'98

Annual Report

Plant Health Management Division

International Institute of Tropical Agriculture

The Institute

IITA is one of 16 non-profit international agriculture research and training centers supported by the Consultative Group for International Agriculture (CIGAR). Their shared mission is the alleviation of hunger and poverty in tropical developing countries by generating appropriate production and protection technologies which benefit the poor and enhance agricultural production while preserving the natural resource base.

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 of the humid and sub-humid tropics of sub-saharan Africa. The program'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 CIGAR and from special projects as listed in this report.

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INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE
PLANT HEALTH MANAGEMENT DIVISION

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EDITORIAL NOTE

The 1998 PHMD Annual Report presents the research activities of the six PHMD-centered projects focusing on integrated management of pests, diseases, and parasitic weeds. In addition, two projects centerd 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 1998. A back-dated list of all publications by PHMD since 1990 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 project and divisional structure as an instrument for research and implementation

In 1998, the institutional and organisational arrangements for implementing the research agenda of IITA have been tested and the role of the different structures has been clarified. The activities of the 16 projects (Table 1) have been discussed with all concerned scientists during reviews by the Research Programming Committee. The projects cut across divisions so that almost all scientists have time allocations in more than one project. These are led by elected project coordinators, who are responsible for the execution of the research agenda as defined in the log frames. Demand of each of the three eco-regions, moist savanna, humid forest, and mid-altitudes, is prioritised for the different projects under the guidance of working group leaders of each eco-zone. The three technical divisions for crop improvement, resource and crop management, and plant health, respectively, provide the scientific home for their scientists and are responsible for the scientific quality of their work through peer review and strategic discussions.

Table 1. IITA's research projects with their respective coordinators and divisional affiliations: CID = Crop Improvement Division, RCMD = Resource and Crop Management Division, PHMD = Plant Health Management Division

Projects		Coordinators	Divisional affiliation
# 1	Short fallow systems	N. Sanginga	RCMD
# 2	Agroecosystems development strategies and policies	V. Manyong	RCMD
# 3	Biological control and biodiversity	H. De Groote	PHMD
# 4.	Integrated management of legume pests and diseases	M. Tamò	PHMD
# 5	Integrated management of maize pests and diseases	F. Schulthess	PHMD
# 6	Integrated management of cassava pests and diseases	R. Hanna	PHMD
# 7	Improving plantain and banana-based systems	D. Vuylsteke	CID
# 8	Integrated management of *Striga* and other parasitic plants	A. Melake-Berhan	PHMD
# 9	Improving postharvest systems	M. Bokanga	RCMD
#10	Farming systems diversification	J. Gockowski	RCMD
# 11	Cowpea-cereals systems improvement in the dry savannas	B.B. Singh	CID
# 12	Improvement of maize-grain legume production systems in West and Central Africa	J. Kling	CID
# 13	Improvement of yam-based systems	R. Asiedu	CID
# 14	Cassava productivity in the lowland and mid-altitude agroecologies of sub-Saharan Africa	A. Dixon	CID
# 15	Molecular and cellular biotechnology for crop improvement	J. Mignouna	CID
# 16	Conservation and utilization of plant biodiversity	Q. Ng	CID
-	Ecoregional program for humid tropical Africa (EPHTA)	E. Atayi	RCMD
-	System-wide program for integrated pest management (SP-IPM)	R. Markham	PHMD

Following the dissolution of the International Cooperation Division, outreach to the national programmes was reinforced by joining the respective activities directly to each of the projects. Within PHMD, the Technology Testing and Transfer Unit (TT&TU), whose funding will end in 1999, concentrates increasingly on becoming the outreach arm of the project on biological control and biodiversity. The same arrangement for implementation and farmers' participatory research executed in restricted core projects is already in place for other IPM projects. In the IPM cowpea project, this is achieved by PEDUNE (the French acronym for ecologically sustainable cowpea plant protection). Similar functions, whereby existing technologies are being combined and tested on pilot sites, are fulfilled by implementation projects for IPM maize, IPM cassava, the IPM part of the *Musa* project. Corresponding proposals have been submitted to donors for the *Striga* and yams projects. This approach allows for farmers' practices to be combined with new approaches and ensures an immediate feed-back.

