative
V. unguiculata IT82E-10	Not tested	Not tested	None	Not tested	Negative
V. unguiculata VITA7	Not tested	Not tested	None	Not tested	Negative
V. unguiculata Ife Brown	Not tested	Not tested	None	Not tested	Negative

2.2.3. Banana weevil life table studies

by C.S.G., K.G. - in collaboration with P. Nemeye, H. Sintim, K. Afreh-Nuamah*

The banana weevil lives up to 4 years and most commonly lays 1-3 eggs/week in the laboratory. Yet population buildup is slow, which indicates shorter adult life spans, reduced oviposition in the field, high mortality of immature stages and/or high emigration rates. Life table work to provide insight into mortality rates of different stages can provide a foundation for any pest management strategies.

Density dependent effects on oviposition and larval survivorship are being studied in laboratory experiments which began in 1998 and will continue into 2000. Oviposition levels were assessed for weevil densities of 5, 10, 20 and 40 females (with equal numbers of males) placed with banana corms in ventilated plastic containers. The results consistently showed a weak density dependent response. Fewer eggs were produced per female at higher weevil densities, but substantially more eggs were produced by larger groups of weevils. Changing corms daily did not increase egg numbers, suggesting

that any density dependent effect on female oviposition rates was affected by adult rather than egg density.

In a second series of experiments, eggs or first instar larvae are being inserted into rhizomes at different densities. The number and stages of larvae were assessed by dissecting the rhizomes 30 days later. Preliminary results have been inconsistent with lower larval survivorship at higher densities in one experiment but not in two subsequent trials.

On-farm studies showed that weevil numbers and weevil damage increased in the first and second ratoon compared with the plant crop, indicating that previous trial and survey results based largely on sampling of weevil numbers and damage on the plant crop, should be interpreted with care. Results from pot experiments indicated that plants under physiological stress were more susceptible to weevil attack than healthy plants. For example, plants that were exposed to a drought regime and artificially infested with weevils, showed higher damage levels than well-watered plants. A separate pot trial showed that there was a significant effect of larval numbers in planting material on the subsequent adult population and corm damage. It is suggested that in Ghana, weevil damage remains low because the plantain cropping cycle is short (<3 years), there is insufficient time for weevil populations to build-up within a field, and therefore egg and larval infestation levels in suckers transferred to new fields are also low. It is predicted that as the cropping cycle is extended, through the introduction of techniques for nematode management, then weevil populations and associated damage may subsequently increase.

2.2.4. Weevil damage mechanisms

by C.S.G

The banana weevil has been reported to kill young suckers, kill roots or interfere with root initiation, reduce nutrient uptake and transport, cause premature leaf senescence, reduce plant size, vigor and tolerance of other stresses, retard maturation rates, increase susceptibility to other pests and diseases, cause toppling and snapping, reduce bunch weights, and affect the number and vigor of followers. However, until recently there has been few data on levels of yield loss attributable to banana weevil and virtually no data on plant physiological response to weevil attack.

Earlier studies at IITA showed that weevil attack can kill up to 40% of planted suckers in a newly established stand placed in a previously infested field. In addition, the weevils killed a similar proportion of replants. In uninfested fields, weevil damage increased from 4% (to the central cylinder) in the plant crop to 17% in the third ratoon, while yield loss increased from 5 to 44%.

Further analysis suggested that damage to the central cylinder had the greatest effect on plant growth and yield in the plant crop, while damage to the central cylinder alone had the greatest influence on yield in ratoon crops. Peripheral damage indicators (e.g. PCI) were poorer indicators of weevil effects on yield loss.

Detailed study on the physiological mechanisms of yield loss to banana weevil will be studied through a Ph.D. dissertation with research activities commencing in 2001.

2.2.5. Weevil behavioral studies

by C.S.G. - in collaboration with G. Kagezi

Information on the distribution and activity patterns of banana weevils are critical to the design and implementation of intervention strategies (e.g. pseudostem trapping, pheromone and kairomone trapping, application of biopesticides, intercropping) which target the adult stage. Previous work had shown that nearly all weevils were closely associated with banana mats or residues. For example, 40% were found in the plant (e.g. leaf sheaths, old galleries), 24% in the soil at the base of the mat and 29% in or under cut residues.

Further studies were undertaken to assess the extent which banana weevils move within the plantation. A total of 2000 weevils were marked individually and released at the base of banana mats into two adjacent plots (one mulched, one unmulched) of 1000 plants with a release rate of 5 males and 5 females per plot. Prior to release, the baseline weevil population was 4-5 weevils per mat. Traps were placed every 2-3 weeks (for one year) and observed for 4 days. Captured (marked) weevils were identified and released. Determinations were made for the distance the weevil had moved from its last observation and from its original release point.

This study showed that many weevils were sedentary for extended periods of time and that weevil movement was greater in the mulched than in the unmulched system (Table 2). For example, 10 weeks after weevil release, 17% of the weevils in the mulched plot and 36% of the weevils in the unmulched

plot were captured at the original point of release. In the 2 to 3 weeks trapping intervals, 31% of the weevils moved more than 10 m in the mulched plot, while only 11% moved more than 10 m in the unmulched plot.

Table 2. Number of weevils recaptured and the total distances they had moved from their original release points in mulched and unmulched plots at the Kawanda Research Station, July 1998 to July 1999

a. Mulched plot

	Total distance moved (m)					
Days after release	0	1 - 10	11 - 20	21 - 30	31 - 40	> 40
1 - 30	41	40	12	5	3	5
31 - 60	11	30	10	6	4	6
61 - 90	16	37	33	20	14	16
91 - 120	10	19	21	10	8	14
121 - 150	3	10	16	6	9	12
151 - 180	4	29	24	19	15	41
181 - 210	2	5	10	3	2	20
211 - 240	1	7	9	6	15	20
241 - 270	1	9	4	7	5	14
271 - 300	0	8	3	3	6	18
> 300	3	9	17	16	14	32
Total	92	203	159	101	95	198

b. Unmulched plots

	Total distance moved (m)					
Days after release	0	1 - 10	11 - 20	21 - 30	31 - 40	> 40
1 - 30	117	77	20	4	4	0
31 - 60	41	46	31	8	5	3
61 - 90	14	19	18	7	5	5
91 - 120	25	24	30	12	7	5
121 - 150	5	15	13	4	6	4
151 - 180	3	12	12	8	2	7
181 - 210	4	16	14	8	6	3
211 - 240	0	6	4	3	1	2
241 - 270	1	8	14	4	5	4
271 - 300	1	2	4	0	0	1
> 300	0	4	9	5	3	7
Total	211	229	169	63	44	41

2.2.6. Weevil biotyping studies

by C.S.G. - in collaboration with V. Ochieng, E. Osir

Biotyping of banana weevil is critical for understanding variation in pest populations across geographical areas and in different ecological zones. This would provide insight into variability in research results from different locations and will be important in understanding differential response to possible weevil controls (natural enemies, host plant resistance). For example, the possibility of distinct banana weevil biotypes has been suggested by differential performance of entomopathogenic nematode strains in killing weevils in Tonga and Australia.

A collaborative project on banana weevil biotypes was initiated with ICIPE in 1997 and will continue through 2000. Genetic diversity of banana weevils from countries in Africa, Asia and Latin America were compared using random amplified polymorphic DNA polymerase chain reaction (RAPD-PCR) using five universal primers. The data showed that considerable variation exists within and between banana weevil populations from different parts of the world

Additional material continues to be collected for comparisons with current focus on diversity across sites within the East Africa Great Lakes Region.

2.2.7. Effect of soil conservation bands, farm yard manure and grass mulch on plant growth and vigor, weevil density and damage

by S.H.O., C.S.G. - in collaboration with H. Ssali

The study investigated the possibility of reversing the decline in production of weevil-infested old plantations of highland cooking banana through the implementation of cultural soil fertility management practices (soil and water conservation contour bunds, mulch and farm yard manure) in Ntungamo district, Uganda. The plantations were over 30 years old and the farmers claimed that their yields were declining due to weevil pressure and declining soil fertility. The study was designed to test whether soil fertility management practices could improve plant vigor and, at the same time, the plant's ability to withstand weevil pest pressure. Observations were made from three treatments: (a) control, (b) soil conservation bunds only and (c) soil conservation bunds plus grass mulch or farm yard manure on plots (12m X 36m each) in the farmers fields. Twenty one farmers participated in the study and were responsible for all stand management including implementation of treatments.

In this trial, weevil populations and damage levels were not influenced by soil conservation practices and soil inputs. The data showed that suckers grew faster, bunches matured earlier and yield was higher in plots with bunds plus mulch. Yield advantages were related to the number of bunches harvested per unit time rather than to differences in bunch weights. These observations suggest that low banana productivity in the study site can be reversed by a combination of construction of soil and water conservation contour bands on the hill slops plus mulch application and crop sanitation.

2.2.8. Responses of banana weevil to K-Mg balances

by S.H.O., C.S.G. - in collaboration with B. McIntyre

Researchers in Tanzania have suggested that banana weevils are influenced by K and Mg balances which purportedly affects plant defense. This hypothesis was tested on a farmers field in Ntungamo.

Experimental plots (15 x 15m) were marked out in a 10 year old farmer's field in February 1997. Treatments included four different levels of NPK + Mg as (1) 100-25-0 + 0; (2) 100-25-100 + 0; (3) 100-25-100 +25; (4) 100-25-100 + 50. The plants were more vigorous in plots receiving higher doses of Mg. Weevil damage was not influenced by treatments. However, damage levels, in all treatments, was very low and it is unclear if a treatment effect might have been manifest under higher levels of weevil pressure.

2.2.9. Response of banana weevil and nematodes to bananas fertilized with NPK

by C.S.G. - in collaboration with B. McIntyre, I. Kashaija

NPK amendments were planted in established farmer's fields in 3 sites in Uganda to see if plantation productivity could be restored and to see the effects on weevils and nematodes. In Rubaale, bananas showed a strong response to fertilizers, while there was little or no effect of fertilizers on plant growth and yield at Kabulasoke and Kalegebanda. Banana weevils and nematodes were serious problems at Kabulasoke, while nematodes were also important constraints in Kalegebanda. Fertilizer treatments had no impact on damage levels of either weevil or nematodes. These pests attack the root and vascular system and most likely inhibited the plant's ability to take advantage of nutrient applications. In contrast, weevil and nematode pressure were each negligible in Rubaale throughout the trial. This suggests that weevils and nematodes need to be controlled before plants can take full advantage of any nutrient amendments.

2.2.10. Nematode-root system interactions - Ghana

by K.G., P.R.S. - in collaboration with C. Brentu, B. Hemeng*

Diagnostic surveys in Ghana showed that the most widespread nematode species on plantain were *P. coffeae*, *Meloidogyne* spp. and *H. multicinctus*, whereas the distribution of *R. similis* was limited to the Western Region. A series of trials were conducted at ARS Kade, to determine the effect of the three most widespread species on plantain root health (damage type, position and severity), to provide insight into damage mechanisms and niche displacement. For each trial, split corms from hot water-treated suckers were placed in sterilized sawdust contained in wooden trays. Three newly emerging roots from each sucker were inoculated with nematodes that were kept in place using plastic cups containing

sterilized soil. Separate trials were conducted to determine the effects of individual species, species combinations, site of inoculation and cultivar on root damage.

M. javanica multiplied slowly within plantain roots and root damage was negligible. In addition, the species was out-competed when in combination with *H. multicinctus* or *P. coffeae*. In contrast, both *H. multicintus* and *P. coffeae* multiplied rapidly in roots, and could co-exist, although damage caused by *P. coffeae* alone was significantly higher than damage due to *H. multicintus*. For example, inoculation with 300 nematodes of a single species on individual roots gave root necrosis of 2%, 24% and 56% after 60 days, due to *M. javanica*, *H. multicintus* and *P. coffeae*, respectively. Roots of the five most widely grown plantain cultivars in Ghana (Apantu pa, Oniaba, Apem, Asammienu and Brodiewio) were all susceptible to attack by *P. coffeae*, although Brodiewio was the most susceptible. Root damage due to *H. multicintus* did not differ from the un-inoculated control except on Brodiewio and Asammienu, suggesting that these cultivars are more susceptible to this species. Damage levels due to *M. javanica* were very low on all cultivars.

2.2.11. Nematode-root system interactions - Uganda

by P.R.S. – in collaboration with H. Talwana, D. De Waele

The spatial distribution of nematode population densities and damage in roots of Pisang Awak, Sukali Ndizi and Nabusa was investigated at three localities in Uganda, each with a distinctive nematode population composition. At Namulonge *R. similis* dominates, at Ntungamo, the dominant species is *P. goodeyi*, while at Mbarara the two species coexists. At all three sites, suckers were removed from mats and assessed for nematode reproduction and damage. Nematode population densities were randomly distributed along the primary roots while nematode damage was significantly ($P<0.05$) higher close to the corm than further along the primary roots, independent of cultivar and location.

It was also observed that *R. similis* infected banana mats had weaker plants and a reduced root system than those that were infected with *P. goodeyi*. The total length of dead roots was significantly higher when *R. similis* occurred.

The relationship between banana nutritional status and nematode infection and damage was also studied. Nematode infection impairs nutrient absorption and distribution in the banana tissues. Potassium was shown to be the most impeded. When 'complete' nutrients were supplied to nematode inoculated plants, it was observed that nematode populations and damage in roots were reduced. Excess or deficient nutrient supply resulted in increased nematode population and damage.

2.3. Yield losses from pests and diseases determined

Background

In Africa, pest problems presented by banana weevils and nematodes may be relatively recent in origin. In East Africa, for example, the weevil achieved pest status in the 1970s, more than 70 years after being introduced, with severe outbreaks occurring in Uganda and Tanzania during the 1980s. It has also been suggested that the nematode *Radopholus similis* may have been a recent introduction. Shifts within the region from highland cooking banana landraces (*Musa* spp., AAA group, 'matooke') to beer bananas (AB, ABB), and replacement of bananas by annual crops, have been attributed, in part, to the weevil/nematode complex. However, the pest status of the weevil and nematodes have never been clearly defined and the biotic and abiotic factors that influence infestation levels and yield losses remain poorly understood.

Recently, it has been realized that banana virus diseases are widespread and are increasingly becoming a field production problem, but their pest status and economic importance are as yet unclear.

On-going and future activities

2.3.1. Yield loss due to weevils

by C.S.G., S.H.O. - in collaboration with H. Ssali, W. Tushemereirwe

A trial was placed in Mbarara to test the hypothesis that bananas growing under fertile soil conditions are more tolerant to weevil attack than those under low fertility. The trial also aimed at quantifying yield losses to weevils. Treatments included fertilized and unfertilized banana plots with and without weevils. Weevil damage and yield data was collected from the plant crop and first ratoon while sucker growth/vigor parameter data were taken on the second ratoon. Application of NPK fertilizers stimulated

faster crop growth. Weevil damage was low and increased from 1.2% in the plant crop to 3% in the first ratoon. Weevil attack extended the crop cycle but bunch weights were similar among treatments during the first two crop cycles.

The effect of weevil damage on sucker growth and vigor was clearly noted in the 2nd ratoon. In unfertilized plots, plants in plots with weevils had smaller girth and were shorter compared to those from plots without weevils. In fertilized plots, no differences were observed in plant growth in plots with and without weevils. The data suggest that vigorous plants may be more tolerant to weevil attack than stressed plants.

2.3.2 Yield losses from nematodes

by P.R.S., A.T. – in collaboration with D. De Waele, B. De Schutter

In Nigeria, yield loss caused by nematode infestation is being evaluated for the plantain landrace 'Agbagba' under mulched and non-mulched regimes. Data (height, girth, root damage, bunch weight, number of hands, number of fingers, pulp/peel ratio, nematode population densities) will be collected until 50 % of the second cycle of the least performing treatment has been harvested. The possible change in composition and density of the nematode population over different crop cycles is also being studied.

Also a cultivar comparison trial is ongoing, to compare the host plant response between the two popular plantain landraces 'Agbagba' and 'Obino l'Ewai'.

Fifteen Musa cultivars were planted in 1995 and evaluated for their host plant response (height, girth, root damage, bunch weight, nematode population densities) to a mixture of plant parasitic nematodes. Data were taken for two succeeding crop cycles; the mother plant crop and the first ratoon crop at flower emergence and harvest of the bunch. The experiment ended in April 1999 and data are being analyzed.

In Uganda, a yield loss trial has been established at Mbarara (1450 masl). At the higher elevations, Pratylenchus goodeyi is the dominant species. The first cycle results suggest that P. goodeyi is less aggressive to highland bananas than R. similis.

2.4. IPM strategies available

Background

Research results suggest that no single control strategy will be likely to provide complete control for banana weevil. Therefore, a broad integrated pest management (IPM) approach might provide the best chance for success in controlling this pest. The components of such a program would include host plant resistance, habitat management (cultural controls) and biological controls.

On-going and future activities

2.4.1. IPM of nematodes using clean planting material and biocontrol agents

by K.G., P.R.S. - in collaboration with K. Afreh-Nuamah, C. Brentu, G. Dixon, B. Hemeng*

Results from on-farm trials established in 1995 and 1997 to study the influence of planting material treatment and crop management practices on pest and disease dynamics, growth and yield of plantain in Ghana are summarized in Tables 3 and 4. Sucker germination was not affected by planting material treatment but farmer management gave significantly lower germination levels than alternative management practices (regular weeding, optimum plant spacing), probably due to less frequent weeding in the first few months after planting (Table 4). For both trials, there was an effect of planting material treatment on root health, with plants from untreated suckers having a significantly higher percentage of dead roots at flowering compared with plants from hot water-treated or nursery-derived plants. Nematode counts from the first trial were unreliable as samples were stored for too long before extraction (data not shown) but counts from the second trial indicated a positive association between densities of *P. coffeae* in the roots and root damage. In the first trial, plant growth was not affected by planting material treatment or management, however, in the second trial, plants derived from treated materials were taller than those from untreated suckers but there was no effect of management regime. The number of days from planting to harvest was significantly affected by management practices, with plots under alternative management maturing approximately one month ahead of farmer-managed plots. In the second trial, the number of suckers at harvest was affected both by planting material treatment and management practices, with the highest number of suckers recorded for nursery-derived plants

under alternative management. In both trials, the heaviest bunches were obtained from treated materials but there was no effect due to management practices. The percentage of bunches lost prior to maturity of the plant crop (due to toppling, stem breakage, failure to flower or premature death) exceeded 75 % for untreated materials under farmers' management in both trials. Percentage bunch loss was significantly reduced by both planting material and alternative management strategies. Production (plant crop) was relatively low for all treatments (<8 t/ha) and this was attributed to the time of flowering coinciding with a prolonged drought, such that bunch filling was impaired. Nevertheless, production was significantly affected by both planting material treatment and management practices, with a 65 % yield increase due to the use of treated suckers and regular weeding in comparison with untreated material under traditional management. Moreover, it was observed from the 1995 trial that planting material treatment in combination with regular weeding, substantially lengthened plantation longevity. Farmers' plots with untreated materials were largely abandoned after the first season due to the high incidence of plant toppling. In contrast, hot water-treated materials that were well-managed, continued to yield for three or four years. From the 1997 trial, it was encouraging to note that nursery-derived suckers performed well, such that the use of plantain nurseries as a source of clean suckers for planting new farms, can be promoted.

During trial establishment, farmers were concerned about recommendations to prune (cut back the pseudostem) and pare (removal of roots and outer corm layers) nursery-derived suckers before transplanting to the farm. A trial was therefore established on-station (ARS Kade) during the major rainy season to determine the effects of pruning and paring on plant growth and yield. The trial was replicated on-farm (Gyedu) but planted during the minor rainy season.

On-farm there was no effect of pruning or paring of nursery-derived suckers on either plant growth, days to maturity or production. On-station, significantly higher yields were obtained for suckers that were pruned and pared, compared with untreated suckers. This difference is attributed to a difference in the time to maturity, with flowering of untreated suckers occurring first and coinciding with the dry season, resulting in reduced efficiency of bunch filling for this treatment.

Table 3. Effect of planting material treatments and crop management on root damage, plant growth and yield of plantain, at four villages in Ghana (1995-1997)

Treatment	Dead roots at flowering (%)	Plant height at flowering (cm)	Days to harvest	Sucker number at harvest	Bunch weight (kg)	% bunches lost	Production t/ha
FM UT [1]	31.9	277	466	6.8	5.4	76.5	2.10
FM H [2]	7.8	291	459	6.2	6.4	63.9	3.84
AM int H [3]	5.4	285	420	7.5	6.9	50.4	5.74
AM mon H [4]	5.7	284	439	6.9	7.5	50.5	6.19
Treatment effect	***	Ns	***	*	***	***	***
Contrasts:							
[1] vs [2]	***	-	Ns	Ns	*	**	***
[2] vs [3]	Ns	-	***	*	Ns	***	**
[3] vs [4]	Ns	-	**	Ns	Ns	Ns	Ns

*, **, ***: F-tests significant at $P<0.05$, 0.01 and 0.001 respectively

Ns: No significant differences $P<0.05$

FM UT	Farmers' management, untreated planting material
FM H	Farmers' management, hot water-treated planting material
AM int H	Alternative management with intercropping, hot water-treated planting material
AM mon H	Alternative management, plantain monocrop, hot water-treated planting material

Table 4. Effect of planting material treatments and crop management on nematode densities, root damage, plant growth and yield of plantain, at three villages in Ghana (1997-1999)

Treatment	% Sucker germination	*P. coffeae* density at flowering /100 g roots	Dead roots at flowering (%)	Plant height at flowering (cm)	Sucker number At harvest	Bunch weight (kg)	% bunches lost	Production t/ha
FM UT [1]	83	7,292	27.1	288	8.0	6.3	77.5	2.3
FM H [2]	84	1,503	4.5	300	5.5	8.0	56.3	5.8
FM N [3]	83	2,482	4.4	314	6.1	8.3	64.2	5.0
AM UT [4]	87	8,518	22.8	284	7.7	7.1	63.2	4.4
AM H [5]	86	898	4.9	301	6.7	8.0	43.2	7.6
AM N [6]	92	2,017	4.1	302	6.9	8.7	47.5	7.7
Treatment effect	*	***	***	***	***	***	***	***
Contrasts:								
FM vs AM	**	Ns	Ns	Ns	***	Ns	***	**
UT vs H & N	Ns	***	***	***	***	***	***	***
H vs N	Ns	Ns	Ns	Ns	**	Ns	Ns	Ns

*, **, ***: F-tests significant at $P<0.05$, 0.01 and 0.001 respectively

Ns: No significant differences $P<0.05$

FM UT Farmers' management, untreated planting material

FM H Farmers' management, hot water-treated planting material

FM N Farmers' management, nursery-derived planting material

AM UT Alternative management, untreated planting material

AM H Alternative management, hot water-treated planting material

AM N Alternative management, nursery-derived planting material

2.4.3. Farmers perceptions and economic analysis of IPM interventions

by K.G. - in collaboration with W. Danso, K. Afreh-Nuamah

Economic analyses showed that the use of clean planting material and improved management practices for plantain production were profitable compared with traditional practices (see completed studies). In addition, financial appraisal of plantain nursery production at three villages in Ghana showed clearly that the production and rapid multiplication of clean planting materials through community nurseries can be a profitable venture, even when there are adverse price fluctuations. Farmers producing clean suckers can benefit both through the use of their own clean planting material to produce improved yields, and also by diversifying their farm income through the sale of clean suckers to other farmers.

Table 5. Farmers' ranking of planting material treatments and management practices tested on-farm in Nyinahin, Ashanti Region (1997-1999)

Treatments tested on-farm[1]

Criteria ranked	FM-UT	FM-H	FM-N	AM-UT	AM-H	AM-N
Growth:						
Germination time	3	1	2	3	1	2
Germination (%)	2	1	1	2	1	1
Establishment	2	1	1	2	1	1
Drought tolerance	2	1	1	2	1	1
Days to flowering	3	1	2	3	1	2
Days to harvest	3	1	2	3	1	2
Number of suckers	2	1	1	2	1	1
Stem breakage	2	1	1	2	1	1
Plant toppling	2	1	1	2	1	1
Production:						
Bunch size	3	2	1	3	2	1
Number of bunches	2	1	1	2	1	1
Number of suckers	2	1	1	2	1	1
Fastest to ratoon	2	1	1	2	1	1
Socio-economic factors:						
Weeding frequency	1	1	1	2	2	2
Labour inputs	1	1	1	2	2	2
Taste and texture	1	1	1	1	1	1
Costs	1	1	1	2	2	2
Benefits	2	2	2	1	1	1

Within a row, 1 represents the best option

[1]FM UT Farmers' management, untreated planting material

FM H Farmers' management, hot water-treated planting material

FM N Farmers' management, nursery-derived planting material

AM UT Alternative management, untreated planting material

AM H Alternative management, hot water-treated planting material

AM N Alternative management, nursery-derived planting material

At Farmers' Fora held at three villages in 1999, collaborating farmers shared their perceptions of nursery production and the use of clean planting materials and improved management. Farmers stated that nursery production provided a means to generate and multiply clean suckers as required. Moreover, nursery-derived materials performed better than untreated suckers and could also be sold (at a higher price than untreated suckers), when required. The major constraints in nursery production were the need for watering during the dry season and the cost of labor required for regular weeding. In addition, it was realized that use of the hot water tank for sucker treatment would be more feasible for farmers' groups rather than individuals. Farmers unanimously acknowledged that the use of clean suckers and improved management on-farm resulted in reduced toppling, improved sucker production, higher yields and longer plantation life. Farmers who had been involved in collaborative trials confirmed that these agronomic benefits had led to higher cash income. Again, the scarcity and cost of labor for regular weeding was cited as a major constraint. In general, their perceptions accurately reflected the results of both the agronomic and economic trial analyses. Table 5 shows the results from farmers' ranking of treatments tested on-farm (1997-1999) in Nyinahin, Ashanti Region. Similar results were obtained from the other villages and for an earlier trial.

Extension officers present at the Farmers' Fora estimated the extent to which plantain IPM technologies had been disseminated from the three villages and adopted by farmers within their districts (Table 6). Clearly, paring was by far the easiest technology to disseminate and adopt due to its simplicity and low cost. The rate of adoption was higher in Asutifi District compared with the other two districts, perhaps due to the presence of another project promoting plantain IPM (GTZ Integrated Crop Protection Project) and the particular importance of the crop in Brong Ahafo region.

Extension agents were asked to consider how dissemination and adoption of plantain IPM technologies could be improved and sustained. The following suggestions were given:

- The formation of farmers' groups with technical assistance from MoFA should form the basis for plantain IPM training as it allows for information exchange and efficient use of available hot water tanks and transport, plus human and financial resources.
- Extension agents and farmers should be encouraged to start small-scale nursery projects even if resources are limited (For example, ten farmers each with 50 suckers would be sufficient to initiate a nursery).
- The continued support of District Directors (MoFA) is essential.
- Funds (e.g. for nursery production) could be solicited from NGOs and district assemblies, while land could be made available by local chiefs. In addition, involvement of schools and churches would also help to disseminate the technologies.
- Simplification of the design and reduction in the cost of the hot water tank could help to make this technology more widely available.
- Extension agents who have collaborated closely with the project should act as resource persons for training of other MoFA staff and farmers.
- Farmers themselves can also fulfill an important role as trainers and motivators.

Table 6. Reported dissemination and adoption of plantain IPM techniques in three districts of major plantain growing regions in Ghana

District / region	Technology	No. MoFA staff aware of the technology	MoFA staff with sufficient knowledge to train farmers	No. of farmers trained by MoFA staff	No. of farmers using the technology
Asutifi, Brong Ahafo	Paring	10	8	317	111
	Hot water treatment	11	11	20	10
	Nursery production	11	10	77	18
Kwaebibrim, Eastern	Paring	8	7	198	37
	Hot water treatment	7	1	0	0
	Nursery production	9	6	21	21
Atwima, Ashanti	Paring	5	4	127	71
	Hot water treatment	5	3	0	0
	Nursery production	5	5	2	2

2.4.4. Habitat management (cultural control) of banana weevils: Clean planting material

by C.S.G., S.H.O. - in collaboration with G. Night, G. Kagezi, M. Masansa, E. Karamura, W. Tinzaara, B. McIntyre, J. Ssenyonga, F. Bagamba*

Habitat management offers a first line of defense against herbivores by creating an environment which reduces pest movement, promotes plant vigor and pest tolerance, and/or is unfavorable to pest buildup. For banana weevil, habitat management includes use of clean planting material; selection of cropping systems unfavorable to the pest; improved agronomic practices to promote plant vigor and tolerance to attack; management of post-harvest residues; and trapping.

The use of clean planting material provides a means of protecting propagules in newly planting fields and retarding pest buildup. Reinfestation rates remain a concern; cleaned suckers used in gap

filling or in planting fields proximal to weevil infested stands are likely to be quickly attacked by weevils. Therefore, research is being conducted on the use of endophytes as biological control agents to provide further pest protection for cleaned planting propagules.

2.4.5. Habitat management of banana weevils: Trapping studies

by C.S.G., S.H.O. - in collaboration with G. Night, G. Kagezi, M. Masansa, E. Karamura, W. Tinzaara, B. McIntyre, J. Ssenyonga, F. Bagamba*

The use of pseudostem traps to control banana weevils is controversial. A trapping study, conducted through farmer participatory research at the Ntungamo benchmark site, showed that intensive trapping could significantly reduce weevil levels. However, results across farms were highly variable such that the benefits of trapping can not be guaranteed. Additionally, most farmers felt that labor and material requirements for trapping was beyond their means. Current research is now oriented towards the use of pheromone and kairomone traps. On-station research has shown that pheromone traps can attract up to 25 times as many weevils as a conventional pseudostem trap.

2.4.6. Habitat management of banana weevils: Crop sanitation

by C.S.G., S.H.O. - in collaboration with G. Night, G. Kagezi, M. Masansa, E. Karamura, W. Tinzaara, B. McIntyre, J. Ssenyonga, F. Bagamba*

It is widely believed that destruction of post-harvest residues (splitting pseudostems and digging out corms) eliminates a breeding site for weevils and reduces damage on standing plants. Although it is clear that destruction of residues will kill any larvae in them, an alternative hypothesis is that these residues act as traps which draw gravid females away from standing plants.

Studies on the role of crop sanitation on banana weevil population dynamics and related damage is being carried out as part of Ph.D. dissertation research. Activities will include (1) studies on oviposition preferences in farmers fields by comparing oviposition rates on flowered plants and residues of different types and ages (2) a laboratory a study on food quality by comparing larval survivorship, developmental time and pupal size in materials taken from plants of different ages and crop residues; (3) an on-station trial comparing types of sanitation (leaving stumps standing; chopping residue stem; chopping residue stem and corm) and weevil population dynamics; (4) on-farm trials of different sanitation practices in two benchmark sites.

Laboratory experiments have been conducted on attraction, acceptance, eclosion success and larval survivorship on different types (i.e. maiden sucker and harvested plant rhizomes and pseudostems) and ages (ranging from recently harvested to very old) of crop residues. In general, rhizomes attracted more weevils than pseudostems, while there was no consistent effect of residue age on weevil attraction. Oviposition was also greater on rhizomes than pseudostems with the highest rate of total oviposition and eggs/female on materials from maiden suckers. These results differ from field studies in which oviposition was greatest on flowered plants and crop residues than on maiden suckers with most eggs being placed in the leaf sheaths of the pseudostem.

Eclosion rates was lower for eggs on very old residues than other age classes. Larval success, as reflected by rates of development, numbers and size of larvae to reach the pupal stage, was greatest on fresh residues.

To prevent weevil attack of crop residues, a number of farmers bury old stumps under soil. Preliminary results suggest that weevils are more likely to find buried residues during the dry season because the moist environment around such stumps are more favorable to weevils. In contrast, oviposition on buried stumps was less than on surface residues during the wet season.

Initial observations under field conditions suggest that weevils will oviposit on crop residues up to 120 days after harvest although oviposition levels show sharp decreases on older residues.

The effects of crop sanitation on weevil population dynamics is being investigated in through farmer participatory research in Ntungamo and in a controlled trial at Kawanda. In Ntungamo, 45 farms were stratified on the basis of sanitation practices (low, medium, high levels) and weevil population densities. The majority of farmers practiced low levels of crop sanitation. Farmers were then allocated to different treatments in which some farmers were asked to improve their levels of management while others continued at their current levels of management. Weevil damage is being monitored monthly while population levels will be estimated every 6 months.

The on-station trial is designed to look at the effects of sanitation on weevil populations under stressed (i.e. inoculated with nematodes) and unstressed conditions. The trial has four treatments: (1) no sanitation and no nematodes; (2) no sanitation and nematodes; (3) sanitation and no nematodes; (4)

sanitation and nematodes. The trial was planted in 1998. However, crop sanitation levels can only be implemented after the first harvest (i.e. 2000)

2.4.7. Habitat management of banana weevils: Mulching

by C.S.G., S.H.O. - in collaboration with G. Kagezi, B. McIntyre, W. Tushemereirwe

Banana weevil adults tend to aggregate at the base of banana mats near the female's oviposition sites in the leaf sheaths and rhizome. The adults are prefer moist environments and populations tend to be higher in mulched systems. Many farmers have observed that mulches favor weevils and try to protect their plants by mulching away from the base of the mat. Two experiments were established to explore the relationships between mulch placement and weevil pest status.

In Ntungamo district, a trial was established on fallowed land in which cooking bananas were mulched with swamp grass. Treatments were a control (no mulch) and mulches placed up to the base of the mat and 50 and 100 cm away from the mat. Weevils were released in the trial (10 per mat) 6 months after crop establishment. Mulched plots tended to have greater populations (on average 17% higher) than the control, but differences were not significant. Yields were substantially higher in mulched plots.

A second trial with cooking banana was placed at the Kawanda Agricultural Research Institute. In this trial, treatments were a control and swamp grass placed to the base of the mat and 50 cm away from the mat. Weevils were released at the rate of 10 per mat 10 months after planting. In plots mulched to the base of banana mats, weevil populations were 29% and 63% higher than in plots mulched 50 cm from the base and controls, respectively. Plots mulched 50 cm from the base of the mat had 26% more weevils than controls. All of these differences were statistically significant.

2.4.8. Biological control of banana weevils

by C.S.G., P.R.S. - in collaboration with A. Abera, M. Griesbach*, P. Nemeye, A. Hasyim, R. Sikora, B. Niere*

Biological control may ultimately provide the most effective means of controlling banana weevils. At present, however, no candidate biological control agents have been identified with potential for eastern Africa. Endemic predators have been identified but these possess little potential for control of the weevil. Foreign exploration in southeast Asia may provide suitable natural enemies but this remains a future activity with unclear probability of success. Laboratory studies on the use of fungal pathogens suggests a potential for control but field efficacy needs to be demonstrated, while at the same time, delivery systems need to be developed.

Myrmicinae ants are believed to be effective biological control agents of banana weevil in Cuba. The effects of ants are being examined in life table studies and will be studied as part of a Ph.D. program beginning at the end of 2000. Attempts are being made to find funding to support foreign exploration for natural enemies of banana in the insect's area of origin in southeast Asia.

Microbial control may provide an effective means of controlling banana weevil and nematodes, extending the protection of clean planting material and enhancing plant growth. Of foremost importance would be the use of mutualistic endophytic fungi. Studies in Uganda have demonstrated the availability of naturally occurring strains of endophytic fungi which cause mortality to both weevils and nematodes. These fungi can be inoculated into tissue culture plants.

Work on endophytes as control agents of banana weevil began in 1996. A total of 250 isolates of endophytic fungi were obtained from cooking banana and "Pisang Awak" at Uganda benchmark sites. *Fusarium*, *Acremonium* and *Geotrichum* strains killed banana weevil eggs and larvae. Candidate strains of endophytes were successfully inoculated into (and re-isolated from) tissue culture plants. In most cultivars, inoculated plants had lower levels of weevil damage.

Current research trials concern screening additional strains of endophytes collected at new sites in Uganda and studies on the persistence of endophytes within the host plant. Preliminary results with some of the new strains of isolates have shown up to 100% mortality of weevil eggs.

Three of the more promising endophyte strains from the original cultures were inoculated to young plantlets at rooting stage. After a month of growth under glass house conditions, the plantlets were transferred into drums filled with sterilized soil or in the field in a location about 200 m from any weevil source. During 2000, endophytes will be isolated from mother plants and suckers and identified using VCG groups.

2.4.9. Socio-economics of banana weevil IPM

by C.S.G., S.H.O. - in collaboration with G. Night, G. Kagezi, M. Masansa, E. Karamura, W. Tinzaara, B. McIntyre, J. Ssenyonga, F. Bagamba*

Cultural controls (habitat management) are the only options currently available to the majority of highland banana producers to reduce infestations of banana weevil. These practices include use of clean planting propagules, improved agronomic practices to promote plant vigor, trapping and crop sanitation. Many of these methods have been long recommended by national programs and NGOs. However, these controls are labor intensive and of controversial benefit: There are virtually no data from properly designed scientific studies to demonstrate the efficacy of any of these method. Nevertheless, variability in weevil attack among neighboring farms suggest that some management practices can and do influence pest status. Ultimately, farmers will decide what types of cultural controls they may find appropriate for their situation and the allocation of their limited resources.

In collaboration with UNBRP and ICIPE, socio-economic surveys were completed in Masaka district in 1998, initiated in Luwero district in late 1999 and will be undertaken in Ntungamo in mid-2000. In Masaka district, a 3 part socio-economic questionnaire was administered on 60 farms in the Masaka benchmark site. This included sections on demographics, labor, inputs and marketing; IPM; and soils and crop management. The survey has provided an extensive data set characterizing farms and management practices. In IPM, the survey addressed (1) farmer knowledge of banana pests and diseases, damage effects and efficacy of controls; (2) prevalence of IPM practices; (3) patterns of adoption of IPM practices (acceptance, rejection, discontinuation); (4) costs of IPM practices; (5) benefit cost analysis; (6) factors influencing adoption. Collected data provide insight into farmer knowledge, suitability of controls and research directions to be undertaken at the site.

Farmers throughout Uganda are cognizant of cultural methods recommended to control banana weevils. Farmer interviews indicate variable levels of confidence and adoption of these methods. Highest levels of implementation appear to be in commercial growing areas, although many farmers employ cultural methods in a sporadic fashion. Within communities, adoption of pest management techniques reflected farmer economic status, levels awareness of control techniques and management objectives. Most farmers implemented cultural controls in order to reduce their existing weevil load; however, a number of farmers employed weevil controls to prevent pest buildup from currently low levels.

2.4.10. Biological control of plant parasitic nematodes using fungal endophytes from bananas.

by P.R.S., C.S.G. – in collaboration with B. Niere, R. Sikora,*

In vivo screening of endophytic isolates for nematode controlling activity continued in 1999. A tissue culture facility for banana was established at Sendusu Farm Station and was fully operative during 1999. Protocols for the inoculation of fungal endophytes onto tissue cultured bananas have been simplified and integrated in routine weaning and nursing procedures applied to tissue cultured bananas. Standard protocols for nematode resistance screening of banana germplasm are being followed to screen fungal activity against the major nematode affecting banana, *Radopholus similis*. Nematode controlling and plant growth promoting effects of fungal isolates on some banana cultivars have been observed. Effects of fungal isolates on host plant reaction towards nematode attack, however, differed among banana varieties. Nematode multiplication and damage (root necrosis) decreased or increased depending on the banana cultivar and the fungal isolate. The search for optimal combinations of fungal isolate – banana cultivar continues to be a research priority.

The most promising isolate of *Fusarium oxysporum*, V5w2, was selected for field-testing. Nematode controlling effects were observed 4 months after planting endophyte-inoculated plants in heavily nematode-infested fields at Sendusu (mixed population of *R. similis* and *Helicotylenchus multicinctus*). Significantly lower densities of *H. multicinctus* were found in roots of tissue cultured plants, cultivar Gros Michel, inoculated with strain V5w2. Biocontrol activity of fungal isolates towards different nematode species and under varying situations of nematode pressure (low, medium, high) remains to be established.

An on-station trial to compare the field performance of tissue cultured bananas, cultivar Nabusa, inoculated with strain V5w2 was planted in December 1999. First results on plant growth, nematode damage and multiplication are expected in 2000.

2.4.11. Fusarium wilt control of banana using non-pathogenic isolates of *Fusarium oxysporum*.

by P.R.S., J.H. – in collaboration with B. Niere, R. Sikora*

Fusarium wilt is a major threat to the production of the major dessert banana cultivars grown in Uganda. Gros Michel (*Musa* AAA), Sukali Ndizi (*Musa* AB), as well as beer bananas of the important Pisang

Awak (*Musa* ABB) subgroup are highly affected by race 1 of the wilt pathogen, *Fusarium oxysporum* f.sp. *cubense*. Since the pathogen is able to survive in the soil for more than 30 years, areas once affected remain unproductive for wilt susceptible cultivars. Measures to control the disease are not available. Pathogen-free planting material from tissue culture planted in disease-free soil offers an alternative to control the disease. Tissue cultured plants, however, are more susceptible to the disease when planted in infested soil than conventional planting material. Biological control of Fusarium wilt with non-pathogenic isolates of *F. oxysporum* has been reported in a range of other crops. Techniques for the inoculation of tissue cultured banana with non-pathogenic *F. oxysporum* isolates already exist and are easily incorporated in the existing technology of tissue culture plant propagation. Cultivars Gros Michel and Sukali Ndizi were inoculated with different non-pathogenic isolates of *F. oxysporum* at weaning stage. Plants then were transplanted to buckets filled with soil infested with one isolate (VCG 01222) of the wilt pathogen. Results of these experiments are expected in 2000.

2.4.12. Non-pathogenicity of biocontrol isolates of *Fusarium oxysporum* toward banana.

by P.R.S. – in collaboration with B. Niere, H.I. Nirenberg, R. Sikora*

The applicability of endophytic isolates of *Fusarium oxysporum* in biocontrol largely depends on the non-pathogenicity to its host. *F. oxysporum* is economically the most important *Fusarium* species with several formae speciales attacking plants in many genera, causing wilt or root rot. The majority of *F. oxysporum* isolates, however, is non-pathogenic soil inhabitants and are often being used in biological control of plant diseases. Morphological differentiation between pathogenic and non-pathogenic isolates is not possible. Vegetative compatibility grouping (VCG) is commonly applied for the characterization of formae speciales within the *F. oxysporum* complex. Vegetative compatibility is controlled by usually several vic genes and is used to identify genetically isolated populations of *F. oxysporum*. Gene combinations once made are fixed in an asexual fungus like *F. oxysporum*. VCGs therefore, reflect genetic similarities between strains hypothesizing that pathogenic forms are more similar to each other than to non-pathogenic isolates. VCG makes use of auxotrophic mutants unable to use nitrate as sole nitrogen source and complementary mutants are paired on a selective medium to detect somatic fusion and heterokaryotic growth. To establish the non-pathogenic nature of isolates used in biocontrol, mutants of the isolates were paired with all known testers for the forma specialis *cubense*, causing wilt of banana. None of the isolates used for the biological control of nematodes and Fusarium wilt was vegetatively compatible with testers of the wilt pathogen indicating their non-pathogenic nature. Vegetative compatibility testing between biocontrol strains revealed that they represent a heterogeneous group of non-pathogenic *F. oxysporum* isolates. In addition, none of the biocontrol strains of *F. oxysporum* inoculated on the highly wilt susceptible cultivar Gros Michel was found to cause wilting or vascular discoloration over a 9 months period. Pathogenicity testing of the most promising fungal isolate, V5w2, on different cultivars of tomato and sweet potato, both susceptible to ff.sp. lycopersici and batatas, respectively, demonstrated the non-pathogenicity to these crops as well.

2.4.13. Clean planting material for Uganda, Rwanda and Zanzibar

by P.R.S. – in collaboration with W. Tushemereirwe, I. Kashaja, C. Kajumba, K. Rajab, S. Gaidashova

The common objective of this technology transfer project is the delivery of healthy banana planting material to the farmers' community. In May 1999, a workshop was organized in Namulonge to train the members involved on the hot water technology and the basics on banana and yam pests and diseases.

In Uganda, the project is carried out in four districts, Mpigi, Luwero, Masaka and Ntungamo. Environmental Alert was involved in the mobilization and supervision of the farmers' activities and extension contact in Mpigi, while for the districts of Luwero, Masaka and Ntungamo, the District Agricultural Officers are involved.

Baseline data were collected to establish the initial damage level and production level before the start of the hot water technology. In total 1713 farmers were trained and 4487 materials were treated and planted (see Table 7).

In Rwanda the main collaborating NGO is World Vision and is responsible together with ISAR for field control, extension staff contacts and farmers' activities monitoring, training in sucker maintenance, hot water treatment demonstration, monitoring and impact assessment. Two regions were chosen for the training and hot water treatment, Butare (Ruhashya and Rusatira communes) and Mutara (Kahi and Gabiro communes).

In Zanzibar, the project is executed by the Plant Protection Division. Training sessions were held and hot water treatment was carried out at 20 different sites in Pemba and 20 in Unguja.

Two hot water tanks have been constructed. One was sent to Rwanda and the other will be given to the farmers in Buganda district. The Minister of Buganda for Agriculture will be responsible for the hand over to the farmers and monitor its used among the different counties in Mpigi and Luwero district.

Training on pests and diseases and hot water treatment will continue, especially in the districts of Ntungamo and Luwero, since most of the work so far was concentrated in Mpigi and Masaka. Monitoring and data collection will be carried out in the areas where the planting has been done.

Table 7. Districts and number of farmers visited, and number of planting material treated in Uganda

District/County	N° of farmers visited	N° of treated materials
Mpigi	*1009*	*1861*
Mende	54	100
Muduma	165	495
Kibibi-Gombe	242	372
Siga	40	
Njeru	154	266
Busiro	166	285
Ntenjeru	51	26
Kasawo	51	153
Busujju	76	164
Luwero	*22*	*62*
Kasangombe	22	62
Masaka	*640*	*2064*
Ssunga	341	902
Nakattete	77	570
Kitanga	222	592
Ntungamo	*42*	*500*
Nyakyera	42	500

2.5. *Utilization of germplasm enhanced*

On-going and future activities

2.5.1. Host plant resistance to banana weevil

by C.S.G.,J.H., D.V. - in collaboration with A. Kiggundu

A screening trial of 45 *Musa* accessions including Ugandan local landraces, exotic introductions, IITA and FHIA hybrids, was set up at IITA-ESARC Sendusu farm, Namulonge Uganda. This trial was supplemented with laboratory bioassays to further elucidate on resistance mechanisms.

Data obtained revealed that the plantain subgroup (AAB) was the most susceptible to banana weevil followed by East African highland banana clones. The exotic bananas, especially Kayinja, Bluggoe (ABB), Kisubi and Ndiizi (AB) were resistant to banana weevil. Plantain derived tetraploid hybrids of the wild banana Calcutta-4 (male parent) were as susceptible as their plantain female parent, indicating a possible dosage effect of the susceptible gene (Table 8). Of the local EAHB, Mbwazirume, Tereza and Nakyetengu showed moderate resistance and may be recommended as possible resistant selections, although further multi locational evaluation may be necessary before such recommendations are made. Total inner damage was found to be the best criteria for screening, and selecting for weevil resistance, since it showed the highest genetic heritability estimate and was highly correlated with all other weevil damage indices.

Significant phenotypic and genotypic correlations were found between corm hardness, dry matter content, sap/resin production, suckering ability and corm size and banana weevil damage. These may

be important mechanisms of resistance in *Musa* and this points to the fact that banana weevil resistance may be a complex polygenic trait.

In agreement with the literature studied, antixenosis was not found to be important as a resistance mechanism in *Musa*. However, results from various no-choice experiments on hatchability and development revealed significant differences. The previously observed resistance cultivars Kayinja, Yangambi-km5 and FHIA03, unlike the more susceptible plantains and EAHBs, significantly increased developmental time and in some cases caused mortality of immature weevil stages. All indicating that antibiosis is the most important resistance mechanism in *Musa*.