Increasingly, evaluation and testing are being conducted in the benchmark areas of the Ecoregional Program, favouring integration of different research areas. As a result, climatic, soil, water, plant cover, crop, and socio-economic, as well as plant health data are brought together in a GIS (geographic information system) framework. This approach guarantees the parsimonious and sustainable use of IITA resources and responsiveness to the national programmes.

Managing PHMD

In 1998, the division again saw some downsizing due to budgetary constraints. Among the principal staff this affected one core position, but we are still represented by principal staff in Ibadan (Nigeria), Cotonou (Bénin), Yaoundé (Cameroon), Kampala and surroundings (Uganda), as well as in Accra (Ghana). On balance, the proportion of female scientists and of Africans was slightly improved, but some staff could only be maintained by short-term contracts. After some interim-solution, the administrator position could be filled again and the administration and physical plant services were reorganised and streamlined.

Funding for several restricted core projects was either renewed or freshly granted. These projects cover cassava green mite control (implementation of biological control), entomopathology (on stemborers), biodiversity studies (as assistance to all projects), aflatoxin (development of crop management practices in conjunction with medical research concerning the long-term effects of this poison), and led to the hiring of three new post docs in 1999. As before, all these so-called restricted core projects, which contribute about 55% of the total PHMD budget, are totally integrated into the research agenda of the approved IITA Medium-Term Plan. The donors who support us in these difficult times are herewith thanked for their support.

In Cotonou, PHMD continues to benefit from having scientists from collaborating organisations [Gesellschaft für Technische Zusammenarbeit (GTZ), Institut de Recherche pour le Développement (IRD, formerly ORSTOM), and Natural Resources Institute (NRI)], whose research agenda is fully integrated into that of PHMD. In addition, IITA Cotonou houses staff of other disciplines and from other institutions, providing a scientifically and intellectually challenging climate.

Research and its implementation depend on a well functioning cadre of administrative and technical personnel. With the streamlining of the support services, a disproportionate number of these local positions was lost and we thank the remaining staff for their dedication to maintain the station.

During 1998, we finally achieved a long sought for goal. Our memorandum of understanding was amended and our diplomatic status was clarified. The ceremony in the Ministry of Foreign Affairs crowned a steady improvement in our relationship with the Benin government. At the same time, links with the Université Nationale du Bénin and the Institut National de Recherches Agricoles du Bénin were strengthened. In 1998, we hosted 13 meetings with scientists from universities, government institutions, and NGOs, which gave us the opportunity to listen to results and opinions from all over Africa. Similar improvements of links have been achieved in the other stations.

Overview of achievements for 1998

Plant protection activities permeate almost all projects and the 1998 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. This is particularly the case for the activities of the two virologists. It is, however, not possible here to include all activities in resistance breeding (including research in biotechnology) and deployment of resistant varieties - often the first line of defence - achieved at IITA. In this research, PHMD staff assisted by providing insects for homogeneous infestation or testing, methodologies for impact assessment, and scoring results.

All projects are also engaged in varied training activities, though this is not always sufficiently publicised. In fact, it is often largely due to previous training activities that PHMD can now rely on such a good cadre for collaboration with some NARES. Human development activities certainly belong to our core duties, though the means to achieve this goal may change in time.

1998 was marked by the following developments in plant protection and plant health management, whereby research and implementation blended into each other and fertilised each other through feed-back:

- Classical biological control remains a speciality of the Cotonou team. Based on the rich collection of natural enemies in the insectary, previously developed control programs are being continued wherever the invasive pest species colonizes new countries, as for instance the cassava green mite and the mango mealybug. It becomes ever more apparent that there is no qualitative distinction between research and implementation. Successful research has immediate impact and there is continuous feed-back from on-farm impact studies to guide continuing research - which continues until the job is declared done.

- The production of a specific insecticide based on entomopathogens has been commercialized to be used against locusts and grasshoppers, which posed novel problems of intellectual property rights. Even with the production of the commercial product in private companies, various research elements are still required to continue, in order to assure success.
- The same production technology and know-how is now being adopted to control other insects like banana weevil, stemborers, or termites. Specific antagonists have been found in all these cases and the first research results are promising. In some cases, antagonists can be manipulated to live inside the plant as endophytes, providing new, intriguing options for implementation as for instance against banana nematodes.
- Interesting farmers participatory research (FPR) is being carried out with highly different models. In the case of the entomopathogen against grasshoppers, technology is being delivered, but its integration into acceptable IPM options is being investigated through FPR. In the case of cowpea IPM, much indigenous knowledge is available for testing, together with new technology from IITA. For the biological control of water hyacinth, rearing of beneficials is being handed over completely to local communities and FPR consists in raising the understanding of the ecology of the system and therefore the patience of the population to wait for the slow, but certain, results.
- The downy mildew eradication campaign is another example, where IITA extended its activities beyond research into assisting the Federal Government of Nigeria as well as local governments of several states in their policy development and in implementing the recommended IPM package, thus stopping the spread of this disease into neighbouring countries.
- The multi-faceted research results concerning different approaches to *Striga* control are now ready to be adapted and tested as packages of IPM options that are specific to different regional and socio-economic conditions. To understand the complicated interactions between the different *Striga* species and their hosts, it is best to think of the myriads of seeds as soil-borne pathogens whose chemical interactions with higher plants are being manipulated by rotation with specific crop varieties and soil management techniques.
- By linking simulation modeling and GIS, decision tools for maize store management are being developed that make the vast but dispersed knowledge from researchers and farmers alike available to NGOs and NARES. Through a better understanding of the ecology and economics of maize stores, management practices can be adapted to weather and market data on a regional basis and monitoring plans can be developed that reduce pesticide use.
- The story on the two cassava mosaic viruses and their recent hybridisation in Uganda becomes ever more fascinating. Interestingly, the tool for solving the problem is already available in the form of varieties that, inadvertently, have been selected for resistance against both viruses.
- The biology of banana streak virus (BSV) proved even more complicated and the research results achieved in world-wide collaboration challenged established notions and, even more so, quarantine regulations. In collaboration with the regulatory agencies, guidelines have now been developed by the Germplasm Health Unit (GHU) for the safe transfer of *Musa* germplasm across borders, which allows IITA to distribute its previously developed sigatoka-resistant banana material.
- The two examples on viruses demonstrate the importance of GHU, which in 1998 has been radically improved. Compulsory passage of all in-coming and out-going plant material and close links to the Nigerian plant quarantine authorities ensure that the politically sensitive quarantine regulations are adhered to scrupulously and we are seen to respect them.
- Similarly, the biodiversity group ensures professional identification based on the large collection of the insect museum. By coordinating identification, which is at the basis of all IPM decisions, and insect and pathogen curation services across all of West Africa, this unit helps NARES to improve their capacity in this vital field.
- Finally, IITA is the convening centre for the System-wide Program for Integrated Pest Management (SP-IPM). The SP-IPM facilitates coordination in IPM research among all interested CG centres by fostering synergies among a network of colleagues with a profound know-how of IPM in the tropics. The aim is to collectively solve plant protection problems for the benefit of the small-scale farmers and to assist other agencies in applying this knowledge in large-scale implementation. The SP-IPM is the CG's assurance that plant protection technology is not left on the shelf, but is being stimulated and implemented in continuous feed-back between researchers and farmers.

In summary, the past year was a productive year, but also a year of consolidation and peace. With the removal of the constant threat of further staff and budget reductions in 1999, we hope to maintain that peace and build upon it. The main problem remains the ever increasing difficulty to attract restricted core funding and we hope for the pendulum to swing back again to a reasonable balance between research, even speculative research, and implementation.

Project 3: Biological Control and Biodiversity

Goal

To enhance the livelihood of resource- poor farmers and maintain sustainability of farming systems through biological control and the preservation of biodiversity by developing and implementing biological control, including microbial control, of pests and weeds in farming systems, conducting biodiversity studies and supporting biosystematics.