Table 8. Means (± standard error) of banana weevil damage variables by genome groups of *Musa* in Uganda. Note that plantain derived hybrids are as susceptible as their female parents.

Genome group	*Musa* type	Mean total weevil damage	Range of total weevil damage
AAB	Plantains	7.8	7.5 - 8.1
AAA-EA	East African highland banana	5.9	2.7 - 9.9
ABB	Kayinja/Bluggoe	3.3	2.3 - 4.1
HYBRIDS	Plantain derived	6.6	6.3 - 7.9
	Banana derived	0.2	0.1 - 0.2
AB	Ndiizi/Kisubi	2.4	1.0 - 3.1
AAA	Yangambi-km5, Cavendish, Gross Michel	1.8	0.4 - 4.0
AA	Wild banana Culcutta-4	0.2	0.2

Preliminary studies on the influence of secondary metabolites were undertaken. The results showed the presence of two or more compounds indicated by peaks on HPLC chromatograms of methanol extracts of corms from resistant cultivars (e.g. Kayinja and FHIA03) that were not present in susceptible cultivars (e.g. Atwalira and Gonja). These substances were also not present in some resistant cultivars like Yangambi-km5 and Cavendish, both of the AAA genome group. This was yet another indication that resistance is complex since different factors are important in different genome groups.

2.5.2. Screening of *Musa* germplasm for resistance to *Radopholus similis* by inoculating individual roots

by P.R.S., , C.D., J.H., A.T., D.V. – in collaboration with D. De Waele, B. De Schutter

Screening for resistance to nematodes using field trials is a very time and labor consuming effort. To screen the large available *Musa* germplasm, including landraces, commonly used exotic bananas and the IITA hybrids, there is a need for a fast and reliable screening protocol.

In Nigeria, different methods to evaluate resistance to *R. similis* were compared using the cultivar Agbagba (*Musa* AAB group). The methods included, inoculating the complete root system by pouring a suspension of 700 nematodes around the pseudostem, inoculating single roots with 50 nematodes by means of nematode-containing *Musa* root discs and inoculating single roots with a suspension containing 50 nematodes. The method whereby single roots were inoculated using a suspension showed the highest nematode density and the lowest coefficient of variation. Therefore, this method was used to compare the reproduction ratio (Rr) of *R. similis* in 'Yangambi-km 5' (*Musa*, AAA group), 'Agbagba' and the IITA-improved hybrid 'TMPx 1658-4'. Reproduction on 'Yangambi-km 5' was lowest (Rr = 0.72), followed by 'TMPx 1658-4' (Rr = 5.70), while the highest reproduction was observed on 'Agbagba' (Rr = 40.45). Reproduction ratios for *R. similis* on 'Yangambi-km 5' and 'TMPx 1658-4' were not significantly different, confirming the known resistance in 'Yangambi-km 5'. The high reproduction ratio for 'Agbagba' confirmed its high susceptibility to *R. similis*. This study demonstrates that inoculating individual *Musa* roots to evaluate resistance to *R. similis* is a valuable and reliable method.

In Uganda, the method of single root inoculation was initiated in 1998, but improvements had to be made. The protocol is now fully standardized and can be used as a routine screening method.

Advantages of this method are that a lower nematode inoculum is needed, fewer plants per hybrid (since more roots per plant can be inoculated) and more hybrids can be screened at the same time. In each experiment, a susceptible ('Valery') and a resistant ('Yangambi-km 5') cultivar are included. 'Valery' shows a high reproduction ratio with this protocol, while a very low or no reproduction ratio

is found for 'Yangambi-km 5', confirming the above. Inoculum is obtained from a single species *in vitro* culture of *R. similis*.

2.5.3. Identification of durable nematode resistance/tolerance sources and genetic analysis of nematode resistance

by P.R.S., , C.D., J.H., A.T., D.V. – in collaboration with D. De Waele, B. De Schutter

In Uganda, several hybrids have been screened for resistance against *R. similis* by inoculating individual roots. The selection of the hybrids for nematode resistance screening was done together with the banana breeding team. The hybrids were compared with 'Yangambi-km 5' as the resistant control and with 'Valery' as the susceptible control. Each root was inoculated with 50 females of *R. similis*, and after 8 weeks the final nematode population was determined. For each hybrid the reproduction ratio was calculated. Genotypes which have a reproduction ratio that is significantly different from 'Valery', but not from 'Yangambi-km 5' support low nematode densities and are therefore interesting genotypes for further evaluation. Promising hybrids include: TMB2x 1411S-10, TMB2x 2569S-2, TMBx 2094S-1, TMP2x 2521S-31, TMP2x 2521S-47, TMHx 660K-1, TMB2x 5265-1, TMBx 22788-11, TMB2x 9128-3, SH-3142. The resistance of TMB2x 5265-1 and TMB2x 9128-2 could point to resistance of 'Tjau Lagada'. The most promising hybrids will be further evaluated in pot trials and in the field, to test the consistency of the method.

A segregating population of the cross TMB2x 6142 X TMB2x 8075 is currently being screened. TMB2x 8075 has Pisang Jari Buaya in the pedigree, which is highly resistant to nematodes. There are 104 progeny of this cross, and so far 28 progeny have been screened. The remaining progeny will be screened in the coming months and we will look into the possibility of doing a genetic analysis of the resistance.

2.6. *Improved genotypes and populations available*

On-going and future activities

2.6.1. Production of transgenic *Musa* with resistance to BSV

by J.d'A.H.

Recruitment of the post-doctoral fellow was achieved. Her activities will be as described in the objectives of the joint project between the John Innes Centre, UK, the Catholic University of Leuven, Belgium and IITA, and will include:

- Diagnostics for activatable integrated forms of the Onne strain of *Banana streak virus* (BSV), genus *Badnavirus* which will be used for screening parental breeding material.
- Information on diagnostics for potentially activatable forms of other BSV strains, which will also be used for screening parental breeding material.
- Diagnostics for symptom-suppressed, episomal forms of BSV which will be transferred to appropriate NARS.
- Transgenic plants protected against episomal BSV infection.
- Transgenic plants with the potential for activation of integrated BSV reduced or eliminated.
- An understanding of the disease caused by BSV, particularly the response to stress.

2.6.2. Virus indexing for germplasm distribution

by J.d'A.H., H.D.M. - in collaboration with A.O Uwaifo, B Agindotan

Routine diagnostic protocols and procedures for BSV have only been modified slightly in 1999. The earlier procedure used by IITA involved 'hardening' the tissue culture plants, after potting, in the screenhouse for about eight weeks before the plants were transferred to a controlled temperature room at 22-24°C. After this the plants were indexed twice over a period of six months. The indexing was by ELISA using the rabbit polyclonal antibody cocktail (PMX) developed by at the University of Minnesota or using a chicken polyclonal antibody developed at IITA. Additionally, immunosorbent electron microscopy (ISEM) using the PMX cocktail antiserum was used as a final confirmatory step. The modified procedure no longer utilizes the controlled-temperature room, as it is likely that the stress of the transition between the screenhouse ambient temperature and that of the controlled-temperature room may be sufficient to induce transcription and production of episomal virus from the integrated sequences. The plants are now tested over a six-month period while being grown in the screenhouse in ambient conditions. Testing is initially by TAS-ELISA using the monoclonal antibodies to BSV raised

at IITA. Although the strain specificity of the antibodies is not known and the test is not fully validated throughout the countries of West Africa, the TAS-ELISA is useful as a preliminary screening method. Subsequent screening of putative virus-'free' germplasm is by further ELISA using the chicken polyclonal antibody and finally by ISEM using the PMx antiserum.

2.7. *Improved cropping systems available*

On-going and future activities

2.7.1. Management practices for plantain production in Ghana

by K.G. - in collaboration with K. Afreh-Nuamah

Results from a participatory rural appraisal in Ghana indicated that farmers consider soil fertility to be a production constraint. While clean planting material can contribute significantly to improved yields, it may also be necessary to enhance soil fertility in order to sustain production on poor soils. An experiment was established at ARS Kade in 1998 to determine the effect of organic soil amendments on pest and disease dynamics, and growth and yield of plantain. Four mulching materials, rice husk, partially decomposed sawdust, partially decomposed cocoa pod husk and poultry manure, were applied to plant bases at 3 months after planting, incorporated to a depth of 5 cm and compared together with a control (no mulch). The mulches were analyzed for their nutrient content prior to application. Foliar and soil nutrient analysis was conducted periodically in addition to determination of physical soil characteristics, soil moisture and temperature. Mulch effects on weed growth, pest and disease damage, growth and yield, were determined.

One year after mulch application, the percentage of plants in the trial that had flowered was 52%, 35%, 25%, 19% and 19% for poultry manure, cocoa pod husk, rice husk, sawdust and the control respectively. From plant growth data collected, it appears that plants treated with poultry manure and cocoa pod husk have performed better than for plants in other treatments. The plant crop is now being harvested and the trial will be maintained as part of a new Ph.D. study.

2.8. *Backstopping activities to NARS*

On-going and future activities

2.8.1. Establishment of a delivery system for healthy improved *Musa* germplasm with field tolerance/ resistance to BSV and resistance to black sigatoka

by K.R.G., J.d'A H., A.T. - in collaboration with F.O. Anno-Nyako

The project purpose is to disseminate improved *Musa* hybrid germplasm and promising landraces to combat two disease problems (banana streak virus (BSV) and black sigatoka disease) that constrain *Musa* production in Ghana.

The following hybrids and landraces have been selected for multiplication to produce 3300 plantlets in total for planting in 2000:

PITA-2 [TMPx 548-9] (available in Ghana)
PITA-5 [TMPx 2796-5] (available in Ghana)
PITA-11 [TMPx 2637-49] (available in Ghana)
TMPx 2481 (available in Ghana)
FHIA 21(available in Ghana)
BITA 2 [TMBx 1378] (recently arrived in Ghana from INIBAP)
BITA 3 [TMBx 5295-1] (recently arrived in Ghana from INIBAP)
Asamienu (Ghanaian landrace)
Apem oniaba (Ghanaian landrace)
Apantu brodewiuo (Ghanaian landrace)
Apantu osoboaso (Ghanaian landrace)

These hybrids and landraces are all in tissue culture and are being multiplied at Department of Botany, University of Ghana, Biotechnology and Nuclear Agricultural Research Institute, and Crops Research Institute (CRI), Kumasi. Consumables and reagents were provided to the Gatsby *Musa* project scientists in Ghana by IITA to facilitate *in vitro* multiplication. In addition, all of the varieties apart from BITA 2 and BITA 3 (recently arrived from INIBAP), are being maintained in the field. The nursery sites for rapid vegetative multiplication are being prepared at Agricultural Research Station

(University of Ghana) Kade and CRI for planting in early 2000. Three primary sites of one hectare each at Kade, Fumesua and Assin Fosu will contain all the eleven varieties produced from both tissue culture and vegetative propagation. The primary sites will be planted in April/May 2000.

As a result of the training at IITA previously done under this project, the natural occurrence of viral BSV was confirmed by enzyme-linked immunosorbent assay (ELISA) on field-grown FHIA 21. ELISA also confirmed that Ghanaian landraces are infected with viral BSV. Supplies of polyclonal and monoclonal antibodies raised at IITA were given to the *Musa* project scientists in Ghana to facilitate the diagnostics at Department of Crop Science, University of Ghana and CRI.

Indexing and agronomic evaluation will be undertaken at the primary and secondary multiplication sites from May 2000. One secondary multiplication site (on station) has been identified in each of the six major plantain-growing regions. Extension staff from the Ministry of Food and Agriculture will work with farmers close to the secondary sites who will be encouraged to establish community nurseries (satellite sites) incorporating proven varieties. Secondary and satellite sites are expected to be planted in May 2001.

Completed studies

Journal articles and book chapters

Abera, A.M., C.S. Gold, S. Kyamanywa & E.B. Karamura, 1999. Banana weevil,* Cosmopolites sordidus *(Germar), ovipositional preferences, timing of attack and larval survivorship in a mixed cultivar trial in Uganda. Acta Horticulturae. (in press).

Abera, A.M.K., C.S. Gold & S. Kyamanywa, 1999. Timing and distribution of attack by the banana weevil (Coleoptera: Curculionidae) in East African Highland Banana (*Musa *spp.) Florida Entomologist: 82:631-641.

Danso, W.O., K.R. Green, S. Adjei-Nsiah & K. Afreh-Nuamah. Economic evaluation of alternative production systems for plantain (*Musa *spp., AAB group) in Ghana. African Crop Science Journal (submitted)

Economic feasibility and profitability of alternative production strategies for plantain in Ghana were evaluated and compared with traditional practices. On-farm trials were established in three plantain-production regions of Ghana (1997-1999) to study the effects of clean planting material and improved management practices on the growth and yield of plantain. The use of hot water-treated suckers or nursery-derived suckers, together with regular weeding and optimum plant spacing, was the most profitable despite higher production costs, reflecting higher yields for the duration of the experiment in comparison with other treatments ($P<0.001$). Within planting material treatments, improved management practices gave higher yields and value/ha than farmers' management practices, although the highest economic returns were obtained when improved management was combined with the use of clean planting material. The use of hot water-treated suckers and improved crop management gave an economic return of cedis 2.1 million/ha ($808/ha) compared with cedis 1.3 million/ha ($500/ha) obtained for untreated planting materials under farmers' management, representing net additional returns of cedis 0.8 million/ha ($308/ha).

Elsen, A., P.R. Speijer, R. Swennen & D. De Waele. Nematode densities, root damage and yield of bananas (*Musa *spp.) cultivated in Uganda. African Plant Protection (in press).

Gauhl, F., C. Pasberg-Gauhl, A. Bopda-Waffo, J.d'A. Hughes, & J.S. Chen, 1999. Occurrence of banana streak badnavirus on plantain and banana in 45 villages in southern Cameroon, Central Africa. Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz 106: 174-180.

Plantain (*Musa*, AAB group) fields in 45 villages in southern Cameroon were surveyed in 1996 for the occurrence of banana streak badnavirus (BSV). No banana plant was observed with any virus-like symptoms. Plantain plants showing BSV-like symptoms were found in 25 villages. The incidence of symptomatic plantain plants in the villages ranged between 0.5% and 7.5% (mean 1.2%). Of the 21 symptomatic and six composite symptomless plantain leaf samples indexed by ELISA for both BSV and cucumber mosaic virus (CMV), 11 symptomatic and one symptomless sample tested positive for BSV. Only one symptomatic sample tested positive for CMV. Indexing by ISEM detected BSV particles in all six symptomless samples. The survey results indicate that BSV is common on plantain in southern Cameroon.

Gauhl, F, C. Pasberg-Gauhl, B.E.L. Lockhart, J.d'A. Hughes & G. Dahal, 1999. Incidence and distribution of banana streak badnavirus in the plantain production region of southern Nigeria. International Journal of Pest Management 45: 167-171

Plantain orchards in the major plantain production area in southern Nigeria were surveyed in 1995 for the occurrence of banana streak virus (BSV) disease. Plantain plants showing BSV-like symptoms were found in 37 of 71 villages visited and in 49 of 147 orchards. BSV was positively identified by ISEM and/or ELISA in 30 orchards in 27 villages. The incidence of symptomatic plants in an orchard ranged from 1 to 17% (mean 4.2%). Of 58 leaf samples taken from plants with symptoms and indexed for both BSV and cucumber mosaic virus (CMV), 36 (62%) tested positive for BSV and none tested positive for CMV. The survey results show that BSV is common and widespread in the plantain-growing area of southern Nigeria.

Godonou, I., K.R. Green, K.A. Oduro, C.J. Lomer & K. Afreh-Nuamah, 1999. Field evaluation of selected formulations of* Beauveria bassiana *for the management of the banana weevil (*Cosmopolites sordidus*) on plantain (*Musa *spp., AAB group). Biocontrol Science and Technology (submitted).

The banana weevil is a major constraint to the production of plantain (*Musa* spp. AAB group), an important staple crop in the humid forest zone of Ghana. Microbial control using the fungus *Beauveria bassiana* was considered to be the most promising alternative to chemical insecticides for small-scale plantain production in Ghana. Field experiments were undertaken to determine the efficacy of two formulations of *B. bassiana* isolate IMI331094 against *C. sordidus*. Oil palm kernel cake-based formulation of conidia (OPKC-C) and conidial powder (CP) were applied to the planting holes and suckers. After artificial weevil release, OPKC-C and CP gave the same high level of weevil mortality (75%) compared with only 1% in the untreated control. Under natural weevil infestation, 42% of weevils collected from suckers treated with OPKC-C died compared with 6% and 3% weevil mortality for CP and the untreated control, respectively. None of the suckers treated with OPKC-C died during the study period (60 days) while 17% and 19% of suckers from the CP treatment and the untreated control respectively, were killed. A study on the spread of fungal conidia using artificially-infected and non-infected adult weevils showed a possible dissemination of *B. bassiana* conidia from infected weevils up to 18 m from the release point. On the basis of these results, the isolate IMI330194 of *B. bassiana* could clearly play a key role in the management of *C. sordidus* adults on plantain.

Gold, C.S., E.B. Karamura, A. Kiggundu, A.M.K. Abera, F. Bagamba, M. Wejuli, D.Karamura, R. Ssendege & R. Kalyebara, 1999. Geographic shifts in highland banana production in Uganda. Acta Horticulturae (in press).

Gold, C.S., M.I. Bagabe & R. Ssendege, 1999. Banana weevil,* Cosmopolites sordidus *(Germar): (Coleoptera: Curculionidae) tests for suspected resistance to carbofuran and dieldrin in Masaka District, Uganda. African Entomology 7:189-196.

Gold, C.S., P. Nemeye & R. Coe. 1999. Recognition and duration of larval instars of banana weevil,* Cosmopolites sordidus *Germar, in Uganda. African Entomology 7:49-62.

Gold, C.S., E.B. Karamura, A. Kiggundu, F. Bagamba & A.M.K. Abera, 1999. Monograph on geographic shifts in highland banana (*Musa*, group AAA-EA) production in Uganda: Site and data summaries. African Crop Science Journal 7:223-298.

Gold, C.S., E.B. Karamura, A. Kiggundu, F. Bagamba & A.M.K. Abera, 1999. Geographic shifts in highland cooking banana (*Musa *spp., group AAA-EA) production in Uganda. Int. J. Sustainable Agriculture and World Ecology 6:45-59.

A multi-disciplinary study was conducted at 9 central and 6 southwestern sites to document shifts in cooking banana production and to elucidate the causes behind these shifts. Cooking banana production in central Uganda sites fell from 18% of total food crop and 7% of total cash crop production in the 1970s to 4% and 2%, respectively in the 1990s. Farmers identified reduced labor availability and management, increasing pest pressure and declining soil nutrient status as the major causes of decline. On-farm verification confirmed farmers observations: Weevil levels were the highest yet found in Uganda while foliar samples indicated nutrient deficiencies in Mg, N, and K. Soil nutrient deficiencies, however, appear to be a direct outcome of reduced management rather than "soil exhaustion" as postulated by farmers.

In southwestern Uganda, the importance of cooking banana as a cash crop has quadrupled since 1970. Banana first penetrated the region because of ease in production and stability of yield. High yields attracted traders and urban market demand drove further crop expansion. With current market incentives, banana management standards have been high. Under current levels of management, it is unlikely that farmers in southwestern Uganda will experience a similar process of decline as that which occurred in the central region. However, concern remains about lack of replenishment of nutrients leaving the farm in the form of fruits sold for market which may eventually lead to a non-sustainability situation.

Kangire, A., C. Gold, E.B. Karamura & M.A. Rutherford,1999. Fusarium wilt of banana in Uganda, with special emphasis on East African highland cooking cultivars (*Musa *AAA-EA). Acta Horticulturae (in press).

Karamura, D., B. Pickersgill, D. Vuylsteke, C. Gold, E. Karamura & A. Kiggundu, 1999. Multivariate analyses of supposed duplicate accessions of East African Highland bananas in germplasm collections in Uganda. Acta Horticulturae (in press).

Rajab, K.A., S.S. Salim & P.R. Speijer. Plant-parasitic nematodes associated with* Musa *in Zanzibar. African Plant Protection (in press).

Rukazambuga, N.D.T.M., C.S. Gold & S.R. Gowen, 1999. Yield loss in East African highland banana (*Musa *spp., AAA-EA group) caused by the banana weevil,* Cosmopolites sordidus *Germar. Crop Protection 17: 581-589.

Yield loss in highland banana due to the banana weevil, *Cosmopolites sordidus,* was studied in field trials in Uganda. Weevils were released at the base of banana mats 9 months after planting. Weevil populations, corm damage, plant growth and yield were assessed over four crop cycles. The effect of damage was greater on bunch weight than on plant growth and rate of development. Yield loss increased with crop cycle and ranged from 5% in the first cycle to 44% in the fourth cycle. The cumulative effect of heavy damage sustained over several crop

cycles resulted in greater reduction in bunch weight than that inflicted by similar levels of damage in a single cycle. The data suggest that *C. sordidus* damage is a leading cause of highland banana decline and disappearance in central Uganda.

Schill, P.S., K. Afreh-Nuamah, C.S. Gold & K. Green, 1999. Farmer perceptions of constraints to plantain production in Ghana. International Journal of Sustainable Development and World Ecology (in press).

Speijer, P.R. & F. Ssango, 1999. Evaluation of* Musa *host plant response using nematode densities and damage indices. Nematropica 29: 189-196.

Speijer, P.R., E. Boonen, D. Vuylsteke, R.L. Swennen & D. De Waele, 1999. Nematode reproduction and damage to* Musa *sword suckers and sword sucker derived plants. Nematropica 29: 197-207.

Speijer, P.R., J. Mudiope, F. Ssango, & E. Adipala. Nematode damage and densities at different plant growth stages of East African highland banana (Musa AAA), cv Mbwazirume. African Plant Protection (submitted).

Nematode damage was assessed on different growth stages of the East African Highland banana (*Musa* AAA, 'Matooke' group) cultivar Mbwazirume, grown in nematode infested and non-infested plots under three crop management regimes. The banana plants were grown for a period of three years either well mulched, cleanly weeded or intercropped with finger millet. Root and rhizome damage and nematode densities were measured of recently flowered plants, suckers detached from recently flowered plants and suckers detached from recently harvested plants. Damage was assessed as percentage dead roots, percentage root necrosis and percentage root bases with lesions. Significantly higher root and rhizome damage was observed in the infested plots compared to the non-infested plots. *Radopholus similis* and *Helicotylenchus multicinctus* were significantly higher in roots detached from infested plants compared to non-infested plants. Nematode damage on banana plants can be best assessed using suckers detached from recently harvested plants. For this crop stage damage and nematode densities were least influenced by crop management. Crop management significantly influenced root necrosis for recently flowered plants and dead roots, root necrosis and *H. multicinctus* densities for suckers detached from recently flowered plants. Crop management may influence plant tolerance for nematodes because suckers grown in well mulched plots produced significantly more roots in infested plots compared to non-infested plots.

Speijer, P.R., F. Ssango, C. Kajumba, & C.S Gold. Optimum sample size for Pratylenchus goodeyi (Cobb) Sher and Allen density and damage assessment in highland banana (Musa AAA) in Uganda. African Crop Science Journal (submitted).

The optimum sample size for assessment of nematode densities and related damage in East African highland banana was estimated at Kikoni parish in Ntungamo district, Uganda. Kikoni parish is at an elevation ranging from 1360 to 1480 meter above sea level and the East African highland banana (*Musa* AAA, Matoke and Mbidde groups) is the dominant crop. The parish is approximately 10 km^2 in size, with an estimated total of 500 farms. Out of these farms, 24 were randomly selected and a minimum of 15 plants per farm were sampled. Root samples were collected from recently flowered plants, assessed for root damage and nematodes were extracted from the scored root segments. Hierarchical classification analysis was performed on the values for density and damage to calculate the coefficient of variation and the method of maximum curvature was used to determine the optimum number of farms in the parish and number of banana plants within each farm for nematode density and damage assessment. *Pratylenchus goodeyi* was the dominant species with densities ranging from 500 to 25,000 per 100g fresh root weight, while the percentage dead roots ranged from 0.8% to 14.0% and the percentage root necrosis from 1.1% to 17.1%. The optimum numbers established, were three farms within the parish and five recently flowered banana plants in each farm.

Speijer, P.R., C. Kajumba & F. Ssango, 1999. East African Highland banana production as influenced by nematodes and crop management in Uganda. International Journal of Pest Management, 45: 41-49.

Production loss caused by nematodes in East African highland banana was evaluated at Sendusu, near Kampala in Uganda, 1120 m above sea level. The commonly grown cultivar Mbwazirume was grown in nematode infested and non-infested plots under heavily mulched, clean weeded and millet intercropped management regimes. Influence of the different treatments was evaluated over the second to the fourth crop cycle and management was observed to have the greatest influence on production. The non-infested heavily mulched plots produced 16.1 tonnes per ha per cycle compared to the clean weeded and non-infested millet intercropped plots only 5.6 and 5.3 tonnes per ha per cycle, respectively. Presence of *Radopholus similis* and *Helicotylenchus multicinctus* reduced the average production in the well mulched, clean weeded and millet intercropped plots by 30%, 32% and 38%, respectively. The nematode induced loss is a result of a reduction of bunch weight, a reduction of flower production and an increase in plant toppling. When plant toppling occurred on a mat, the chance was highly reduced that this mat produces a harvestable bunch in the following cycle. Damage by the banana weevil, *Cosmopolites sordidus*, was higher on nematode infested plants compared to non-infested plants. It may be that in nematode infested plants, weevil larvae are more successful in developing or that that adult weevils prefer nematode infested plants for egg disposal. No interaction between Black Sigatoka and nematode infestation was observed.

Thomas, J.E. M.L. Iskra-Caruana, L.V. Magnaye, D.R Jones, B.E.L. Lockhart, J.d'A. Hughes, M. Tessera & A.J. Quimio, 1999. Diseases caused by viruses. In: D.R. Jones (ed.) Diseases of Banana, Abaca and Enset. CABI Publishing.

Tushemereirwe W.K., M. Holderness, C.S. Gold & M. Deadman,1999. The leaf spot complex on highland bananas in Uganda. Acta Horticulturae (in press).

Conference papers, workshop proceedings, abstracts, newsletters

Brentu, C.F., 1999. Effect of nematode control techniques on the growth and yield of plantain (**Musa** ***AAB). M.Phil. Thesis, University of Science and Technology, Kumasi, Ghana.***

Brentu, C.F., P.R. Speijer, K.R. Green & B.M.S. Hemeng. Micro-plot evaluation of the pest status of **Pratylenchus coffeae, Helicotylenchus multicinctus** ***and*** **Meloidogyne** ***spp. on plantain (*****Musa** ***AAB, cv. Apantu-pa) in Ghana. SON-Conference Monterey, US, 2-6 July 1999***

The pest status of three nematode species was determined on Apantu-pa, the preferred cultivar of plantain (*Musa* AAB) in Ghana. Hot-water treated suckers, planted in 3 L bags containing sterilized soil, were inoculated one month after planting with a single species, a species mixture or not inoculated. Single species populations of *Pratylenchus coffeae*, *Helicotylenchus multicinctus* and *Meloidogyne* spp. were used at 1000 or 10,000 nematodes per plant or in a mixture of 3000 nematodes for each species per plant. Three months after planting, the inoculated suckers were transplanted into micro-plots (0.7m^3 concrete containers filled with sterilized soil). All species significantly (P<0.05) reduced the bunch weight, when compared to the non-inoculated control. High inoculation densities of *H. multicinctus* and *Meloidogyne* spp. reduced production by 26% and 30%, respectively, while the species mixture reduced production by 47%. Production losses exceeding 70%, compared to the control (P<0.05), occurred under high inoculation densities of *P. coffeae*. This reduction was, in particular a result of the high toppling incidence (60%) of plants carrying bunches in the *P. coffeae* infested plots. Given that *P. coffeae* is the most widespread and abundant nematode species on plantain in Ghana, it is evident that this species represents a major production constraint.

De Waele, D. & P.R. Speijer, 1999. Nematode resistance in **Musa*****. pp. 119-126 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.***

Godonou, I., 1999. The potential of **Beauveria bassiana** ***for the management of*** **Cosmopolites sordidus** ***(Germar, 1824) on plantain (*****Musa** ***AAB). Ph.D. Thesis, University of Ghana, Legon.***

Biological control of the banana weevil was considered the most promising management option for small-scale plantain production and studies were, therefore, undertaken to determine the efficacy of the entomopathogenic fungus, *Beauveria bassiana* (Bals.) Vuill. in the management of *C. sordidus*.

The duration and spatial distribution of the different developmental stages of *C. sordidus* within plantain plants were determined to provide background information for evaluation of *B. bassiana* against the banana weevil. The mean egg incubation time and the mean developmental period from larva to pupa and pupa to adult were 6.3 ± 0.2, 28 ± 0.6 and 7.1 ± 0.3 days respectively. The developmental period from egg to adult ranged from 33 to 51 days with a mean of 40.4 ± 0.7 days. Within the plantain plant, approximately 80% of the eggs were located in the rhizome, >80% of the larvae were found at the rhizome level and all of the pupated larvae were located in the rhizome, suggesting that this is where a biocontrol agent should be targeted, rather than the pseudostem.

Three strains of *B. bassiana* were obtained and evaluated on the basis of virulence tests and potential for mass-production. From the results of these tests, strain IMI330194 of *B. bassiana* was selected for subsequent studies. Laboratory studies using a water fungal inoculum applied to corm pieces or pseudostem traps, showed that *B. bassiana* could control all stages of *C. sordidus*, with up to 21.3%, 36.4% and 42.3% of eggs, larvae and adults respectively showing signs of fungal disease. Pot experiments to compare different formulations of the strain IMI330194 against adult weevils showed that the highest mortality (>60%) was obtained with groundnut oil plus kerosene-based formulation of improved conidial powder (GOK-ICP) or groundnut oil-based formulation of improved conidial powder (GO-ICP) or oil palm kernel cake-based formulation of conidia (OPKC-C), when tested immediately after application. A persistence trial showed that OPKC-C of IMI330194 still gave 61.0% weevil mortality one month after application compared with only 12.3% for improved conidial powder (ICP) of IMI330194 and 3.9% for control with no conidia. In field trials with artificial weevil release, mortality of adult weevils exposed to ICP of IMI330194 and OPKC-C of IMI330194 ranged from 53.4 to 75.5%, compared to <8% in control with no conidia. Under natural weevil infestation, 17.7% of plantain suckers treated with ICP of IMI330194 and 19.4% of untreated suckers were killed by weevil attack. In contrast, none of the suckers planted with OPKC-C of IMI330194 were killed. A study on the spread of fungal conidia using artificially infected and non-infected adult weevils showed a possible dissemination of *B. bassiana* conidia from infected weevils up to 18 m from the release point. On the basis of results from the present study, the strain IMI330194 of *B. bassiana* could clearly play a key role in the management of *C. sordidus* adults on plantain.

Godonou, I., O. Idohou, K.R. Green, J. Langewald & C. Lomer, 1999. Control of banana weevil, **Cosmopolites sordidus,** ***with*** **Beauveria bassiana** ***formulated on oil-palm kernel cake. Society of Invertebrate Pathologists Meeting, California, August 1999 (abstract).***

The principal constraints facing banana and plantain producers in West Africa are declining soil fertility, black

sigatoka disease, nematodes and banana weevils. IITA has developed varieties resistant to black sigatoka and a hot-water dip treatment reduced nematode infestation. We have recently developed a robust formulation of *Beauveria bassiana* produced on oil-palm kernel cake (OPKC) which provides good control of banana weevil during the first few months after planting.

The current technology needs further testing and implementation, and represents an advance over previous research in two areas – ease of production and persistence. The isolate, IMI330194 was selected because it is robust and was best able to resist invasion by application of three common contaminating fungi (*Aspergillus niger, Fusarium moniliforme* and *Penicillium hirsutum*) in the mass production system.

Compared with application of *Beauveria bassiana* spores as dry powder, *B. bassiana* on OPKC lasted several months. In a field trial with three replicates on 30m x 30m plots, none of the plantain suckers treated with *B. bassiana* on OPKC were killed, while 17 and 19% died from banana weevil attack in the dry powder treatments and controls respectively.

Green, K.R. & K. Afreh-Nuamah. Plantain IPM in Ghana: A case study. In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

The development of integrated pest management strategies is seen as a vital step towards improving the yields and plantation life of plantain, a preferred staple in Ghana. Farmer-participatory trials are an important component of ongoing research to address the major constraints namely, lack of planting material, nematodes and weevils. Techniques for the rapid multiplication of clean planting material (using split-corm methodology and nursery management) are now available to farmers. The use of clean suckers together with improved management lead to increased yields compared with traditional practices (>100 % increase at one site). Paring of planting material to control nematodes has been adopted by at least 40 % of plantain farmers at each of three villages but research is ongoing to determine whether this method is as effective as hot water treatment over time. Studies indicate the potential of the fungus *Beauveria bassiana* as a biological control agent for the banana weevil, and a substrate that can be used for the mass-production and application of the fungus has been identified. Options for the management of black sigatoka, weeds and viruses in Ghana are also being developed. Impact assessment has shown that techniques for improving plantain production that are now available to farmers are economically feasible and that farmers' perceptions are favorable. Widespread adoption is now being encouraged through a Plantain Farmer Field School initiative.

Green, K.R., S. Adjei-Nsiah, A. Mensah-Bonsu & K. Afreh-Nuamah. Proceedings of an International Symposium on Plantain and Banana for Food Security, Douala, Cameroon. November 1998 (in press).

The production of plantain, a preferred staple food in Ghana, is constrained by a pest and disease complex including nematodes and banana weevil. The effects of these biotic constraints are often compounded by the use of infested planting material. Farmer-participatory trials are on-going at three villages in Ghana to develop and test techniques for the production and rapid multiplication of clean planting material. Suckers are disinfested by paring or hot-water treatment and multiplied using a 'split-corm' technique, followed by germination and growth in nursery beds. A study was undertaken at the three villages, using structured questionnaire interviews, to evaluate farmers' perceptions of the methods being developed and to determine the resources, education and incentives that are needed to encourage widespread utilization of the technology. Results indicated that farmers are aware of the methods available and have seen that they can result in improvements in plantain production with respect to yield and plantation life. Paring of suckers, which is a simple, low cost technique, was particularly popular and has been adopted by at least 40 % of the plantain farmers in each of the villages studied. Nursery production and hot water treatment were also considered to be practices worthy of adoption, particularly in two of the villages. These findings represent progress since a participatory rural appraisal conducted in 1993, when farmers were unaware that infested planting material was the main cause of pest attack on plantain and planting material treatment was rarely undertaken.

Gold, C.S., N.D.T.R. Rukazambuga, E.B. Karamura, P. Nemeye & G. Night, 1999. Recent Advances in Banana Weevil Biology, Population Dynamics and Pest Status with Emphasis on East Africa. pp 35-50 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Hughes, J.d'A., 1999. Integrated management of viruses infecting* Musa *spp. In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Hasyim, A. & C.S. Gold. 1999. Potential of classical biological control for banana weevil,* Cosmopolites sordidus *Germar, with natural enemies from Asia (with emphasis on Indonesia). pp 59-71 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Holderness, M., W.K. Tushemereirwe & C.S. Gold. 1999. Cultural controls and habitat management in the integrated management of banana leaf diseases. pp 149-163 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Kangire, A., M.A. Rutherford & C.S. Gold, 1999. Distribution of Fusarium wilt and populations of **Fusarium oxysporum** *F. sp.* **cubense** *on bananas in Uganda. Proceedings of an International Seminar and Workshop on the Banana Fusarium Wilt Disease: Banana Fusarium Wilt Management towards Sustainable Cultivation. 18-20 October 1999. Gentings Highland Resort, Malaysia.*

Kaplan, D.T., W.K. Thomas, L.M. Frisse, J.L. Sarah, J.M. Stanton, P.R Speijer, D.H. Marin & C.H. Opperman, 1999. Towards resolution of the **Radopholus** *conundrum. SON-Symposium, Monterey, USA, 2-6 July 1999.*

Kashaija, I., R Fogain & P.R. Speijer, 1999. Habitat management and cultural controls. pp. 109-118 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

The paper discusses different crop management options to prevent or reduce nematode damage. The use of nematode free planting material can be very effective in the situation that parasitic nematode-free land is available. The use of mulches is highly effective in enhancing plant growth, through moister conservation and increase of nutrient availability. Mulches can greatly influence the nematode species profile through lowering the soil temperature. However the relative loss due to nematode attack remains similar. The use of break crops as cassava and sweet potato can significantly reduce the pre-plant nematode inoculum in the soil. The method is highly effective in the situation of high land pressure and when used in combination with the use of nematode free planting material. Various reports have been made of traditional and none traditional inter cropped repellent plants, however, few are of practical use.

Kiggundu, A., D. Vuylsteke & C.S. Gold. 1999. Recent advances in host plant resistance to banana weevil, **Cosmopolites sordidus** *Germar. pp 87-96 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.*

Mensah-Bonsu, A., K.R. Green, S. Adjei-Nsiah, E.K. Andah & K. Afreh-Nuamah. Proceedings of an International Symposium on Plantain and Banana for Food Security, Douala, Cameroon. November 1998 (in press).

An on-going project in Ghana aims to develop integrated management strategies that are appropriate for resource-poor plantain farmers and can be applied to reverse the reported decline in plantain yields and plantation life. An on-farm trial was established at three sites in Ghana to study the effects of clean planting material and improved management practices on the growth and yield of plantain. Economic analysis was conducted in conjunction with the trial at two sites, to determine whether the strategies implemented were profitable. The results showed that the use of hot-water treated suckers together with improved management practices (regular weeding and optimum plant spacing) and intercropping, led to improved and sustained yields in comparison with farmers' traditional practices. The management strategy was profitable over a three year period and adoption resulted in a return of approximately 2.99 million cedis / ha ($1294 / ha), representing a compensation of approximately 1.1 million cedis / ha ($475 / ha) compared with the use of untreated material and traditional management practices.

Niere, B.I., P.R. Speijer & R.A Sikora. Strains of **Fusarium oxysporum** *improve plant health of tissue cultured bananas. Second International Fusarium Biocontrol Workshop, September 15 -17, 1999, Dijon, France.*

Fusarium is the dominant fungal genus colonizing roots and corms of the banana cultivar Pisang Awak (Musa ABB). *Fusarium* spp. contribute to 18% (roots) to 38% (inner corm tissue) of all fungi isolated, with *Fusarium oxysporum* being the single most common species isolated from banana tissue. None of the sampled plants showed symptom of wilting, although Pisang Awak is highly susceptible to the banana wilt pathogen, *F. oxysporum* f.sp. *cubense* (FOC). It is believed that the majority of *F. oxysporum* isolates colonizing banana rhizomes are non-pathogenic. VCG testing of these isolates with all known testers for the forma specialis *cubense* are being undertaken to verify these findings.

Strains of *F. oxysporum* have been isolated from Ugandan banana roots and inoculated onto tissue cultured plantlets. Beneficial effects of endophytic isolates on bananas include reduced nematode multiplication and damage, and enhanced plant growth at an early stage of plant development. Results on the biocontrol of Fusarium wilt of the banana cultivars Sukali Ndizi (*Musa* AB) and Gros Michel (*Musa* AAA), both susceptible to FOC race 1, are pending.

In banana, the technique of fungal endophyte inoculation can easily be incorporated into the existing delivery system of tissue culture planting material and as such contributes to a technology improvement. Plant health improvement through the use of fungal endophytes is a novel and promising approach to sustainable banana production.

Niere, B.I., P.R. Speijer & R.A Sikora. Novel approach to the biological control of banana nematodes. Deutscher Tropentag 1999, October 14 – 15, 1999, Berlin, Germany.

Plant parasitic nematodes cause considerable losses in East African Highland Banana. The use of clean planting material, such as hot water treated suckers and tissue-cultured plants, is the best way to control nematodes.

Chemical control with nematicides, beside their detrimental effect on human health and the environment, is often prohibitively expensive to small-scale farmers serving local markets. Plant health improvement of tissue cultured plants through the use of fungal endophytes is a novel and promising approach to sustainable banana production. Ideally, endophytes once applied protects the plant from inside against pests and diseases and subsequent applications of the biocontrol agent are not necessary. Fungal endophytes have been shown to have biological control activity towards a range of pests and disease in many crops. In banana, beneficial effects of fungal endophytes include: reduced nematode multiplication and damage and enhanced plant growth at an early stage of plant development. The technique of fungal endophyte inoculation can easily be incorporated into the existing delivery system of tissue culture planting material and as such contributes to a technology improvement. Interactions of the fungal isolate and the banana clone have been observed and on station trials are being conducted in Namulonge, Uganda to evaluate the most promising fungal isolates.

Niere, B.I., P.R. Speijer & R.A Sikora. Mutualistic endophytic fungi - role in biocontrol and safety of application. Workshop on Tri-Trophic Interactions in the Rhizosphere and Root-Health, IOBC/OIBC Study Group Meeting, November 3 – 5, 1999, Bonn/Bad-Honnef, Germany.

The use of *Fusarium oxysporum* strains in biological control systems largely depends on their non-pathogenicity to the respective host plants. To differentiate between non-pathogenic root colonizers and pathogenic forms, pathogenicity testing on differential cultivars and vegetative compatibility grouping (VCG) was applied to potential biocontrol strains of *F. oxysporum*. None of the isolates caused disease symptoms on banana, or tested vegetatively compatible with all known VCG testers of *F. oxysporum* f.sp. *cubense*, attacking banana. These results indicate that the strains of *F. oxysporum* used in biocontrol of plant parasitic nematodes are truly non-pathogenic to banana and corroborate their important role in modern tissue culture propagation systems.

Niere, B.I., P.R. Speijer & R.A Sikora. Mutualistic fungal endophytes from bananas for the biological control of* Radopholus similis. *In: European Society of Nematologists (eds). Proceedings of the 24th Conference, held at Dundee, Scotland, UK 3-9 August 1988 (in press).

Mutualistic fungal endophytes have been shown to have biological control activity toward plant parasitic nematodes in banana. Endophytes were isolated from Ugandan banana roots and screened in vitro. Culture filtrates of some of the fungal isolates were able to inactivate and cause mortality of *Radopholus similis*. Especially isolates of *Fusarium oxysporum* and *F. solani* were shown to be highly effective in immobilizing nematodes in vitro. Four isolates of *F. oxysporum* were inoculated singly onto tissue cultured banana plants (*Musa* AAA, cv Bogoya) by dipping plantlets at the weaning stage in a spore suspension of 10^6 spores/ ml. After transplanting from the humidity chamber to the shade house, re-colonization of the plants by the endophytes was detected. The plants were inoculated 3 months after weaning with a nematode suspension containing *R. similis* and *Helicotylenchus multicinctus*. Results on nematode penetration and multiplication as well as the effect of endophytes on plant growth parameters will be presented.

Niere, B., P.R. Speijer, C.S Gold & R.A. Sikora, 1999. Fungal endophytes for the biocontrol of nematodes. pp. 313-318 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Endophytes isolated from Ugandan banana roots were screened in vitro for biological control activity toward plant parasitic in banana. Culture filtrates of some of the fungal isolates were able to inactivate and cause mortality of Radopholus similis. Especially isolates of Fusarium oxysporum were shown to be highly effective in immobilizing nematodes in vitro. Four isolates of F. oxysporum were inoculated singly onto tissue cultured banana plants (cv. Gros Michel) by dipping plantlets at the weaning stage in a spore suspension of 10^6 spores/ml. After transplanting from the humidity chamber to the shade house, re-colonization of the plants by the endophytes was detected. Thirteen and 32 weeks after weaning, root segments of 3 equally developed roots were encased in 100 ml cups and inoculated with R. similis females. Root and plant health assessment as well as nematode extraction took place 6 weeks after inoculation. Mutualistic effects of the inoculated fungal endophytes have been shown in vivo. At the plant age of 19 weeks, one isolate of F. oxysporum effectively reduces multiplication of nematodes on the root level while plants inoculated with another isolate show enhanced plant growth. In 32 weeks old plants inoculated with endophytes, plant growth promoting effects could not be observed but nematode multiplication was reduced in plants inoculated with two of the four isolates of F. oxysporum.

Okech, S.O., E.B. Karamura & C.S. Gold. 1999. Banana IPM in Uganda. pp 225-236 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Seshu Reddy, K.V., C.S. Gold & L. Ngode. 1999. Cultural control strategies for banana weevil. pp 51-57 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Speijer, P.R., 1999. Clean planting materials for bananas and yams. Agriforum 9: 4.

Speijer, P.R., C.S. Gold & J. Dusabe, 1999. Relative importance of nematodes, weevils (*Cosmopolites sordidus*)

and leaf diseases as* Musa *production constraints in central Uganda. Proceedings of the 14th Symposium of the Nematological Society of Southern Africa, 30 May – 2 June 1999, Dikhololo, South Africa: 16.

Speijer, P.R., C. Kajumba, & J. Dusabe, 1999. Nematode induced production loss for the cultivars Nabusa (*Musa *AAA, 'Matooke' group), Pisang Awak (*Musa *ABB) and Sukali Ndizi (*Musa *AB) in Uganda. In: Proceedings of the 14th Symposium of the Nematological Society of Southern Africa, 30 May – 2 June 1999, Dikhololo, South Africa: 32.

Speijer, P.R., Ch. Kajumba & T. Tushemereirwe. Dissemination and adaptation of a banana clean planting technology in Uganda. In: INIBAP, Proceedings International Symposium Bananas and Food Security, held at Douala, Cameroon, 10-14 November 1998 (in press).

In1993 the technology of hot water therapy to free banana planting material from plant parasitic nematodes was introduced into Uganda. The method itself is highly effective and can increase banana production by 30% or more in the first crop cycle, when compared to farmers standard material. Over 3000 farmers have established small plots with heat disinfested material over the last five years. The major channel of dissemination were farmer trainings and demonstration given by the Ugandan National Banana Program/International Institute of Tropical Agriculture. The major adaptation of the technology was the use of tall (>1 m in pseudostem length) type of planting material, *versus* the originally short (<15 cm in pseudostem length). The benefits farmers observe of the technology is the increase of bunch weight, increase in sucker production and reduction of bunch loss due to plant toppling. The disadvantage if the technology is the level of organization required for treatment, as generally treatment is done for groups of over 100 farmers on one day. The technology may be more sustainable at village level when the tank, required for treatment, has multiple uses for example the treatment of yam planting material or curing of vanilla.

Speijer, P.R. & R. Fogain. Musa and Ensete nematode pest status in Africa. pp. 99-108 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Evaluation of various surveys in *Musa* in Africa provided the following trends. The most common occurring nematode species are *Helicotylenchus multicinctus*, followed by *Meloidogyne* spp. *Radopholus similis* generally occurs in 30% to 50% of the samples, with an exception of central Uganda, where the nematode is widely distributed and found in 70% or more of the samples. Its occurrence rapidly declines over 1400 masl. *Pratylenchus goodeyi* is a typical highland nematode and rarely observed below 800 masl. *Pratylenchus coffeae* and *Hoplolaimus pararobustus* appear in pockets in Africa. *Pratylenchus coffeae* is very common in Ghana and Nigeria, while high incidence of *H. pararobustus* is restricted to Nigeria and Cameroon. The most common nematode pest associated with *Ensete* is *P. goodeyi*. The species, *H. multicinctus, R. similis, P. coffeae* and *P. goodeyi*, all appear to be associated with production losses ranging from 30% to over 80% per cycle. The widest spread *Musa* groups in Africa, plantain and highland banana, are highly susceptible and incur large annual losses. Production losses are more severe in the lower elevation zones of Africa, compared to the highland zones. Production loss of *P. goodeyi* to *Ensete* needs to be established.