Highlights

- A virulent isolate of the fungus *Beauveria bassiana* was selected as a biopesticide against the banana weevil *Cosmopolites sordidus,* and used in a formulation based on oil palm kernel, applied to the soil (see also project 7).
- A reference collection of plant epidermes from more than 150 plant species was established. This collection permits the study of the diet of many phyllophagous insects living in the agrosystems from the humid savanna zone.
- The general survey on the grasshoppers from Benin was continued and 127 species are now recorded.
- The LUBILOSA *Metarhizium* product was included in the list of FAO products recommended for use in locust control, with a specific comment on its utility in wetlands and other conservation areas.
- Commercial production of *Metarhizium* was started by a company in South Africa, and registration has now been granted.
- Donors have given provisional support for a fourth phase of the LUBILOSA project, specifically giving support to the small commercial companies. This represents an area of growing interest to the CGIAR. The LUBILOSA trust fund was approved by donors, and represents a novel mechanism for sharing the benefits of publicly funded research projects in which international institutes and NARES have collaborated.
- Large scale ecotoxicological studies, carried out for the first time in the Sahel, indicated the ecological specificity of *Metarhizium* compared with a standard chemical application.
- Several NGOs in Mali and Niger tested *Metarhizium* with the support of national plant protection services, and expressed serious interest in including the biopesticide in their programs.
- A coordination workshop on termite microbial control was held in Nairobi; test organisms and experimental protocols were harmonized.
- The microbial biodiversity collection and database was established.
- Two international prizes were received, one from the University of California, Berkeley ('Kenneth S. Hagen Medal in Biological Control'), the other by the International Society for Tropical Root Crops - African Branch ('Distinguished Service Award'), indicating that the work in classical biological control executed by the IITA Biological Control Center for Africa is gaining peer acceptance, both in America and Africa.

Project 4: Integrated Management of Legume Pests and Diseases

Goal

To reduce the risk of crop losses in farmers' fields in sub-Saharan Africa by means of integrated pest management technologies which increase cowpea and soybean productivity in a sustainable manner.

Highlights

- Advanced breeding lines selected for low levels of resistance to pod borer, *Maruca vitrata,* were evaluated by collaborators in five countries. Under high natural infestations, the best accessions gave grain yields of 462 kg/ha and 662 kg/ha in Zaria and Kano, respectively. These represent more than three-fold increases over local check varieties.
- One cross-compatible wild *Vigna* (*V. unguiculata* subsp. *dekindtiana*), closely related to cultivated cowpea, was found to consistently exhibit high levels of antibiosis against the pod-

sucking bug *Clavigralla tomentosicollis*. This is important with respect to the introgression of pest resistance into cowpea.

- A new group of insecticidal proteins (e.g. from *Mucuna* or African yam bean) has been identified as donor of genes for potential use in the transformation of cowpea for resistance to *M. vitrata* and *C. tomentosicollis*.
- The systematic investigation of the legume entomofauna in southern Cameroon revealed a parthenogenetic strain of a thrips parasitoid similar to the one found in India, and tentatively identified as *Ceranisus femoratus*. In Cameroon, *C. femoratus* could be recovered from larvae of the flower thrips *Megalurothrips sjostedti* only, with peak parasitism levels of 66%. It is now the object of intensified rearing efforts in the laboratory in Cotonou.
- A strain of the entomopathogenic fungus *Metarhizium anisopliae* obtained from ICIPE was tested in the laboratory and revealed to be effective in killing all stages of *M. sjostedti*.
- On-farm trials in Benin, Ghana, and Senegal revealed that applications of neem leaves as an insecticide (15 kg /10 l water) could double cowpea yields. In Benin, participatory trials with aqueous applications of papaw leaves extracts, involving over 100 farmers, indicated insecticidal/repellent properties as efficient as neem.
- Burying of infected plant debris was found to reduce inoculum of cowpea bacterial blight (CoBB).
- A new semi-selective medium is now available for easy detection of the incitant of CoBB, *Xanthomonas campestris* pv. *vignicola*.
- An antiserum and ELISA system have been developed for quick and easy detection of *Macrophomina phaseolina* in seeds and plants.
- Traits for resistance or susceptibility to viruses were segregated in IITA's breeding lines. This gives the possibility of not only breeding for resistance, but breeding for avoidance of latent (symptomless) infection. Latent infection can be seed-borne and can serve as a source of inoculum to infect highly susceptible lines and cause up to 100% yield loss in those lines.
- For the socio-economic impact assessment of PEDUNE, benchmark sites were delimited in Benin, Burkina Faso, Cameroon, Mali, and Niger.