Speijer, P.R., F. Ssango & D. Vuylsteke, 1999. Field evaluation of Musa germplasm for nematode resistance and tolerance in Uganda. SON-Symposium, Monterey, USA, 2-6 July 1999.

Speijer, P.R., A. Tenkouano, T. Dubois, B. De Schutter & D. De Waele, 1999. Evaluation of Musa landraces and hybrids for nematode resistance and tolerance in southeastern Nigeria. SON-Symposium, Monterey, USA, 2-6 July 1999.

Ssango, F. & P.R. Speijer, 1999. Path analysis of nematode densities, nematode and weevil damage indices in relation to bunch weight of East African highland banana (*Musa *AAA) under two-field management practices. SON-Symposium, Monterey, USA, 2-6 July, 1999.

Ssennyonga, J., F. Bagamba, C.S. Gold, W.K. Tushemereirwe, E.B. Karamura & E. Katungi. 1999. Understanding current banana production with special reference to integrated pest management in southwestern Uganda. pp 291-310 In: E. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a wokshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998. INIBAP. Montpellier.

Talwana, H.L., P.R. Speijer & D. De Waele, 1999. Spatial distribution of nematode population densities and nematode damage in roots of three banana cultivars in Uganda. In: Proceedings of 4th African Crop Science Conference, 11-14 October 1999, Casablanca: 37-38.

Van Woensel, G. 1999. Invloed van abiotische omgevingsfactoren op de reproductie, pathogeniciteit en competitie tussen bananen nematoden in Oeganda. MSc. thesis. Eindverhandeling Katholieke Universiteit Leuven, Belgium, 171 p.

Plant protection related activities of Project 5

IMPROVING YAM-BASED SYSTEMS

by R. Asiedu (project coordinator), J.d'A. Hughes, A.M.W. Manyong, J.C. Meerman, H.D.M. Mignouna, N.Q. Ng, S.Y.C. Ng, P.R. Speijer, G. Tian, P. Vernier,
assisted by O. Azeez, T. Ogunjobi, I. Rotifa

Project rationale

In many yam-growing areas, the most serious constraints to productivity are the high costs of planting material and of labor for field operations. Increased pressure for land resulted in shortened fallow with the subsequent decrease in soil fertility and increase in pest and disease levels. Among others, nematodes cause yield reductions in the field, and losses continue during storage leading to increased losses of food quality and quantity as well as of planting materials for the following growing season. This damage worsens by the interactions of nematodes with fungal and bacterial pathogens. Resistant varieties are needed to reduce losses due to pests and disease attacks. In addition, methods to improve cultural practices will add to optimal use of available resources.

The objectives of this study are to introduce strategies for non-chemical control of nematodes in the field and during storage, to develop and apply methods resistance screening to nematodes, and to defining geographical distribution of nematodes affecting yams and their impact on production.

Outputs

5.1. Characterization of biological and socio-economic constraints in yam-based systems and farmers management strategies

On-going and future activities

5.1.1. Evaluate distribution and severity of yam pests and diseases in West Africa

by J.d'A.H. - in collaboration with L. Kenyon, S.K. Offei, J. Peters, O.J. Olatunde

Yam virus surveys were carried out in 1998 and 1999 in the major yam growing areas of Ghana. Yam plants were scored for symptom type, symptom incidence and symptom severity. Leaf samples were collected from *Dioscorea* species plants that showed different virus-like symptoms and from symptomless plants for virus indexing. They were tested for the presence of yam viruses by enzyme-linked immunosorbent assay (ELISA). The leaf samples were tested *for Yam mosaic virus* (YMV), genus *Potyvirus, Dioscorea alata virus* (DaV), genus *Potyvirus, Dioscorea latent virus* (DLV), genus *Potexvirus, Dioscorea alata virus* (DaBV), genus *Badnavirus, Dioscorea dumetorum virus* (DDV), genus *Potyvirus, Dioscorea bulbifera virus* (DbBV), genus *Badnavirus* and *Cucumber mosaic virus* (CMV), genus *Cucumovirus*. Triple antibody sandwich (TAS-) ELISA, using monoclonal antibodies previously raised at IITA, was used to detect YMV in the yam leaf samples. Protein A sandwich (PAS-ELISA) was used with the specific polyclonal antisera to detect the other six yam viruses.

The majority of the yam leaves expressed virus-like symptoms. The most common symptoms were mosaic, leaf chlorosis and mottling. YMV was detected in over half (59%) of the symptomatic leaf samples of *D. rotundata* but in less than 1% of the symptomatic *D. alata*. Only 28% of the *D. rotundata* samples from Volta Region were infected with YMV while in the rest of the yam-growing region of Ghana (Eastern, Central, Western, Brong-Ahafo and Ashanti Regions) over 70% of the samples were infected. DaV was found to infect *D. alata* but not *D. rotundata*. Even in *D. alata* the incidence was less than 1%. None of the other viruses for which the samples were tested were found during the survey. The symptoms of YMV and DaV were found in young yam shoots soon after germination. The infection was therefore unlikely to have been caused by vector transmission but by virus present in the tubers derived from virus-infected mother plants.

Over 90% of the symptomatic leaves of *D. alata* and 42% of the symptomatic *D. rotundata* leaves failed to test positive for any of the seven viruses for which they were screened. This implies that there are pathogens (probably viruses, viroids or phytoplasmas) that are the causal agents of the virus-like symptoms and that have yet to be characterized.

5.1.2. Establishment of the geographic distribution of yam nematode pests in the Republic of Benin

by J.C.M., P.R.S., P.V., R.A. – in collaboration with A. Tchabi, M. Gumedzoe*

A total of 6 locations were selected within the yam producing area of Benin. From 39 farmers fields yam tuber samples and soil samples were collected from early and late maturing cultivars. Note was taken whether the yam was grown after slash and burn (S1), or in a so-called S2 crop rotation with cereals (mainly maize / sorghum). Scores were taken for presence of nematodes and insect, and yield data was recorded. Preliminary results from the milked cultivars (October 1999) show that the incidence of *Meloidogyne* spp. is very low. *Scutellonema bradys* appears to be the major plant parasitic nematode affecting yam in Benin being present in 67 % of the sampled farmer fields. No plant-parasitic nematodes were detected in the soil. Cultivar and regional variation seems to exist as the infection rate varied from 250 to 330.000 nematodes per 100 gram yam tissue.

5.1.3. Establishment of the geographic distribution of yam nematode pests in East Africa

by J.C.M., P.R.S., P.V., R.A. – in collaboration with A. Tchabi, M. Gumedzoe*

A partial picture of the geographic distribution of nematodes affecting yam is available for Uganda. *Pratylenchus sudanensis* dominated the samples taken from various cultivars in the major yam growing regions of Uganda. *Meloidogyne* spp. were observed in low densities, and no *S. bradys* was found in any of the samples. Priority of sampling has been shifted to Rwanda, Tanzania and Zanzibar as there are no descriptions of the nematodes associated with yam are available for those countries. Staff of the national program in Kagera region in Tanzania has been trained in nematode extraction techniques in order to send fixed samples to Uganda for identification and counting.

5.2. *Development and evaluation of strategies for integrated control of pests and diseases in yam-based systems*

On-going and future activities

5.2.1. Screen yam germplasm for resistance to field and storage pests/diseases

by R.A., J.d'A.H., N.Q.N. - in collaboration with A. Oladiran, B. Odu

All the 24 *D. rotundata* accessions planted in 1998 were planted in a screenhouse for re-evaluation. After mechanical inoculation of these accessions with YMV, TDr 95-115, TDr 95-128, TDr 93-48, TDr 93-46 exhibited no symptoms and tested negative for the virus by ELISA. Furthermore, these four accessions, together with TDr 93-49, TDr 35, and TDr 2224, remained uninfected when inoculated with YMV using the vectors *Toxoptera citricidus*, *Aphis craccivora* and *Rhopalosiphum maidis*. Eighteen newly collected accessions of *D. rotundata* landraces were planted in a screenhouse and subsequently indexed serologically for infection by YMV, DaV and CMV. Seven accessions that tested negative for virus infection were mechanically inoculated with YMV. All the seven clones tested negative when indexed serologically. These will be further evaluated in a screenhouse in 2000. Twenty of the *D. rotundata* accessions evaluated in 1998 and two breeder's lines (susceptible checks) were planted at four sites in Nigeria: Ubiaja, Ibadan, Abuja, and Jos. These sites represent the Forest, Forest/Savanna Transition, Southern Guinea Savanna, and Mid-altitude Savanna ecologies, respectively. The accessions have been scored for virus symptom incidence and severity.

Thirty-two accessions of *D. alata* were inoculated with YMV both mechanically and by aphid vectors in a screenhouse. Two accessions, TDa 291 and DAN 087, did not show symptoms of virus infection after inoculation, and tested negative serologically. The number of *D. alata* accessions evaluated at Ibadan during 1998 planting season was increased to 41 and these were planted for evaluation in March at Ibadan. These genotypes (39 landraces and 2 breeder's lines) were scored for virus symptom incidence and severity at about one month after emergence. Further scoring was not possible as the field was infected with anthracnose (*Colletotrichum gloeosporioides*) which masked the virus symptoms.

In vitro plantlets of wild and semi-domesticated *Dioscorea* species were transplanted into controlled temperature room at 22-24°C and with supplementary lighting in order to 'harden' them. These were indexed serologically and one accession of each of the following species tested negative for the presence of YMV: *D. praehensilis*, *D. togoensis*, *D. bulbifera*, *D. hirtiflora* and *D. abyssinica*. The accessions of *D. bulbifera* and *D. togoensis* have been mechanically inoculated with YMV to test for resistance to the virus. The inoculated plants will be serologically indexed.

Controlled crosses were made between male and female parents (total of 11) selected from the *D. rotundata* landraces under evaluation in the multi-site trial. Selection of parents was based on results obtained from last year's evaluation for resistance. F_1 progenies from the various cross combinations

(resistant x susceptible, resistant x resistant and susceptible x susceptible) will be assessed in a screenhouse in 2000 for seed-transmitted viruses and for reaction to inoculation with YMV.

5.2.2. Characterize yam pathogens; study the aetiology and epidemiology of pests and diseases of yams

by R.A., J.d'A.H., N.Q.N. - in collaboration with A. Oladiran, B. Odu, G.I. Atiri, L.N. Dongo

In addition to *A. gossypii, A. craccivora, R. maidis* and *T. citricidus*, the ability of four new vectors to transmit YMV has been confirmed. These are *A. spiraecola, Pentalonia nigronervosa, T. aurantii* and *R. nymphaea*. Virus-tested plantlets of TDr 87/00211 (a YMV-susceptible breeder's line of *D. rotundata*) were used in this study and the mosaic symptoms characteristic of YMV-infected TDr 87/00211 were induced after vector transmission.

Symptoms were induced in *Vigna unguiculata* after mechanical inoculation from leaves of *D. alata* showing symptoms of mild chlorosis collected from Nassarawa State and leaves with chlorotic mottling collected from Benue State (both in the Southern Guinea Savannah).

Yam virus 59 (from Benue State) induced symptoms of bleaching, leaf distortion and puckering on *V. unguiculata* cv. IT84s – 2114. The cowpea reacted with mild bleaching one week after inoculation and then puckering, leaf distortion and subsequently severe bleaching occurred.

Yam virus 121 (from Nassarawa State) induced symptoms of chlorosis, and green vein-banding on *V. unguiculata* cv. TVu 2657 after mechanical inoculation. The virus induced pinpoint lesions on inoculated leaves of *Chenopodium murale* three days after inoculation. Systemic chlorotic lesions were observed on *C. quinoa* and *C. amaranticolor* also three days after inoculation. The symptoms were persisted on systemically infected leaves throughout the life of the plants. This virus also caused symptomless infection of *Gomphrena globosa, Datura stramonium* and *Nicotiana benthamiana*. Infection of *Glycine max* cv. *Malayan* resulted into severe leaf distortion and puckering.

Yam virus 106, also from Nassarawa State, was isolated from a leaf sample showing symptoms of necrosis. Symptoms of mild mottling were induced on *V. unguiculata* cv. TVu 76 after mechanical inoculation.

All three virus isolates were found to be transmissible by aphids to herbaceous indicator plants. Serological studies indicated that the isolates were distinct although serologically related, and probably could be referred to as strains. Serolpgical tests also indicate that the isolates are members of the genus *Carmovirus*. Yam viruses 59, 121 and 106 have been tentatively named *Dioscorea mottle virus* (DMoV), genus (?) *Carmovirus* - mild mottle strain (DMoV-MM), mild chlorosis strain (DMoV-MC) and necrosis strain (DMoV-N) respectively based on the symptoms exhibited by the host plants

5.2.3. Improvement of the methodologies for screening of yam host plant response to nematodes.

by J.C.M., P.R.S., R.A., S.N. – in collaboration with B. Kayode, J. Mudiope**

In Nigeria, tests to establish the possibility of *S. bradys* to maintain and multiply itself on yam tissue culture plantlets and to show damage symptoms *in vitro* have been set up using TDr 131 and TDr 179. One month old yam plantlets obtained from tissue culture were inoculated with 50 or 100 surface-steriled nematodes in sterilised test tubes. Extraction of roots and growth media after one month show very few life nematodes and no symptom expression yet. Further experiments will be set up to increase the rate of recovery, and possibly multiplication of the nematode, using different inoculation densities and culture methods.

Experiments have been set up also in Uganda, to compare nematode densities from roots and corresponding tubers after a growing period of four months to establish a relationship between nematode numbers found in the soil, root and tubers and their related symptoms.

5.2.4. Assessment of hot water therapy of seed yams in collaboration with NGO's and pilot farmers

*by J.C.M., P.R.S., R.A. - in collaboration with S. Akele, A. Nwankpuma, Y. Taylor, A. Yussuf,d J. Mudiope**

In southern Nigeria, the 1998 trials were repeated on-farm in Oyo North and Kwara State (farmer managed) and in Ebony and River States (extension officer managed). In all trials hot-water treated tubers gave a higher production, compared to standard planting material. However, in six of the 12 location in River State very few tubers were attacked by nematodes and no differences in yield between the hot-water treated and non-treated tubers were observed. In Ebony State nematode numbers on the trial farm were very low, and only cultivar differences could be detected. Alley-farming with a mixture of *Leucaena* sp. and *Glyricidia* sp. does not seem to have an effect on the nematode population or tuber

treatment. Greater differences, as a result of less storage loss, are anticipated after three months storage in the cases where the nematodes are present. Tuber scoring and nematode counting after storage will reveal this early 2000.

Farmers are impressed with the positive effect of the hot-water treatment and are eager to treat more yams for the next growing season. Adaptation of the hot-water treatment may depend on the development of a cheaper design of the tank, alternative ways to control the temperature or alternative uses of the tank. A trial was set up in Kwara State to evaluation the adaptation of the tank of IITA using local available material and knowledge used to parboil yams for processing. Farmers generally used the appropriate temperature recommended for treating yam tubers, but left the tubers in the water for a much shorter period, ten to fifteen minutes rather then 25 minutes. Nematode extractions of tubers at harvest and after storage will show the efficacy of the 'local' treatment compared to the IITA managed hot-water treatment.

In Uganda, the hot-water treatment was introduced to farmers in the yam producing Luwero, Mpigi, Masaka and Ntungamo regions, using one local cultivar. Tuber yield and nematode scores have been taken at harvest, and the nematode identification and counting are currently in progress. Hot-water treatment was.also used to establish a field trial in the ASARECA project in each of the regions in Uganda using two accessions from Nigeria. The trials are set up to follow the nematode population dynamics during the growing season in farmers fields for a period of not less than two years.

5.2.5. Screening for resistance in yam germplasm to nematodes affecting yam

by J.C.M., P.R.S, R.A. - in collaboration with R. Plowright, C. Kwoseh, J. Mudiope*, R. Maslen*

In Nigeria, a reference trial, including 13 breeder lines of *D. rotundata*, and landraces of *D. rotundata* (37), *D. esculenta* (3), and *D. alata* (8) was planted at Ibadan.. The trial design was a split plot, one being artificial inoculated with 75 gram of yam peel infected with nematodes (*S. bradys*), and one plot having natural (very low) levels of nematodes in the soil. Scoring at harvest revealed significant differences in yield and level of damage caused by nematodes and nematode-related rots between the inoculated and control plots. Extractions were made for nematode counts at harvest and will be repeated after 3 month storage (early 2000). Using this and other recently developed screening techniques 220 accessions of *D. rotundata* have now been screened. Only variation in susceptibility to the yam nematode (*Scutellonema bradys*) and the root knot nematode (*Meloidogyne incognita*) nematodes was observed so far and no resistant accession could be identified. Two accessions of *D. dumetorum* (from Ghana and Cameroon) proved highly resistant to *S. bradys.*

In Uganda, two accessions from Nigeria and one local cultivar have been screened in polythene bags for resistance or tolerance to nematodes. Not sufficient nematode inoculum could be obtained and the experiment has to be repeated. Along with the screening of the accessions, a field trial was designed to obtain data on yield losses in the Uganda yam germplasm caused by those nematodes.

5.3. Evaluation of integrated soil and crop management practices for soil fertility maintenance and pest control in yam-based systems

On-going and future activities

5.3.1. Evaluation of cover crops for reduction of nematode inoculum in soil prior to yam planting

by J.C.M., G.T., P.V., P.R.S., R.A. – in collaboration with B. Claudius-Cole, B. Fawole*

A PhD project was started to study the effect of various cover crops and herbaceous legumes on the nematodes affecting yams. Pot experiments were set up to examine the response of *Aeshynomene histrix, Mucuna pruriens utilis, Pueraria phaseoloides, Stylosanthes guianensis, Centrosema pubescens* (all creeping cover crops), *Crotalaria juncea, Cajanus cajan, Crotalaria ochroleuca,* and *Tagetes erecta* (herbacious and erect) to the yam nematode *S. bradys* and the root knot nematode *M. incognita.* Soil and root samples are taken to establish the recovery of those nematodes in the soil under any of those crops, and to study the response of the roots and possible entry of the nematodes. Two accession each of *D. rotundata* and *D. alata* (TDr 93-31, TDr 608, TDa 92-2, TDa 294) were planted in the field and intercropped with eight of the cover crops (*C. juncea* did not germinate) and subsequently inoculated with either *S. bradys* or *M. incognita*. Soil samples were taken at planting, during the growing season, and at harvest. Tuber scores were also taken at harvest, and this will be repeated after 3 months storage along with nematode extraction, identification and counting. The dynamics of nematodes associated with cover crops and yams are also followed at the IITA-farm in Abuja, FCT. Soil and root samples are taken from plots planted with either *Aeshynomene histrix* or *Mucuna pruriens utilis* grown after a yam

crop, and from yam plots grown after a cover crop. Samples will be taken at planting, once during the growing season, and at harvest.

5.4. Production of pest- and disease-free germplasm

On-going and future activities

5.4.1. Produce disease-free virus tested propagules of selected genotypes for international distribution *by S.Y.C.N., J.d'A.H.*

Both direct and indirect ELISA methods were used to detect yam viruses in yam plantlets derived from tissue culture in order to ensure their virus-'free' status prior to multiplication and international distribution. Where polyclonal antibodies were used, generally PAS-ELISA was preferred (to detect DaV, DLV, DaBV, DDV, DbBV and CMV) and TAS-ELISA was used with monoclonal antibodies for detection of YMV.

Eighty yam plants were tested for viruses (YMV, DaV, DLV, DaBV, DDV, DbBV and CMV) after 'hardening' in the growth room. A further 80 sets of *N. benthamiana* samples that had been inoculated with sap from the yam plants were also tested for YMV as a confirmatory test for the virus. Where symptoms were seen on the yams but none of the characterized viruses were detected, the yams were also tested for DMoV strains. Approximately 21% of the plantlets tested positive for YMV, 20% for DaV, 26% for DaBV and 5 % for CMV. Fourteen of the yam plantlets screened for yam viruses were infected with more than one virus. The multiple virus infections were YMV with either DaV or DaBV.

Completed studies

Journal articles and book chapters

Odu, B.O., J.d'A. Hughes, S.A. Shoyinka & L.N. Dongo, 1999. Isolation, characterization and identification of a potyvirus from* Dioscorea alata *L. (water yam) in Nigeria. Annals of Applied Biology 134: 65-71

A yam potyvirus was isolated from *D. alata* samples collected in Nigeria. The virus was not transmissible mechanically but was transmitted by *A. craccivora* to four cowpea cultivars (Ife Brown, IT84S-2114, IT82E-10 and Tvu2657), and from which it could be mechanically transmitted between the cowpea cultivars. In infectivity-tests using cowpea extracts, the virus had a dilution end point of 10^{-4}, a thermal inactivation point of 60-65°C and longevity *in vitro* of 2 days at room temperature. The virus coat protein had an estimated molecular weight of 32 100 daltons. The virus was identified as an isolate of Dioscorea alata virus (DaV; syn. Yam virus 1) due to its biological characteristics and its serological reaction with antiserum raised against DaV. The virus is not related to yam mosaic virus, but distantly related to blackeye cowpea mosaic virus and cowpea aphid-borne mosaic virus.

Conference papers, workshop proceedings, abstracts, newsletters

Meerman, J.C. & P.R. Speijer, 1999. On-farm testing and large scale distribution of nematode-free yam planting material in southern Nigeria. In: Proceedings of the 14th Symposium of the Nematology Society of Southern Africa, Dikhololo, Pretoria, South-Africa. 30 May – 3 June 1999. Presentation.

Speijer, P.R., J. Mudiope, N.R. Maslen, J.C. Meerman, N.M.W. Wanyera & R. Asiedu, 1999. Reduction of yam (Dioscorea spp.) storage loss through use of clean planting material. National Resource Institute, U.K., NARO, Uganda, IITA, Nigeria. Poster

PUBLICATIONS 1995-2000

1995

Journal Articles and Book Chapters

Asanzi, M.C., N.A. Bosque-Pérez, L.R. Nault, D.T. Gordon & G. Thottappilly, 1995. Biology of *Cicadullina* spp. (Homoptera: Cicadellinae) and transmission of maize streak virus. *African Entomology* **3**:173-179.

Berner, D.K., J.G. Kling & B.B. Singh, 1995. Striga research and control—a perspective from Africa. *Plant Disease* **79**:652-660.

Boavida, C. & P. Neuenschwander, 1995. Influence of host plant on the mango mealybug, *Rastrococcus invadens. Ent. exp. applic.* **76**:179-188.

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Outreach

TECHNOLOGY TESTING AND TRANSFER: STRENGTHENING NATIONAL PLANT PROTECTION PROGRAMS

by W.N.O. Hammond, A.A. Sy, M. Zweigert
assisted by R. Adeoti, H. Agbayahoun, R. Allomasso, S. Anato, C. Atcha

Project Rationale

Crop protection research at International Agricultural Research Centers (IARCs) in particular and at other institutions continues to yield valuable results in the form of agents for classical biological control and improved varieties with resistance to pests and diseases. In order for farmers to derive the full benefits of these research efforts, there is an increasing need to effectively transfer technologies developed through the National Agricultural Research and Extension Systems (NARES). However, many NARES continue to suffer from various financial, educational and administrative constraints, which hamper local research activities. Within IITA/PHMD, the Technology Testing and Transfer Unit (TT&TU) which was initially established to assist NBCPs in disseminating biological control agents, expanded to become an outfit which aims at activating and strengthening NARES to enable them to adopt, expand and disseminate research results of biological control, host plant resistance, and habitat management programs of PHMD, through special funding from the governments of Germany, Austria, and Switzerland. In addition the TT&TU has been very active in the regional projects/networks which have been set up; some are crop-specific such as PEDUNE, and others pest oriented (LUBILOSA) whose main purpose is to coordinate, assist and improve NARES activities in these selected areas.

In order to implement ecologically sustainable pest control, technology development at IARCs and NARES on the one hand, and transfer of these technologies to farmers within various farming systems on the other hand, should be viewed as a dynamic process. In this regard, activities which were carried out in 1998 and still continue include the following: (1) experimentation & transfer/adaptation/adoption of technologies, (2) training, (3) other strategies to strengthening NARS & regional organizations (4) insect rearing, logistic support & familiarization visits. Details are given in the tables.

Outputs

1. Experimentation & transfer/adaptation/adoption of technologies

Major achievements and impact were made in the four keys areas:

- surveys and pest management of cassava green mite, whiteflies & whiteflies-borne viruses, bacterial blight and diagnostic surveys
- development of improved management strategies and practices to control banana pests (nematodes, weevils, sigatoka)
- biological /integrated management of water hyacinth, mango mealybug and *Striga*
- biological control of pearl millet ear borer

2. Training

2.1. Degree-Related Training

Two PhD fellowships are directly funded from SDC within TT&TU, and two others get complementary funds from SDC (see students' list in the annex).

2.2. Individual non-degree related training

67 National Experts with a level of "Ingénieur Agronome" & BTA benefited from TT&TU support. Those young experts were trained in the following 6 areas : cassava pests (18) maize pests (34) cowpea pests (4) plantain pests (1) termites (3) water hyacinth (7).

2.3. Group training

- Plant Quarantine Experts Technical Orientation visit to the IITA Seed Health Unit: 7, Phytosanitary Control Experts, Benin.
- Impact Assessment of Agricultural Technologies on Food Security in Sub-Saharan Africa : 17 Experts of PhD, MSc, and Ingénieur levels across Benin, Burkina Faso, Cameroon, RDC, Cote d'Ivoire, Guinea, Niger, Senegal, Chad, Togo.

2.4. Selected Proposals from NARS-ECSA & IITA-Uganda

- Occurrence and Incidence of Mycorrhizae on East African Highland Banana (Musa AAA) and Pisang Awak (Musa AAB) in Uganda & Rwanda

3. Strengthening NARES and regional organizations

3.1. Workshops and International Congresses

- Banana International IPM-Workshop; Banana IPM Ahead: Mobilizing IPM for sustainable banana production in Africa: 53 Experts from: Germany, Belgium, Burundi, Cameroon, Congo, Côte d'Ivoire, Ethiopia, France, Ghana, Indonesia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, South Africa, Tanzania, Uganda, United Kingdom. [Proceedings sponsored by SDC].

4. Insect rearing, logistic support & familiarization visits

- Mass-rearing of *Teretriosoma nigrescens*, a predator of Larger Grain Borer has continued.
- Logistic for *T. nigrescens* mass-rearing was provided to Nigerian NARS through a special project financed by GTZ.
- Greenhouses/screen houses have been maintained and/or installed in Benin, Mozambique, Nigeria.
- Cassava and cowpea plant are produced under greenhouses for insects or mite mass-rearing.
- About 30 official visitors are led in IITA tour visit for familiarization.

NARES/IITA-PHMD COLLABORATIVE RESEARCH ACTIVITIES

Country	Collaborating Institutions & national project collaborators	Activities 1998/99	Future activities	Donors of special projects & IITA project coordinator
1. Benin	Plant Protection Service (SPV) National Institute of Agricultural Research (INRAB) University of Benin	In the framework of an EC project in collaboration with University of Göttingen, Germany, which started in September 1998, field trials on IPM of cassava bacterial blight were installed in 3 ecozones.	Adaptation of IPM methods for control of cassava bacterial blight to ecozones; identification of mechanisms of resistance to CBB; transfer of detection methods to NARS	EU [Wydra]
	National Extension Service (CARDER) Plant Protection Service (SPV) National Institute of Agricultural Research (INRAB)	PEDUNE activities focused on the transfer of the use of plant based insecticides such as aqueous extracts of neem and pawpaw leaves to control cowpea pests, the improvement of storage techniques such as the use of hermitic drums, solar drying, which enable storage for more than six months compared to 2 months. The project has been consolidating efforts on testing improved varieties on-farm. One MSc fellowship on-going.	From 2000, PEDUNE activities will be essentially on large-scale dissemination of the use of botanical pesticides, storage techniques, impact assessment of technologies and continue training farmers, extension agents, NGOs agents and technicians through Farmer Fields Schools.	SDC [Hammond]
	Plant Protection Service (SPV) National Institute of Agricultural Research (INRAB) University of Benin	Impact assessment of *T. aripo* in the biological control of CGM continued in moist and dry savanna ecozones. Provided specialized training in collection and curation of arthropod specimens and in CGM biocontrol technology. Yield losses of 22 cassava varieties due to cassava bacterial blight continued. One Ph.D. student continues his studies on cassava bacterial blight, and three Ph.D. students initiated their studies on various aspects of cassava green mite biocontrol. Cassava postharvest pest surveys were initiated.	Socioeconmic studiesn and impact assessment of CGM biocontrol will contiune. Experiments with cultural practices to enhance biocontrol will continue. Current students will continue their on CGM biocontrol, and two Ingenieur Agronome will initiate their memoires on cassava green mite ecology and control. Backstopping national programs in mite identification will continue to be provided on demand. Cassava postharvest pest surveys will continue.	Denmak IFAD [Hanna, Meikle, Coulibaly]
	Plant Protection Service (SPV)	Socioeconomic studies on the importance of termites as pests in crops, stores and wooden structures, in the context of the development of a mycoinsecticide.	Field testing of *Metarhizium anisopliae* as repellent against termites	DFID [Langewald]

1. Benin (cont.)	Plant Protection Service (SPV) Direction de Pèche Lagunaire	Biological control of water weeds. Follow-up surveys and releases of natural enemies.	Follow-up of classical biological control. Exploration of microbial control of water hyacinth	core; DFID [Neuenschw; Langewald]
	Department de l'Alimentation et Nutrition Apliqué (DANA); Rotary Clubs of Bénin; Ministry of Health	Planning and training workshops for maize quality control campaigns, human health /nutrition study and post-harvest technology testing	Implemention of a maize quality public information campaign will begin in 2000, as will urban market mycotoxin monitoring activities, model farm (poultry) feasibility studies, human health/nutrition studies and on- farm testing of mycotoxin control technologies.	Rotary International; BMZ/GTZ; The Netherlands; USDA; FAO; [Cardwell, Hell]
	Plant Protection Service (SPV)		Development of a microbial insecticide for peri-urban crops.	DFID [Cherry]
	Plant Protection Service (SPV)	Field releases of *Neozygites floridana*, for microbial control against the cassava green mite, and follow-up surveys	Field releases of *Neozygites floridana*, for microbial control against the cassava green mite, and follow-up surveys	core [Cherry]
2. Burkina Faso	National Agricultural Research Institute/INERA [A. Sawadogo, D Traoré, A. Somé, R. Dabiré, O. Ouédraogo]	Biological Control of *Striga hermonthica & Striga gesnerioides*: Map out of the distribution spectrum of *Smycronix umbrinus and S. guineanus* and definition of its relationship with *Striga* species; Increase and conservation of *Smycronix* population; Assessment of the impact of the predator larvae on the reduction of the *Striga* seeds bank.	Biological Control of *Striga hermonthica & Striga gesnerioides*: - Determine consumption capacity of embryos and seeds of *Striga* by *Smycronix guineanus and S. umbrinus* - Determine *Striga* seed reduction index versus *Smycronix* increase - Determine the longevity and mode of persistence of natural enemies - Assess the economic impact of Striga throughout selected ecological niches - Assess the economic impact of natural enemies in the management of *Striga* in Burkina Faso.	SDC [Sy]

2. Burkina Faso (cont.)	National Agricultural Research Institute/INERA [L. Ouédraogo, R. Dabiré, B. Mamounata, B. Ouétian, M. Ouedraogo]	Integrated Control of Water Hyacinth: Samples of *Neochetina eichorniae* and *Neochetina bruchi* were ordered from IITA-PHMD for mass rearing. Preliminary surveys were carried out in order to select the best representative sites for the release of the predators. When the prevalence of the Water Hyacinth was estimated in the areas of Ouagadougou and Dougoumato, results showed i) that 5 ha and 1 ha are heavily affected in Ouagadougou and Nagbangré and ii) that about 30 ha were heavily affected in Dougoumato area. Best sites were selected for further release of the predator ; these key sites include : 9 sites in the Dougoumato area and 3 sites in Ouagadougou area. Sensitization for predators'adaptation in the new environment ; notice (observation) of an increasing evolution of adults' population in laboratory and checked environment. Pest management : positive controls of the use of unmoisturizing biomass for cattle and pigs fodder	Integrated Control of Water Hyacinth: Global assessment of the geographical distribution of Water hyacinth in Burkina Faso - Map out three target hot spots that will be subjected to massive release of predators *(N. eichornae and N. bruchi)* - Assessment of economic importance of Water hyacinth in the three selected hot spots - Strengthening of National capacities in terms of maintaining rearing and mass release of the predators - Mass release of at least two predators throughout, 20 sites at Dougoumato, 5 sites at Kadiogo and 5 sites at Bazega. - Further work in laboratory pour better knowledge of predators (better knowledge on rearing) - Elaboration of the public awareness documentory on water hyacinth	SDC [Sy]
	INERA, PEDI/KAYA, FUNG , PEDISAB, PPI,	PEDUNE: Burkina is involved in improved seed production, safe of virus and with minimum insecticide appliacation in field, involving many collaborators and farmers organizations. An MSc fellowship is on-going.	PEDUNE: Major activities are the large diffusion of improved varieties, training of NGOs extension agents and farmers; intensification of on-farm trials; on technologies transfer. Burkina has focused also on varietal screening against virus and technologies impact assessment Post-graduate training will be continued. Farmers Fields School will be established	SDC [Hammond]
3. Burundi	National Agricultural Research Institute (ISABU)		If security situation improves, *T. aripo* spread and persistance surveys, and impact assessment trials would be conducted. Specialized training in collection and curation of arthropod specimens and in CGM biocontrol technology will be provided on demand.	Denmark [Hanna]
4. Cameroon	IRAD, University of Dschang, PMVA, ONG (SAILD, CDD)	PEDUNE: Principal activity is the dissemination of improved storage techniques, solar drying, triple bagging and ash treatment. Efforts are also concentrated on varietal screening for on-farm trials and conduct benchmark study. One MSc fellowship on-going.	PEDUNE will concentrate its activities on the large-scale dissemination of technologies including improved storage, resistant varieties. Socioeconomic impact assessment will be conducted, FFS established.	SDC [Hammond]

4. Cameroon (cont.)		Impact assessment of *T. aripo* in the biological control of CGM were completed, and *T. aripo* spread and persistence surveys continued. Provided specialized training in collection and curation of arthropod specimens and in CGM biocontrol technology, and identified mite specimens sent by the collaborators. Surveys on distribution and abundance of the African root and tuber scale were initiated.	Distribution and abundance studies of African root and tuber scale will continue. Interplanting cassava varieties for the enhancement of biocontrol will be initiate. Specialized training in collection and curation of arthropod specimens and in CGM biocontrol technology, and mite identification service will continue to be provided on demand.	Netherland Denmark [Hanna]
	IRAD, Bambui station	Maize health – Screening for resistance to the Grey Leaf Spot disease of maize		IITA [Menkir, Cardwell]
5.Côte d'Ivoire	National Center for Agricultural Research [K. Nguetta, M. Kehe]	Biological Control of Mango Mealybug: The whole Korhogo has been mapped out in 1998, integrating Korhogo itself, Sinématiali, Ferkessedougou, Tafiré, Ounangolodougou, M'bengué, Kouto, Boundiali and Dikodougou : *R. invadens* and its main parasitoids were more abundant in towns than in villages, and then more abundant in villages than on the countryside; the presence of hyperparasitoids has also been noticed. Work planning techniques have been set up for the purpose of lab and mass rearing : i) intensive production of *Ficus polita*, which supports the rearing, the purification of *R. invadens*; ii) and the mass rearing of both parasitoids. Some rearing experiments have also been conducted in natural conditions, thereby showing the importance temperature and hygrometry factors : it is difficult for *R. invadens* and its parasitoids to survive above 38-40º C and below 50% of relative humidity.	Biological Control of Mango Mealybug: - Quantitative assessment of the economic impact of Mango Mealy Bug in selected areas - Farmers are sensitized about the role and interest of biological control strategy against Mango Mealy Bug - Maintenance, mass rearing and release of predators against Mango Mealy Bug in Korhogo area - Assessment of economic impact of natural enemies in the biological control of Mango Mealy Bug - Assessment of the impact of hyperparasitoids in the dynamic of the populations of *G. tebygi*, *A. mangicola* and *R. invadens*	SDC [Sy]
	Plant Protection Division / MINAGRA [R. Niagne, A.T. Koné, K. Konan]	Biological Control of CGM: A country-wide surve determined the geographical distribution of the pest (*Mononychellus tanajoa*), and the spread of the predator *Typhlodronalus aripo*. CGM was present throughout the country but densities were low to moderate. *T. aripo* was in much of the cassava growing areas.		SDC [Sy, Hanna]

6. Deomcratic Republic of Congo	Institut National pour L'edude et la Recherche Agronomic (INERA)	*T. aripo* releases were carried out in several areas in Bas-Congo. *T. aripo* establishment and spread surveys were conducted. Provided mite identification and curation service. Trials on the impact of soil fertility on cassava root scale were initiated with assistance from EARRNET..	Because *T. aripo* has readily established, further release and surveys for establishment and spread will be conducted in other provinces. *T. aripo* impact studies will be initiated. The project will continue to provide training and identification service. Abundance and distribution of African root and tuber scale will be determined in Bas-Congo.	Denmark [Hanna, Toko]
7. Ethiopia	Institute of Agricultural Research [M. Bogale]	An African Highland Initiative special project was awarded to survey nematodes and weevils on Ensete and banana. The leader of the survey team, Mesfin Bogale, of Ambo research station visited IITA-ESARC for 3 weeks to analyze the data set and prepare a journal paper.	The second part of the survey (dry season survey) has been completed and data analyzes is planned.. A proposal to evaluate Ensete (>300 landraces) susceptibility to P. goodeyi was prepared and has been submitted to AHI.	AHI [Speijer]
	Crop Production and Protection Technology, and Regulatory Department/Ministry of Agriculture (CP&PT&RD/MOA) [B. Kabeto, A. Admase]	Nine different insects were observed in association with *Striga hermonthica* in the areas surveyed excluding termites (*Isoptera*). They were identified only to the family level. The most important of them are billbugs (*Colleoptera, Curculionidae*): One of them is the very wide spread causes considerable damage to the reproductive structures of the *Striga* plants. Many plant diseases were observed causing damage on *Striga* in the survey areas, the mos important one being powdery mildew. The specific pathogenic organism causing the diseases however, was not yet identified. Diseased plant specimens have been collected for further identification and tests.		SDC [Sy]
	University Addis Abeba	Microbial control of termites (Ph.D. thesis). Collection and selection of *Metarhizium anisopliae* strains	Field testing of *Metarhizium anisopliae* strains against termites	SDC [Langewald]

8. Ghana	Crop Research Institute, Kumasi University of Ghana, Legon University of Science and Technology, Kumasi University of Cape Coast Ministry of Agriculture (MOFA [Afreh-Nuamah]	The West African plantain project focused at three major activities: 1) the production of clean planting material, combined with the development of pilot nurseries and improved management practices, 2) yield loss assessment studies for weevils, nematodes, and sigatoka, and 3) lab and field testing of entomopathogenic fungi against the weevil.. Good results were obtained prioritizing the various nematode species in Ghana and a draft scientific paper is being prepared. Under the CABI-Bioscience supported yam nematology project one Ghanian scientist is being training in methods for nematode resistance evaluation.	The west African plantain project will unfortunately end by December '99. However, most results have been incorporated in the FAO farmers training schools, resulting in a country-wide dissemination of the reseach results. By the end of the project at least 3 Ghanians should have been trained at Msc level.. One presetation will be given at the Nematology Conference in Monteray, USA in 1999. A set of field trial results is anticipated to be aivailable by mid 1999	BMZ CABI - Bioscience [Speijer] SDC [Hammond]
	SDC [Hammond]	PEDUNE: On-farm trials were well established including minimum insecticide application , solarization and storage techniques and the use of plant based insecticides as neem. In order to strengthen farmer participatory approaches to cowpea IPM technology dissemination a regional Training of Trainers (ToT) /Farmer Field Schools (FFS) was carried out where 27 participants (NGOs and national extension agents) form all nine PEDUNE countries participated	More efforts will be directed to extend FFS, to disseminate technologies such ás minimum insecticide application , solarization and storage techniques. Socio-economic studies and on-station trials, especially local detergents and fungicides assessed for disease control will be conducted.	SDC [Hammond]
	Denmark IFAD [Hanna]	Cassava green mite research continued at low level, primarily spread and persistence of predatory mites at 3 periods during the year. Two NARS staff were trained in CGM management. Mite identification was provided on demand. Backstopping of NARS activities through IFAD investment project continued.	Backstopping activities for NARS in cassava crop protection will continue. *T. aripo* spread and persistence surveys will continue. Interactions between *T. aripo* and *T. manihoti* and impact on CGM biocontrol will be determined. A student will initiate MSc. at University of Cape Coast. Specialized training in mite collection and identification and in CGM biocontrol technology will be provided.	Denmark IFAD [Hanna]

8. Ghana (cont.)	University of Ghana, Legon, Cape Coast University of Science and Technology, Kumasi Ministry of Agriculture (MoFA) Plant Protection and Regulatory Services Department (PPRSD)	The West African Plantain Project came to an end in 1999. During this year, it continued to focus on three themes in collaboration with NARS; i) production and rapid multiplication of planting material, ii) evaluation of practices for IPM and crop management, and iii) development of a biocontrol agent for the banana weevil. Farmers field days gave MoFA staff and farmers from neighbouring districts an opportunity to review progress. Impact assessment showed that nursery production and improved plantain production practices were profitable and that farmers' perceptions were favourable.		BMZ [Green]
	Ghana Standards Bureau & Food Research Institute; Rotary Clubs of Accra	Planning and training workshops for maize quality control campaigns and technology testing	Implemention of a maize quality public information campaign will begin in 2000, as will urban market mycotoxin monitoring activities, and model farm (poultry) feasibility studies.	Rotary International [Cardwell, Doko]
	Plant Protection and Regulatory Services Department (PPRSD), EPA		Development of a microbial insecticide for peri-urban crops	DFID [Cherry]
9. Guinea	The National Biological Control Program (PGLB) of the Plant Protection Service	CGM project supported a limited cassava green mite survey and *T. aripo* releases. One entomologist participated in course on socioeconomics. Provided mite identification and curation support.	CGM project continues a three year program for implementation of CGM biocontrol, which includes *T. aripo* releases, spread and persistence surveys, impact studies and farmers training.	Denmark [Hanna, Toko]
10. Kenya	Kenya Agricultural Research Institute (KARI)	The regional OFDA CMD project continued. Country-wide CGM and *T. aripo* surveys were conducted. Mite identification and curation service was provided. Participatory evaluation of multiple pest and disease resistant varieties were conducted.	A range of activities will be done in collaboration with NARS and NGO partners in western Kenya including monitoring surveys, evaluation of CMD resistant germplasm and multiplication. Extension and NGO staff will be trained in cassava plant health management. CGM project continues activities in implementation of biocontrol, which includes *T. aripo* releases, spread and persistence surveys, impact studies and postgraduate training.	Denmark USAID (OFDA) [Legg] [Hanna, Toko]
	Kenya Agricultural Research Institute (KARI)	Socioeconomic studies on the importance of termites as pests in crops, stores and wooden structures, in the context of the development of a mycoinsecticide.	Field testing of Metarhizium anisopliea against termites in maize	DFID [Langewald]

11. Madagascar	FOFIFA (National Research Centre)		Diagnostic surveys of mites will be conducted in collaboration with EARRNET.	Denmark [Legg, Hanna]
12. Malawi	Department of Agricultural Research	PHMD scientists and technicians assisted with two CGM surveys, *T. aripo* release follow-up, and on-site training in CGM biocontrol. Two technicians were trained in CGM management.	CGM project continues activities in implementation of CGM biocontrol with NARES and NGOs, which includes *T. aripo* (and other exotic phytoseiid) releases, spread and persistence surveys, impact studies and farmers training. One MSc student will initiate studies on interactions between local and exotic phytoseiids and impact on CGM biocontrol.	Germany IFAD [Hanna] [Toko]
13. Mali	Institute of Rural Economy/I.E.R C. Diarra, B. Dembele, A. Coulibaly, P. Bengaly & K. Coulibaly	Effect of millet and cowpea association on Striga management : The treatments associating millet and cowpea (alternate rows or alternate plants within the same row or as a mixture within the same hill) result in 60% of growth reduction of S. hermonthica. Meanwhile, the two first variants (alternate rows and alternate plants within same rows) induced: i) up to 80% of reduction of Striga flowering plants and ii) up to 90% yield increase as compared to the traditional farmer practice. iii) In addition, one could notice a significant yield increase of cowpea. iv) When the target crops were sorghum (area of Kolokani), the treatment including cowpea (mixture with sorghum in the same hill or alternate hills in the same row) resulted in 50% yield increase. The pathogens Fusarium oxysporium/strain M12-4A used as a mycoherbicide confirmed its efficacy in reducing significantly the proportion of flowering Striga plant in all areas, thereby allowing up to 80% higher yields. More than 150 black and white posters have been developed in Bamanan, the major national language. Additional 600 color posters will be made available for distribution to farmers, NGOs, Extension CMDT and OHVN etc.	Integrated *Striga* management: - Continuation of host range studies - Quality control of chlamydospore powder - Production of chlamydospore on various substrates in laboratory - Writing two chapters of the Ph.D. thesis - Conservation and virulence of fungal inoculum studies - Study efficacy of a new formulation under field conditions Chlamydospore powder into a production system	SDC [Sy]
	CARE, Vision Mondiale , IER	PEDUNE: The use of botanical pesticides including neem, pawpaw leaves to control cowpea pests in fields have been tested on-farm. Mali is also involved in improved seed production and dissemination of resistant improved varieties against striga and drought.	PEDUNE: Dissemination of improved varieties; on-farm testing in controlling cowpea pests including *Callosobruchus maculatus* with neem extracts; improved storage techniques. Training at different level and impact assessment Farmers Fields School will be established	SDC [Hammond]

13. Mali [cont.]	Direction Nationale de l'Appui du Monde Rural ; Direction Général de la Réglementation et de Contrôle ; SECAMA ; ADAF GALLE ; Stromme foundation ; CCA	LUBILOSA: Demonstration trials and farmer participatory trials, public awareness raising seminars in collaboration with NARES and NGOs.	LUBILOSA: Demonstration trials and farmer participatory trials, public awareness raising seminars in collaboration with NARES and NGOs. Introduction of Green Muscle™ for grasshopper control	DFID, SDC, DGIS [Langewald]
14. Mozambique	National Directorate of Agriculture (DINA) National Institute for Agricultural Research (INIA) [S. Mangana]	Serafina Mangana, of the Plant Protection Department, spend three weeks in Uganda for data analysis and to write a journal paper on the incidence of root knot nematodes in cassava in Mozambique. A PhD proposal to follow up on this research has been prepared.	Funding is sought for Serafina Mangana to be able to continue to research on cassava nematology	SDC [Sy, Speijer]
	National Institute for Agricultural Research (INIA), World Vision	PEDUNE: focused its activities on-station and on-farm trials and training. Many improved varieties and storage techniques including ash have been tested in Inhambane province. Two MSc fellowships are on-going.	PEDUNE: All trials including plant extracts testing, tests of solarization and triple bagging will be continued in Inhambane province, and will be started in Nampula and zambezia provinces. Traning at different level and socioeconomic study will constitute also a very important activiy.	SDC [Hammond]
		PHMD scientists participated in country-wide surveys of cassava green mite and associated natural enemies. *T. aripo* was released in three provinces, and follow-up surveys were conducted. Implementation of CGM biocontrol continued. Two NARS staff received training in CGM management.	CGM biocontrol implementation will continue in collaboration with NARES and NGOs. Virtually nothing is known about the status of cassava virus diseases in Mozambique, and an assessment will therefore be carried out in mid-2000. A cassava IPM training course will be conducted in June 2000.	Denmark [Hanna, Legg]