Project 5: Integrated Management of Maize Pests and Diseases

Goal

To reduce pre- and postharvest losses of maize caused by insects, diseases, and fungal grain contaminants. IITA scientists work with NARES partners to diagnose constraints, test resistant germplasm, and explore options in host plant resistance, habitat management, and biological control. Combinations of control options are assembled in an integrated pest management package and tested with the participation of scientists (including socio-economists) and farmers.

Highlights

Preharvest maize

- Several exotic and East African species and strains of natural enemies of stem borers were received from ICIPE since 1994, one of which was released and now found established in Benin on *Sesamia calamistis*. Another strain of a larval parasitoid which parasitizes both *S. calamistis* and *Busseola fusca* was introduced into Benin in 1998. IITA also provided South Africa and Brazil with natural enemies from West Africa; results are pending on the impact of the releases.
- Building on the foundation of the IITA/FAO/Nigerian Department of Agriculture Downy Mildew Eradication Campaign, for the third year in a row, World Vision donated time and money to intensive extension efforts, which will eventually reach thousands of farmers.
- Maize is a particularly good host plant for the fungus *Fusarium moniliforme*, which has been implicated as a causal agent for health problems in animals (horse brain lesions) and in humans (esophageal cancer). Recent results show that significantly more stemborers and storage beetles are found in plants infected with *F. moniliforme*.
- Trap plants that are too attractive can have negative effects. Recent data show a spill-over of stem borers attracted to trap plants on to adjacent maize plots.

Postharvest maize

- A postharvest CD-ROM with a user friendly simulation of the grain store environment showing population dynamics of the larger grain borer, *Prostephanus truncatus*, its predator *Teretriosoma nigrescens*, and its competitor, the maize weevil, *Sitophilus zeamais*, was developed. The CD, to

be released in March 1999, is a repository for data and a training tool. GIS and remote sensing are to be used to track and predict distribution of *P. truncatus*.

- New maize germplasm has been imported to breed for improved maize storability. Universities from the US sent IITA their 10 best-bet aflatoxin-resistant lines which are being introgressed into tropically adapted materials. CIMMYT sent 8 genotypes with resistance against *Sitophilus* and *Prostephanus* for testing under West African conditions.
- An IITA/CABI workshop on entomopathology and stored product management explored options for controlling losses of stored maize to insect pests. In a first-of-its-kind workshop on maize quality, processing, and utilization, WECAMAN/IITA hosted 30 scientists from 13 countries of West and Central Africa.

Project 6: Integrated Management of Cassava Pests and Diseases

Goal

To increase and sustain cassava productivity through the reduction of crop losses due to pests and diseases.