15. Niger	Crop Protection Division, DPV [Danga]	Biological Control of pearl millet head borer: Experimental Fields were selected in traditional *Heliocheilus albipunctella* infestation zone. A rearing system of *B. hebetor* and his alternative host (*Ephestia Kuehniella)* was installed in Maradi at entomological laboratory of INRAN (Tama Station)	Biological Control of pearl millet head borer: To continue the training of technicians and paysant on the rearing of *B. hebetor* and it's alternative host and the evaluation of the infestation in farm level. To contunue the rearing *of B. hebetor* in Niamey and start a another rearing in Maradi To continue the survey *of H. albipunctella* in the project areas To set up a efficient rearing methode rearing of *B. herbetor* at farmer level	SDC [Sy]
	INRAN, Université de Niamey, DPV, DFPV, Care International, ADRI	PEDUNE: development of resistant/tolerant varieties against Striga and bilogical control of bruchids. Botanical pesticides as neem, tobacco and pepper to control field pests were validated on-farm trials.Efforts were concentrated on the delination of benchmark stites, training and degree-related programs	PEDUNE: Dissemination of some technologies (use of botanical pesticides, solarization and triple bagging techniques for storage, resistant improved varieties) and training of farmers and NGOs Extension gents will constitute essential activities from 1999. Socioeconomic evaluation will also be an important activity. Impact evaluation will also be an important activity. Farmers Fields School will be established	SDC [Hammond]
	DPV; CARE; PROSOPAS	LUBILOSA: Demonstration trials and farmer participatory trials, public awareness raising seminars in collaboration with NARES and NGOs.	Introduction of Green Muscle™ for grasshopper control	DFID; SAD; DGIS [Langewald]
16. Nigeria	NAOC-Agip: Green River Project, Obrikom, River State. SUM-NRC: Izi, near Abakaliki, Ebonye State.	In collaboration with two NGO's in Nigeria pilot trial were established to deliver yam clean planting material to the farmers community, using a hot-water technology. Presently the '98 harvest is being stored. It is anticipated that storage loss reduction, will be the major contribution of the technology.	Preliminary results were promising, therefore, for the '99 season new trials are being established.	Netherlands [Speijer]

16. Nigeria [cont.]	IAR/ABU, KNARDA	PEDUNE: Training of over 2000 farmers and technicians on solarization and triple bagging techniques for grain storage, on-farm testing on the use of botanical pesticides to control field pests and multiplication of cowpea varieties/elite lines by farmers are the major activities. Training and degree-related programs were also undertaken.	PEDUNE: From 2000, major activities will be the wide dissemination of technologies including the application of botanical products to control cowpea pests and diseases and conduct impact assessment to evaluate the rate adoption of technologies. Nigeria will also concentrate efforts to validate on-farm severe resistant improved varieties. Farmers Fields School will be established	SDC [Hammond]
	National Root Crop Research Institute, Umudike	Impact assessment of *T. aripo* in the biological control of CGM were completed in two ecozones. *T. aripo* spread and persistence surveys were conducted. Cassava varieties were screened for their preference to T. aripo. CGM project continued to provide service for identification and curation of arthropod specimens.	*T. aripo* spread and presistence surveys will continue. Interplanting with *T. aripo* preferred varieties would be tested in farmers' fields. Characterization of *T. aripo* preference for cassava varieties will continue. CGM project will continue to provide backstopping for mite identification and curation.	Denmark [Hanna]
17. Rwanda	The NBCP of the Institute of Agricultural Science of Rwanda (ISAR) Plant Protection Service	An assessment was made of the status of cassava virus diseases in the country, some individual training provided in virus diagnostic techniques and support provided in virus screening for the cassava germplasm development program. A major new IITA/ISAR led collaborative project entitled 'Agricultural Technology Development and Transfer Project' was initiated in 1999. It involves a wide range of partners including 3 CGIAR centers, 6 regional research networks, and a number of local and international NGOs.	PHMD will continue to provide backstopping to the IITA/ISAR project in a broad range of cassava and *Musa* plant health activities.	USAID [Legg]
	ISAR	A proposal was developed on the provision of banana clean planting material for new settlers in Rwanda	The propsal was funded and will be implemented, starting 1999	ASARECA [Speijer]
	ISAR Plant Protection Service	PHMD scientists initiated collaboration with newly established technology development and transfer project for increased income and sustainable food security	Collaboration with the technology development and transfer project for increased income and sustainable food security will continue.	USAID [Legg]
18. Senegal	ISRA, DPV, Vision Mondiale, PNVA, SODEVA,IRA, CERTP, OP (CNCI, URAPD, UGPM)	PEDUNE: Major activities were the test and dissemination of botanical pesticides, particularly neem and *Boscia senegalensis* for storage and field pests.	PEDUNE: continue testing and disseminating botanical pesticides. Iimpact assessment of technologies will be carried out. Farmers Fields School will be established.	SDC [Hammond]

19. South Africa	Vegetable and Ornamental Plant Institute (VOPI)	Collaborative links have been established between PHMD virologists and counterparts in South Africa.	PHMD (from IITA-ESARC) and VOPI plant health scientists will jointly provide backstopping on cassava plant health activities planned for the second phase of SARRNET. A Malawain student will commence studies in Pretoria.	USAID [Legg, Hanna]
	University of Pretoria Plant Protection Research Institute(Dr. Rami Kfir)	PEDUNE: On-going MSc training of 4 students	PEDUNE: Possibility of establishing quarantine station for parasitoids of *M. vitrata*	SDC [Hammond]
	PPRI	LUBILOSA: Field testing of Green Muscle™ for red locust control; registration.	LUBILOSA: Field testing of Green Muscle™ for red locust control	SDC; DFID; DGIS [Langewald]
	PPRI		Microbial control of water hyacinth. Pathogen collection	DANIDA [Langewald]
20. Tanzania	Root and Tuber Crops Programme	A stakeholders workshop was held to initiate a regional project to tackle the CMD pandemic, incorporating training for project partners.	As part of the regional OFDA CMD project, a range of activities will be done in collaboration with NARS and NGO partners in the Lake Zone, including monitoring surveys, evaluation of CMD resistant germplasm and multiplication. Extension staff will be trained and CMD information leaflets published and disseminated. PHMD in collaboration with other partners will co-ordinate the establishment of an open quarantine facility on the Uganda-Tanzania border in order to facilitate the introduction of CMD resistant germplasm from Uganda to Tanzania.	USAID (OFDA) [Legg]
	Plant Protection Service in the Ministry of Agriculture and Livestock Development, Zanzibar	Survey on Musa production constraints in Zanzibar:.part of the results were used to develop a PhD thesis on impact assessment of various IPM technologies to reduce Musa production constraints. Also a proposal was prepared for the dissemination of banana clean planting material . The proposal was funded	Impact assessment of various IPM strategies to improve Musa production in Zanzibar. The impact assessment will include the implementation and evaluation of the technology transfer project on banana clean planting material	SDC [Sy, Speijer] ASARECA [Speijer]

20. Tanzania (cont.)	Plant Protection Service in the Ministry of Agriculture and Livestock Development	Surveys of whiteflies and whitefly-born viruses of cassava continued. *T. aripo* spread surveys were conducted. PHMD scientists continue to provide backstopping service in mite identification and curation, and will assist in surveys to the extent of CMD pandemic in Tanzania. CGM biocontrol implementation continued. Two NARS staff were trained in CGM management. One MSc student started his work on socioeconomics of CGM biocontro and one farmers training course was conducted in Mara region.	CGM project will continue biocontrol implementation with new three-year program, which includes *T. aripo* releases, spread and persistence surveys, impact studies, postgraduate training, and farmers training. CMD control campaign will continue.	IFAD Rockefeller USAID [Hanna, Legg, Toko]
21. Togo	Institut Togolais de Recherche Agricole (ITRA), Togo The National Plant Protection Service (SPV) Directorate of Agricultural Research	In the framework of an EC project in collaboration with University of Göttingen, Germany, which started in September 1998, a survey on cassava diseases was conducted with NARS scientists; root rot and bacterial blight samples were collected and isolated; field trials on IPM of cassava bacterial blight were installed in 3 ecozones. The spread of *T. aripo* was monitored and mite training was provided. *T. aripo* impact studies were completed. Impact of cassava-maize intercropping on CGM and exotic phytoseiids completed.	Adaption of IPM methods for control of cassava bacterial blight to ecozones; identification of mechanisms of resistance to CBB; transfer of detection methods to NARS. Cultural practices will be tested to enhance CGM biocontrol. New EC project will focus on implementation of and adoption of CBB control technologies.	EU Denmark [Wydra, Hanna]
	ITRA; Rotary Clubs of Lomé; Ministry of Health	Planning and training workshops for maize quality control Campaigns, human health /nutrition study and post-harvest technology testing	Implemention of a maize quality public information campaign will begin in 2000, as will urban market mycotoxin monitoring activities, model farm (poultry) feasibility studies, and on farm testing of mycotoxin control technologies	Rotary International; BMZ/GTZ; The Netherlands; USDA; FAO; [Cardwell, Hell, Hounsa]

22. Uganda	National Agricultural Research Organization (NARO) Makarere University	Collaboration with the national cassava research program (NCRP) focused on CMD management activities including cassava mosaic virus monitoring and diagnostics, farmer participatory evaluation of CMD resistant varieties and the development of quality management protocols for the maintenance of plant health within multiplication schemes.	Close collaboration with the national cassava program will continue and include farmer participatory evaluation of CMD resistant varieties, the investigation of the use of varietal mixtures for CMD control, cassava mosaic virus species/strain interactions and training of extension/NGO staff and farmers. Two MSc students will initiate studies on efficiency Aphelenid parasitoids of Bemica tabaci and the interaction between cassava gemini vruses.	Denmark USAID Rockefeller [Legg]
	National Agricultural Research Organization (NARO) Makarere University	CGM biocontrol implementation continued. PHMD scientists participated in country-wide surveys to determine spread of *T. aripo*. Participatory evaluation of multiple pest and disease resistant varieties were conducted. A regional stakeholder workshop on CGM management was held in April 1999. An MSc student started his studies on variety preference by *T. aripo*. Two farmers training courses were conducted.	CGM project continues activities in implementation of CGM biocontrol, which includes *T. aripo* releases, spread and persistence surveys, screening of cassava varieties for preference by *T. aripo*, impact studies, and farmers training.	IFAD [Hanna, Toko]
	National Agricultural Research Organization (NARO) Makarere University	IITA works closely with NBRP in all phases of research including development of research strategies, collaborative on-station and on-farm trials and training of staff in higher degree programs and short courses. A proposal on production of banana clean planting material using hot-water was prepared and funded. Also a proposal Management of Highland Banana nematodes and Fusarium in Kabale, Uganda., was prepared. Funding for this proposal is likely, but is still depending on structural changes within AHI in Uganda	The project on the production of banana clean planting material will be implemented in at least one of the UNBRP bench-mark sites (Luwero)	Rockefeller Foundation AHI ASARECA [Gold] [Speijer]
23. Zambia	Mt. Makulu Research Station, Department of Research within the Ministry of Agriculture	*T. aripo* establishment and spread surveys were conducted. Screening for plant perference by phytoseiid predators conducted. Two NARS staff were trained in CGM management.	CGM project continues activities in implementation of CGM biocontrol, which includes *T. aripo* (and other exotic phytoseiid) releases, spread and persistence surveys, impact studies and postgraduate and farmers training.	IFAD Denmark [Hanna]

IITA/PHMD POSTGRADUATE TRAINING

MSc/MPhil, completed

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Abang, Mathew M.	Cameroon	96/97	IITA/self	Green/Wanyera
Abera, Agnes	Uganda	95/98	RF	Gold
Abole, Emmanuel	Ghana	94/96	ESCaPP/Winrock	Yaninek
Agboka, K.	Togo	97/98	self/IITA	Schulthess
Aigbe, Sylvester O	Nigeria	96/97	self	Florini/Schilder
Alibei, Justin	Sudan	93/94	Norway	Tamò
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Animashaun, A. M.	Nigeria	86/88	IITA	Yaninek
Anledu, C.	Nigeria	94/95	ESCaPP	Yaninek
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Baba-Moussa, A.A.	Benin	97/98	self	Cardwell/Schulthess
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Bello, T.M.	Nigeria	94/95	WB	Schilder/Thottappilly
Boateng, Bernhard	Ghana	94/96	IITA/DANIDA	Meikle
Bourassa, Caroline	Canada	96/97	LUBILOSA	Lomer
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d'Almeida, Ivens	Benin	93/94	self	Neuenschwander
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Name	Country	Date	Sponsor[1]	IITA supervisor[2]
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Asanzi, M. Christopher	Zaire	88/91	IITA/USAID	Bosque-Pérez
Banjo, D. M.	Nigeria	93/97	self	Jackai
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Bokonon-Ganta, Aimé H.	Benin	92/96	IITA/GTZ	Neuenschwander
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Bruce-Oliver, Samuel	Gambia	89/93	IITA	Yaninek
Camara, Mamadou	Mali	92/96	IITA/BMZ	Borgemeister
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Desmarais, Gaétan	Canada	94/96	IDRC	N'wander/Akinwumi
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Fanou, André	Benin	97/99	BMZ/SDC	Wydra
Fesschaie, Anania	Germany	93/97	BMZ	Wydra
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Koona, Paul	Cameroon	96/98	IITA	Jackai/Lajide
Langewald, Jürgen	Germany	90/93	GTZ	Lomer
Manuel, Bob Rosetta B.[3]	Nigeria	88/91	IITA	-
Mebelo, M.	Zambia	97/98	IITA/SARRNET	-
Meikle, William	U.S.A.	89/92	RF	Herren

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Name	Country	Date	Sponsor[1]	IITA supervisor[2]
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Muaka, Toko	Zaire	90/92	IITA/USAID	Yaninek
Mungo, Catherine	Cameroon	92/97	IITA	Florini
Murega, Thomas N.[3]	Kenya	87/90	IITA	-
Ndemah, Rose	Cameroon	96/99	IITA/IFAD	Schulthess
Ndonga, M.F. Millicent[3]	Kenya	86/89	IITA	-
Ngoko, Zachée	Cameroon	96/99	IITA/IFAD	Cardwell
Njukeng, Patrick.	Cameroon	94/98	IITA/Italy	Thottappilly/Hughes
Nsiama, She H.D.	Zaire	80/85	IITA	Herren
Ntonifor, Nelson	Cameroon	90/94	IITA	Jackai
Oduor, I. George	Kenya	91/95	IITA	Yaninek
Ogu, C.	Nigeria	95/97	IITA	Hughes/Thottappilly
Ogwang, James[3]	Uganda	87/90	IITA	-
Oigiangbe, O.N.	Nigeria	96/98	self	Jackai/Lajide
Ojo, Joseph Bamidele	Nigeria	91/98	IITA	Yaninek
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Name	Country	Date	Sponsor[1]	IITA supervisor[2]
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di Umba, Umba	DR Congo	95/99	IITA	Dashiell/Berner
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Essono, Germain	Cameroon	97/00	Self/IITA	Ayodele/Cherry
Gnanvossou, Desiré.	Benin	98/00	DANIDA	Hanna

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Name	Country	Date	Sponsor[1]	IITA supervisor[2]
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Griesbach, Matthias	Germany	96/99	DAAD	Gold/Speijer
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Kwosch, Charles	Ghana	96/99	IIP	Asiedu/Speijer
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Minamor, Andrew Amegbedzi	Ghana	96/98	DFID	Hughes
Mudiope, Joseph	Uganda	99/01	IITA	Speijer/Asiedu
Ngakou, Albert	Cameroon	99/01	IITA	Tamò
Niere, Bjoern	Germany	97/00	BMZ	Speijer
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Name	Country	Date	Sponsor[1]	IITA supervisor[2]
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[1] DAAD: Deutscher Akademischer Austauschdienst, Germany; DBF: Daimler-Benz Foundation, Germany; DFPV: Département de Formation en Protection des Végétaux, Niger; FF: Ford Foundation, USA; IIBC: International Institute of Biological Control, UK; OAU: Organization of African Unity, Ethiopia; RF: Rockefeller Foundation, USA; UNB: Université Nationale du Bénin, Benin; Winrock: Winrock International, USA; acronyms of other sponsors are given in the donors' list.

[2] most MSc, all ARPPIS students and some externally sponsored PhD students do not have a direct IITA supervisor

[3] Through the African Regional Postgraduate Program for Insect Science (ARPPIS)

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Abubakar Tafawa Balewa University, Bauchi, Nigeria: *A. Adebitan*

Action Aid, Blantyre, Malawi: *E. Musopole*

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Crops Services Department, Ho, Volta Region, Ghana: *N. Oware-Owusu*

Danish Insitute of Agricultural Sciences, Flakkebjerg, Denmark: *N. Holst*

Danish Pest Infestation Laboratory, Lyngby, Denmark: *H. Skovgaard, L. Stengaard-Hansen*

Departamento de Sanidade Vegetal, Maputo, Mozambique: *A.A. Jones*

Département de Formation en Protection des Végétaux (DFPV), Niamey, Niger: *C. Kooyman, E. Sarr*

Direction de la Protection des Végétaux et du Conditionnement (DPVC), Ouagadougou, Burkina Faso: *J.B. Toe*

Direction de la Protection des Végétaux, (DPV), Niamey, Niger: *S. Gan-Bobo*

Direction de la Protection des Végétaux, (PV), Conakry, Guinée-Conakry: *S. Baldé, M. Camara, A. Fofana, K. Kalivogui, P. Moriba, L. Traoré*

Dupont Company, Stine-Haskell Research Center, Delaware, U.S.A.: *J. Green*

Ecole Nationale Supérieure Agronomique (ENSA), Yamoussoukro, Côte d'Ivoire: *K. Foua-Bi*
Ecole Nationale Superieure Agronomique, Montpellier, France: *S. Kreiter*
Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland: *S. Dorn*
Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Brazil: *A. Maps, B. Ospina, J.T. Yorinori*
Environmental Management Associates (EMA), Accra, Ghana: *R. Hoevers*
Escuela Agrícola Panamericana (EAP), El Zamorano, Honduras: *S. Gladstone, V.F. Wright, M. Zeiss*
Federal University of Technology, Akure, Nigeria: *L. Lajide, T.I. Ofuya*
Federal University of Technology, Owerri, Nigeria: *C.C. Asiabaka, C.I. Ezendinma*
Ferme Semencière d'Alafiarou, Direction Nationale de l'Agriculture, Parakou, Benin :*C.G. Dossouhoui*
Food and Agriculture Organization (FAO), Rome, Italy: *G.G.M. Schulten*
Friedrich-Schiller-Universität, Jena, Germany: *B. Voelksch*
Fundación Hondureña de Investigación Agrícola, LaLima, Honduras: *A. Rafie, F. Rosales, P. Rowe*
Gesellschaft für technische Zusammenarbeit (GTZ), Eschborn, Germany: *A. Bell*
Ghana Atomic Energy Commission, Accra, Ghana: *R. Ahiabu, E. Dinku*
Horticulture Research International, Welletbourne, U.K.: *A.A. Brunt*
Imo State University, Okigwe, Nigeria: *G. Mbata*
Imperial College, Silwood Park, England: *S. Leather*
Institut d'Etudes et de Recherches Agricoles (INERA), Kamboinsé, Burkina Faso: *C. Dabire, I. Drabo*
Institut d'Etudes et de Recherches Agricoles (INERA), Ouagadougou, Burkina Faso: *S. Paco*
Institut d'Etudes et de Recherches Agricoles (INERA), Ouahigouya, Burkina Faso: *D.F. Traore*
Institut des Savannes (IDESSA), Ferkessedougou, Côte d'Ivoire: *D. Acle, L. Akanvou*
Institut des Sciences Agronomiques du Burundi (ISABU), Bujumbura, Burundi: *P. Ndayiragije*
Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM), Montpellier, France: *C. Assigbetse, B. Boher, O. Bonato, V. Verdier*
Institut National des Recherches Agricoles du Bénin (INRAB), Cotonou, Benin: *P. Adegbola, D.Y. Arodokoun, G. Gbéhounou*
Institut National des Recherches Agricoles du Bénin (INRAB), Ina, Benin: *A. O. Sanni*
Institut National des Recherches Agricoles du Bénin (INRAB), Niaouli, Benin: *K. Aïhou, R. Dossou, N.G. Maroya, O. Sanni*
Institut National des Recherches Agronomiques du Niger (INRAN), Kollo, Niger: *A. Aboubakar, A. Basso, I. Germaine, P. Halidou, S. Maiga*
Institut National des Recherches Agronomiques du Niger (INRAN), Maradi, Niger: *Hamma Hassan, H.A. Kadi,*
Institut National des Recherches Agronomiques du Niger (INRAN), Niamey, Niger: *S. Ly*
Institut National pour L'etude et la Recherche Agronomique (INERA), Kinshasa, DRC: *T. Hangy, K.M. Lema*
Institute for Subtropical and Tropical Crops (ISTC), Nelspruit, South Africa: *S. Schoenen*
Institute of Agricultural Research and Training, College of Agriculture, Akure, Nigeria: *A.O. Adetoro*
Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria: *E. Iken, O. Obajimi, B.A. Ogunbodede*
Institute of Agricultural Research, Ahmadu Bello University (IAR/ABU), Zaria, Nigeria : *O. Alabi M.C. Dike, K. Elemo, A.M. Emechebe, S.T.O. Lagoke, O.O. Olufadjo, J. Voh*
Institute of Agronomic Research & Development (IRAD), Bamenda, Cameroon: *Z. Ngoko*
Institute of Agronomic Research & Development (IRAD), Maroua, Cameroon: *G. Ntoukam*
Institute of Agronomic Research & Development (IRAD), Yaoundé, Cameroon: *J. Ayuk-Takem, J. Ngeve*
Institute of Agronomic Research, Ekona, Cameroon: *B. Bakia, M. Besong, E. Awah, R. Ndemah, Z. Ngoko, C. Poubon, M. Tchuanyo*
Instituto Nacional de Investigaçao e Desenvolvimento Agraria (INIDA), Sao Jorge, Cabo Verde: *M.-L. Lobo-Lima*
Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), Mexico: *R.M. Ríos*
Instituto National de Investigaçao Agronomica (INIA), Maputo, Mozambique: *M. Amane, A.M. Zacarias*
International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria: *K. Makouk*
International Center of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya: *A. Hassanali, Y. Khan, S. Lux, E. Osir, W.A. Overholt, K.V. Seshu Reddy, J. Ssenyunga*
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Bagauda, Nigeria: *O. Ajayi*

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Bulawayo, Zimbabwe: *K. Leuschner*

International Institute of Biological Control, (IIBC), C.A.B. International, London, U.K.: *R. Bateman, M. Cock, D. Greathead, N. Jenkins, D. Moore, C. Prior, M. Thomas, J. Waage*

International Institute of Biological Control, (IIBC), C.A.B. International, Nairobi, Kenya: *G. Allard, G. Hill*

International Institute of Entomology, (IIE), C.A.B. International, London, U.K.: *T. Jones*

International Institute of Parasitology (IIP), C.A.B. International, London, U.K.: *J. Bridge, R. Plowright*

International Livestock Research Institute (ILRI), Ibadan, Nigeria: *S. Tarawali*

International Mycological Institute (IMI), C.A.B. International, London, U.K.: *M. Holderness, M. Rutherford, J. Waller*

International Network for the Improvement of Banana and Plantain (INIBAP), Montpellier, France: *D. Jones*

International Network for the Improvement of Banana and Plantain (INIBAP), Los Banos, Philippines: *R. Valmayor*

International Plant Genetic Resources Institute (IPGRI), Rome, Italy: *M. Dickmann*

International Rice Research Institute (IRRI), Los Baños, Philippines: *A. Baniou*

Irish Foundation for Co-operative Development (IFCD), Rakai, Uganda: *R. Mayiga*

John Innes Centre (JIC), Norwick, U.K.: *G. Harper, R. Hull*

Justus Liebig Universität, Giessen, Germany: *H. Hummel, H. Schmutterer*

Kabwe Research Station, Kabwe, Zambia: *E. Munsanje*

Kagera Agricultural and Environmental Management Project (KAEMP), Bukoba, Tanzania: *J. Anania, D. Rukazambuga*

Kano Agricultural Research and Development Association (KNARDA), Kano, Nigeria: *S. Dantata, S. Gaya, U. Ibrahim, A. Ma'aruf*

Kasetsart University, Bangkok, Thailand: *M.. Weerwit*

Katholieke Universiteit, Leuven, Belgium: *R. Swennen, D. de Waele*

Kenya Agricultural Research Institute (KARI), Kakamega, Kenya: *H. Obiero, O.M. Odongo*

Kenya Agricultural Research Institute (KARI), Machakos, Kenya: *J. Kamau*

Kenya Agricultural Research Institute (KARI), Nairobi, Kenya: *C. Kariuki*

Kenya Plant Health Inspectorate Service (KEPHIS), Muguga, Nairobi, Kenya: *P. Njoroge*

Laboratoire de Pathologie Végétale (LPV), Ambatobe, Madagascar: *S. Ranomenjanahary*

Lagrotech Consultants Limited, Kisumu, Kenya: *M. Onim*

Livestock and Pest Control Division, Federal Ministry of Agriculture and Natural Resources, Lagos, Nigeria: *J.J.A. Akinnibagbe*

LOCUSTOX, FAO, Dakar, Senegal: *H. van der Valk*

London School of Hygiene and Tropical Medicine, London,UK: *A. Hall*

Louisiana State University, Baton Rouge, Louisiana, U.S.A.: *K. Fischer*

Luapula Regional Research Station, Mansa, Zambia: *M. Mebelo*

Makerere University, Kampala, Uganda: *E. Adipala, S. Kyamanywa, M. Ogenga-Latigo, P. Rubaihayo*

Makoka Research Station, Thondwe, Malawi: *G. Phiri*

Malawi-German Plant Protection Project, Lilongwe, Malawi: *J. Gwinner*

Mara Farmers Initiative Project (MARA-FIP), Musoma, Tanzania: *W. Ng'unda, E. Bwana*

McGill University, Monréal, Canada: *V. Rahavan*

Ministry of Agriculture and Livestock Development (MALD), Dar es Salaam, Tanzania: *F. Katagira, O. Mfugale, B. Pallangyo*

Ministry of Agriculture, Extension Service, Kampala, Uganda: *B. Byarugaba*

Ministry of Food and Agriculture, Accra, Ghana: *D.Q. Annang, E. Dosoo, O. Ofori*

Montana State University, Bozeman, Montana, USA: *W. Swearingen*

Mt. Makulu Research Station, Chilanga, Lusaka, Zambia: *M.A. de Vos, F. Javaheri, E. Musonda, A. Sumani*

Mycotech Corporation, Butte, Montana, USA: *C. Bradley, S. Jaronski*

National Agricultural Research Organisation (NARO), Kawanda, Kampala, Uganda: *F. Bagamba, E. Karamura, I. Kashaija, J. Namaganda, C. Nankinga, W. Tinzaara, M. Wejuli*

National Agricultural Research Organisation (NARO), Namulonge, Kampala, Uganda: *Y. Baguma, G. Bigirwa,*

S.C. Jeremiah, T. Kalule, J. Kamau, R. Mayala, R. Molo, J. Ogwang, S. Ogwal, W. Otim-Nape, W. Sserubombwe

National Banana Program, ISAR, Butare, Rwanda: *M. Cyubahiro Bagabe*

National Cereals Research Institute (NCRI), Badeggi, Nigeria: *A. Idowu, B.A.O. Okusanya, A. Uwala*

National Museums & Galleries of Wales, Cardiff, U.K.: *J. C. Deeming, P. Morgan, M. R. Wilson*

National Root Crops Research Institute (NRCRI), Umudike, Nigeria: *A.O. Ano, T.N.C. Echendu, A.A. Melifonwu, S. Orkwor, F. Ogbe, E.C. Nodu, J. Ikoorgu*

National Seed Service, Ibadan, Nigeria: *E. Adegbuyi*

Natural Resources Institute (NRI), Chatham, U.K.: *T. Chancellor, A. Cook, R. Cooter, J. Cropley, M. Downham, D. Hall, R. Gibson, J. Gilli, I. Gudrups, C. Haines, R. Hodges, L. Kenyon, F. Kimmins, R. Maslen, J. Orchard, W. Page, J.M. Thresh, H. Wainwright*

Nigerian Agip Oil Company-Agip Green River Project, Port Harcourt, Nigeria: *S. Akele, N.D.Onyeaghala*

Nigerian FDA Downy Mildew Task Force, Ibadan, Nigeria: *O.A. Adenola*

Nigerian Federal Department of Agriculture (FDA), Abuja, Nigeria: *Dr. Edache*

NOVARTIS-Nigeria, Lagos, Nigeria: *P.N. Ikemefuna*

Obafemi Awolowo Univerity, Institute for Agricultural Training, Moor Plantiation, Ibadan, Nigeria: *B. A. Ogunbodede*

Obafemi Awoluwo University, Ile Ife, Nigeria: *A.E. Akingbohungbe, M.A.B. Fakorede, S.A. Shoyinka*

Oklahoma State University, Stillwater, Oklahoma, USA: *T. Phillips*

Old Dominion University, Virginia, U.S.A.: *L.J. Musselman*

ONFARM (NGO), Kisumu, Kenya: *M. Onim*

Orange Free State University, Bloemfoentein, South Africa: *M. Labushagne, S. Loew, M. Wingfield*

Organization of African Unity/Inter-African Phytosanitary Council (OAU/IAPSC), Yaoundé, Cameroon: *N. Nkouka*

Oyo State Agricultural Development Project (OYSADEP), Ogbomosho, Nigeria: *E. I. Bolaji*

Pan African *Striga* Control Network (PASCON), IAR, Zaria, Nigeria: *S. T. O. Lagoke*

Plant Protection and Regulatory Services Department, Pokuase/Accra, Ghana: *E. Blay, G.A. Dixon, A.R. Cudjoe*

Plant Protection Department (PPD), Dar-es-Salaam, Tanzania: *R. Mohammed*

Plant Protection Research Institute, Pretoria, South Africa: *R. Kfir*

Plant Protection Service, Department of Bacteriology, Wageningen, Netherlands: *J. Janse*

Plant Quarantine Service (PQS), Kawanda, Uganda: *O. Opolot*

Post Harvest Development Unit, Min. of Food and Agriculture, Ho, Ghana: *T. Ofosu, F. Motte, K. Acquaye, and S. Addo*

Programme on Mycotoxins and Experimental Carcinogenesis Medical Research Council, Tygerberg, South Africa: *W.F.O. Marasas*

Project Planning and Implementation Consultants, Accra, Ghana: *D. Inkoom, O.C. Nkum*

Projet de Gestion des Ressources Naturelles (PGRN), Cotonou, Bénin: *N. Ahouandjinou*

Purdue University, Indiana, U.S.A: *P.M. Hassegawa, L.L. Murdock, R.E. Shade*

Queensland Department of Primary Industries, Brisbane, Australia: *J. Thomas*

Queensland University of Technology, Brisbane, Australia: *J. Dale*

Reading University, Reading, U. K: *C. Birch, H. van Emden, S. Gowen, J. Peters, B. Pickersgill*

Research Institute for Plant Protection (IPO-DLO), Wageningen, The Netherlands: *H. Huttinga, E. van Balen, J. Vink*

Rice Research Station, Rokupr, Sierra Leone: *S.N. Fomba*

Rotary International (RI), Evanston IL, U.S.A.: *S. Townsend*

Royal Danish Agricultural University, Copenhagen, Denmark: *S. Harding*

Santé Maternelle et Infantile, Soins de Santé Primaires, Cotonou, Benin: *E. Gbaguidi*

Sasakawa Global 2000, Benin: *M. Galiba*

Savannah Agricultural Research Institute (SARI) Nyamkpala, Tamale, Ghana: *S. Asante, R. Kanton, K.O. Marfo, A.B. Salifu*

Scottish Crops Research Institute (SCRI), Dundee, Scotland: *B.D. Harrison*

Service de la Protection des Végétaux, Cacaveli/Lomé, Togo: *D. Agounké, Y.S. Gogovor*

Service de la Protection des Végétaux, Cacaveli/Lomé, Togo: *D. Agounké, A. Biliwa, Y.S. Gogovor*

Service de la Protection des Végétaux, Porto-Novo, Benin: *A. Bokonon-Ganta, M. Noudofinin, J. Sagbohan, S. Saïzonou*

Solok Research Institute for Fruit, Solok, Indonesia: *A. Hasyim*

South African Sugar Experiment Station, Mount Edgecombe, Durban, South Africa: *D. Conlong*

Station de Recherche sur les Cultures Vivrières, Niaouli, Benin: *K. Aïhou, B. Maroya*

Sudan United Mission - Nigeria Reformed Church-branch, Abakaliki, Nigeria: *A. Nwankpuma, L. de Wit*

Tanzania Root and Tuber Crops Programme (TRTCP), Maruku, Bukoba, Tanzania: *I. Ndyetabura*

Tanzania Root and Tuber Crops Programme (TRTCP), Ukiriguru, Mwanza, Tanzania: *S. Jeremiah, B. Chirimi*

Texas A&M University, College Station, Texas, U.S.A.: *J.W. Smith Jr.*

Tropical Fruit Research Station, New South Wales, Australia: *N. Treverrow*

Tropical Pesticides Research Institute (TPRI), Arusha, Tanzania: *R. Abdallah*

Ugandan National Banana Research Programme, UNBRP, Kawanda, Uganda: *W. Tushemereirwe*

United States Department of Agriculture (USDA), Fredrick, Maryland, U.S.A.: *R. French, N. Schaad*

United States Department of Agriculture (USDA), New Orleans, U.S.A.: *P.J. Cotty*

United States Department of Agriculture, New Orleans, USA: *R. Brown*

Universidad Autonomo de Mexico, Estacion de Biologia Chamela, San Patricio, Edo. de Jalisco, Mexico: *F.A. Noguera*

Universität Bonn, Bonn, Germany: *R. Schuster, R.A. Sikora*

Universität Frankfurt, Frankfurt, Germany: *G. Kahl*

Universität Göttingen, Göttingen, Germany: *K. Rudolph*

Universität Hannover, Hannover, Germany: *H.-M. Poehling, C. Borgemeister*

Universität Hohenheim, Stuttgart, Germany: *H.H. Geiger, G. Welz, C.P.W. Zebitz, J. Zeddies*

Université de Monréal, Monréal, Canada: *J.G. Pilon*

Université de Nantes, Nantes, France: *A. Fer*

Université de Niamey, Niamey, Niger: *T. Adam*

Université de Yaoundé I, Yaoundé, Cameroon: *A. Ngakou, D. Nwaga*

Université du Bénin, Lomé, Togo: *M.Y.D. Gumedzoe, G. Lawson, Y. Smith*

Université du Québec, Monréal, Canada: *C. Vincent*

Université Laval, Québec, Canada: *C. Cloutier*

Université Nationale du Bénin (UNB), Cotonou, Benin: *B. Ahohuendo, S. Ambaliou, P. Atachi, G. Biaou, D.K. Kossou, A. Odjo*

Université Omar Bongo, Libreville, Gabon: *J. Boussienguet*

Universiteit Gent, Gent, Belgium: *P. Van Damme*

University of Agriculture, Abeokuta, Nigeria: *K. Okeleye, T. O. Tayo*

University of Agriculture, Makurdi, Nigeria: *A. Nwankiti*

University of Alexandria, Alexandria, Egypt: *O. Al-Menoufi*

University of Amsterdam, Amsterdam, The Netherlands: *F. Bakker, A. Janssen, M. Sabelis, L. van der Geest*

University of Arizona (UA), Tucson, Arizona, USA: *J. Brown*

University of Buea, Buea, Cameroon: *N.N. Ntonifor*

University of California, Berkeley, U.S.A.: *N. Mills*

University of California, Davis, California: *F. Zalom*

University of California, San Diego, U.S.A.: *M. Chrispeels*

University of Cape Coast, Cape Coast, Ghana: *M. Botchey, J. Kwarteng, Y. Opoku-Asiama*

University of Dschang, Dschang, Cameroon: *J. Foko, I.A. Parh*

University of Florida, Homestead, U.S.A.: *J. Peña*

University of Ghana, Agricultural Research Station, Kade, Ghana: *K. Afreh-Nuamah, K. Osei, S. Quartey*

University of Ghana, Kpong, Ghana: *E.O. Darkwa*

University of Ghana, Legon, Accra, Ghana: *E. Acheampong, R.K.A. Ahiabu, J. Allotey, J.N. Ayertey, W. Danso, I. Egyr, K. Oduro, S.K. Offei*

University of Ibadan, Ibadan, Nigeria: *S. Adesinyan, V. Adetimirin, T. Amusa, G.I. Atiri, E.A.J. Ekpo, F.K. Ewete, O.O. Fadina, O. Fagade, B. Fawole, A.T. Hassan, T. Ikotun, M.F. Ivbijaro, J.A. Odebiyi, A.O. Oladiran, J.A.I. Omueti O.O. Tewe*

University of Illinois, Urbana, Illinois: *S. Lazarowitz, H.T. Wilkinson*

University of Ilorin, Ilorin, Nigeria: *G. Olaoye*
University of Leeds, Molecular Medical Epidemiology Dept., Leeds, UK: *C. Wild*
University of Leiden, Leiden, The Netherlands: *C. van Achterberg, J.J. M. van Alphen*
University of Minnesota, St. Paul, U.S.A.: *B. Lockhart*
University of Nairobi, Nairobi, Kenya: *J.A. Chweya*
University of Natal, Pietermaritzburg, South Africa: *L. Haines*
University of Sao Paolo, Brazil: *G. J. de Moraes*
University of Science and Technology, Kumasi, Ghana: *R.T. Awuah, B. Hemeng*
University of Science and Technology, Port Harcourt, Nigeria: *L.A. Dan-Kalio, J.A. Osakwe, K. Zuofa*
University of Virginia, Charlottesville, Virginia, U.S.A. *M. Timko*
University of Wageningen, Wageningen, The Netherlands: *J. Bar, M. Dicke, A. van Huis, D. Peters*
University of Wageningen, Wageningen, The Netherlands: *M. Dicke*
University of Wales, Cardiff, U.K.: *M.A. Jervis*
University of Washington, Pullman, U.S.A.: *L.K. Tanigoshi,*
Weizmann Institute of Science, Rehovot, Israel: *J. Gressel*
West African Rice Development Association (WARDA), Bouaké, Côte d'Ivoire: *A. Youdeowei*
West and Central Africa Maize Network (WECAMAN), Bouaké, Côte d'Ivoire: *B. Badu-Apraku*
Winrock International, Abidjan, Côte d'Ivoire: *R. Agbassy-Boni, C. Djedji*
Winrock International, Arlington, Virginia, U.S.A.: *P. Craun-Selka, M.C. Peccoud-Diakité, T. Shah, E. Smith*
World Vision International, Mozambique: *C. Asanzi, V. Parkinson*

SYSTEM-WIDE PROGRAM ON INTEGRATED PEST MANAGEMENT

by L. Brader (chairman of the Inter-Center Working Group on IPM), R. Markham (program coordinator), P. Neuenschwander, in collaboration with all PHMD scientists

Project Rationale

Integrated Pest Management (IPM) is increasingly recognized as a key element in sustainable agricultural development, but the International Agricultural Research Centers (IARCs) of the Consultative Group for International Agricultural Research (CGIAR) have in the past had rather limited success in incorporating this discipline into their research and development agenda. Constraints to success have included the traditional focus of the IARCs on genetic improvement of mandate crops, over-reliance on technology based on agricultural inputs (including pesticides) and inadequate links between IARC researchers and farmers. As part of the CGIAR response to Agenda 21, a System-wide Program on IPM (SP-IPM) was established in 1996 to address these weaknesses and to ensure, through closer coordination and improved approaches, that IARC research is more responsive to the needs of IPM practitioners.

The Program brings together the interested centers of the CGIAR (nine currently participate actively), plus two non-affiliated centers (AVRDC and ICIPE) with a special interest in IPM, as well as the IPM Forum and the Global IPM Facility. Representatives of these organizations constitute the Inter-Center Working Group on IPM which meets annually to set overall policy, agree a work program and allocate the program budget. The SP-IPM is led by IITA, whose Director General is program leader and which hosts the secretariat. Task Forces are set up to examine key issues and develop an appropriate response - in some cases including developing proposals for inter-center research. The task forces bring together key stake-holders, including national research and extension organizations, NGOs, and specialist research organizations (including those associated with bilateral development agencies). IITA leads the Task Forces on Beneficial Microorganisms and Parasitic Flowering Plants and participates actively in several other activities of the SP-IPM.

Building on the experience of centers with a proven record of success in IPM research and implementation, the program takes an holistic approach to IPM, based on sound ecological analysis of problems in agricultural systems and multi-disciplinary research to find solutions within the framework of natural resource management to promote plant health. Special emphasis is placed on involving farmers (to ensure that research is driven by needs and that results are adoptable) and on developing appropriate models of partnership between organizational stake-holders. Attention is also given to promoting information exchange amongst IPM practitioners and raising awareness of IPM issues and achievements amongst policy-makers and the general public.

Outputs

1. *Improving coordination among CG centers and partners*

by R.M., L.B.

Policies are defined, priorities selected and more effective methodologies identified and promoted through annual meetings of the Inter-Center Working Group on IPM (comprises representatives of all interested Centers, as well as two representatives of the FAO/World Bank IPM Facility and one of the IPM Forum). Representatives of the private sector (Global Crop Protection Federation) and of an NGO involved in agricultural development policy (FoodFirst) have also been invited to join the Working Group. Task forces and discussion groups are established to develop a coherent response by CG centers to major issues and challenges; small grants (to hold meetings, prepare publications, carry-out assessments/ feasibility studies etc.) are allocated by the Inter-Center Working Group to facilitate these activities. Progress is monitored by the program leader and the secretariat, who maintain frequent communication with center representatives, key partners, policy makers and donors. A database of CGIAR IPM projects resources is being developed in collaboration with IPM Europe and is available on-line through the SP-IPM website (www.cgiar.org/spipm).

2. *Developing task forces*

Background

As a general procedure, task forces are developed to respond to major IPM research challenges and opportunities for intervention. Key stakeholders and potential partners are identified and the existing situation diagnosed (usually in context of a meeting or meetings, plus correspondence). First, the extent, importance and current understanding of the problem is analyzed. Then, recent, current and planned activities already addressing this problem are reviewed, outstanding needs, and partners with complementary resources are identified (where CG and partners have comparative advantage). A response is formulated (recommendations, research proposal etc.) and a project is developed based on consensus and participatory development, involving peer-review, endorsement by the group, and submission to donors.

On-going and future activities

2.1 International whitefly IPM project

by R.M. - in collaboration with B. James, J. Hughes, J. Legg, P. Anderson

Diagnostic work on whitefly problems in Latin America and Africa, supported by Denmark under Phase 1 of the project, was substantially completed during the current year and the results are now being drawn together and fully analyzed as a basis for proposing further action. When fully synthesized, with the publication of a book and establishment of a web-site in late 2000, the documentation from this project will provide the most comprehensive overview so far available of the importance of whitefly-associated problems of tropical food crops. With new support from Australia and new major research partners coming on board during 1999, the diagnostic work was extended to include Asia, with this sub-project under the leadership of AVRDC. New Zealand and the United States joined the donor consortium to add research components on host plant resistance to, and biological control of, whiteflies in Latin America, to be carried out by CIAT. Further support from the United States allowed the project to tackle a crisis situation in East and Central Africa, under the leadership of IITA, as detailed elsewhere in this report.

2.2 Farmer participatory research

by R.M. - in collaboration with B. James, A. Braun

The need for the international agricultural research centers to develop and incorporate more effective models for farmer participatory research and training into their agenda has been recognized as a priority since the establishment of the SP-IPM. However, with several competing approaches being advocated by different stake-holders, it has proven difficult to establish a consensus on the best way to develop this Task Force. During 1999 a lively e-mail discussion group was established to examine the various issues at stake, leading by the end of the year to a new proposal being formulated. The Global IPM Facility and the Inter-Center Program on Participatory Research and Gender Analysis will join with the SP-IPM in supporting a series of 'study tour' exchanges between IPM projects in different regions which embody different models of farmer participation. Synthesis of these experiences, through a learning workshop in 2001, will lead to a critical analysis of the strengths and weaknesses of the various approaches in fulfilling particular development objectives, and practical recommendations of how these approaches can best be incorporated into new IPM projects.

2.3 Beneficial Micro-organisms

by R.M. - in collaboration with A. Cherry, C.J. Lomer

It is widely believed that microbial pesticides, based on fungi, bacteria and viruses could play a much greater role in IPM. Carefully-selected products can substitute directly for hazardous synthetic products, providing more specific, environmentally-friendly alternatives. Several Centers have been successful in developing and using microbial products but others are deterred by lack of understanding of both technical and regulatory aspects. The SP-IPM Task Force seeks to encourage and support the wider use of beneficial microorganisms in IPM by promoting the exchange of expertise and information, and by working with other partners to address statutory constraints. As a first step towards promoting a more favorable regulatory environment for biopesticides, the Task Force is working with FAO to develop and distribute a questionnaire to gather information about the procedures governing the use of these products around the world. Task Force members are also participating in the International Biopesticide Consortium for Development, led by CAB International, which seeks to help would-

be developers of biopesticides to progress through the many intervening steps, from promising research results to practical application of a new product.

2.4 Partnerships for IPM Adoption

by R.M, P.N. – in collaboration with F. Schulthess

Assembling the right team and using the right (participatory) approaches are key elements in ensuring that promising research results are successfully translated into practical IPM options that are widely adopted by farmers. Under a new initiative for which funding was approved by the CGIAR at the end of 1999, the participating research Centers will join with local research organizations, extension services and NGOs to try to address the priority crop health concerns identified by farmers in a series of pilot sites. The partners will work with farmers to identify 'best bet' solutions, drawn from scientific research and traditional knowledge, and to evaluate them in the farmers' fields. If successful, these pilot sites will serve as focal points for raising awareness of the benefits of IPM, among other farmers, decision-makers and the general public. The first pilot sites will be established during 2000 to tackle priority problems of cereal-legume systems in Africa.

3. *Promoting wider awareness of IPM research*

Background

An internet site was established in 1998 and continues to provide a source of up-to-date information on current CGIAR projects and developing plans in the broad field of IPM. A second program report, covering 1998 and 1999, is being prepared to communicate results to donors, partners, and selected policy-makers. In addition, occasional publications highlighting progress on SP-IPM activities, featuring IPM projects of individual centers and drawing attention to key issues relevant to IPM implementation in the context of sustainable agriculture have been produced. Plans are now being developed to use video as a medium for promoting awareness of IPM, with inter-center work on parasitic plants likely to be chosen as the first focus for attention.

3.1 Regional IPM Workshop for NGOs

by R.M, L.B. – in collaboration with B. James, A. Sy

Partnerships between NGOs and research organizations, national and international, are increasingly important in promoting the widespread adoption of IPM by farmers. With support from the CGIAR NGO committee and IITA's TT & TU project, a workshop was convened at IITA's Benin Station at the end of March 1999 to look at the constraints and opportunities facing NGOs seeking to incorporate IPM into their development programs. Representatives of 20 NGOs and two NARES from 12 African countries met with IPM specialists from five international organizations (CABI, ICIPE, WARDA, IITA and IAPSC) for five days of discussions and field visits. As well as gaining a better understanding of one another's perspectives, the participants gained first-hand experience of farmer participatory techniques for training and technology evaluation, as well as seeing some of the latest IPM options being generated by research. The participants established a network, supported by an e-mail list-server, for which IITA functions as secretariat, to help them to keep in touch, exchange information and provide mutual support.

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