Highlights

- Africa-wide implementation of cassava green mite (CGM) biological control by exotic phytoseiid predators was continued in 1998. The exotic phytoseiid predator *Typhlodromalus aripo* has shown excellent establishment and spread in West Africa, and parts of Central and East Africa. *T. aripo* is now found in 16 countries, spreading at the rate of up to 200 km per season.
- Cost/benefit studies in West Africa showed that biological control of cassava green mite has resulted in farmer benefit of $144, $98 and $195 per hectare, respectively for Benin, Nigeria, and Ghana from 1983 to 1997; and an internal rate of return of 100%, or at least 10 times higher than returns on any public investment (see also project 2).
- A method for ensuring successful field release of the Brazilian isolates of the fungus *Neozygites floridana* on live infested mites was developed and used to introduce the fungus into mite populations. The first two introductions did not result in establishment and further attempts are planned in 1999.
- PCR techniques were used to map the distribution of cassava mosaic geminiviruses, detect mixed geminivirus infections, and show that the current expansion of the cassava mosaic virus disease (CMD) pandemic in East Africa is associated with an increase in the range of Uganda Variant (UgV) of CMD. The pandemic was reported for the first time in Tanzania. Evidence was also found for protection against severe isolates of UgV in plants already infected with mild virus strains.
- Monoclonal antibodies were used to detect East African Cassava Mosaic Virus (EACMV) in Nigeria, Togo, Cameroon (where African Cassava Mosaic Virus is common), as well as in South Africa (reported in project 16).
- The identities of four potentially important whitefly parasitoids, *Encarsia transvena*, *Eretmocerus* spp., *Encarsia lutea*, and *Encarsia* sp. (*luteola* group) occurring on cassava in Sub-Saharan Africa were determined.
- Monospecific, polyclonal antiserum and DNA probe for quick and easy detection of cassava bacterial blight (CBB), *Xanthomonas campestris* pv. *manihotis*, and a method for quick testing of pathogens for virulence and varieties for resistance against root and stem rots were developed and tested.
- In trials comparing CBB impact on 22 IITA and local cassava varieties in 3 ecozones [forest-savanna transition, dry savanna, and rainforest], TMS 30572 showed the highest yield stability. However, in 1994 this variety suffered up to 50% yield losses in the dry savanna.
- Reduction in CBB severity and losses could be achieved by burying infected plant debris to destroy CBB inoculum and by delaying harvest to 18 instead of 12 months in the dry savanna; pruning infected leaves; and intercropping with maize. CBB inoculum in cassava seeds was found to be destroyed with a 30-min. hot water treatment at 60 °C, or a 4-day hot air treatment at 65 °C.
- Field observations and analysis of feces (see project 3) showed that cassava is a major component of the diet of the variegated grasshopper, *Zonocerus variegatus*, not only during the early part of the dry season as previously thought, but also during the latter part of the dry season and during the rainy season.

- In Uganda, root-knot nematode damage was shown to be associated with shortened crop rotation. High populations of this nematode were shown to reduce the establishment of cassava cuttings.
- Five termite genera were identified causing damage to cassava in Zambia of which three, *Microtermes*, *Ancistrotermes* and *Odontotermes* were consistently associated with severe stem and cutting damage. Losses ranged from 3-35% and were least in the two local improved selections.
- Bench and on-site training courses in cassava pest management for NARS scientists were conducted in 1998. Several Ph.D. students from various African countries began their research on CBB (3), root rot pathogens (1), and cassava green mite (3). Seven post-graduate trainees were also involved in research on cassava pests over 6-12 months.

Project 7: Improving Plantain- and Banana-based Systems

Goal

To develop and disseminate improved technologies for sustainable *Musa* production in sub-Saharan Africa. The project designs strategies for integrated pest and disease management, improves high-yielding cultivars with multiple resistances and desirable fruit quality, and develops sustainable resource and crop management practices.

Highlights *(Only plant protection related results are reported here)*

- A survey found that farmers in Cameroon are unaware of the presence/effects of nematodes on plantain; also they did not know the simple paring technique to clean suckers. In contrast, since 1993, when plantain growers in three pilot villages in Ghana were shown the paring technique through an IITA/NARS IPM project, 40% have adopted it. Adoption of clean planting material and improved management practices by these farmers was profitable over a 3-year period, resulting in returns of $1300 per hectare, equivalent to $475 compensation when compared to farmers' traditional practices.
- The pest status of three nematode species on plantain was determined in Ghana. *Pratylenchus coffeae* was the most damaging nematode, causing production loss of 70%, due largely to the high incidence (60%) of plant toppling.
- *Beauveria bassiana*, an entomopathogenic fungus with potential to control banana weevil, was mass-produced cheaply on a by-product of oil palm processing. The kernel cake enhanced the fungus' persistence on plantain suckers. Some 61% weevil mortality occurred when suckers were attacked by weevils 28 days after application. Mortality was 12% with fungal powder only and 4% in the untreated control.
- Mutualistic fungal endophytes showed significant biological control activity on *Radopholus similis*, the most aggressive banana nematode. The *Fusarium* endophytes were isolated from roots of highland banana landraces in Uganda.
- The first five tetraploid black sigatoka-resistant hybrids, derived from East African highland bananas, were selected as elite breeding lines for the production of secondary triploid cultivars at the IITA station in Uganda.
- Five national scientists from Benin, Ethiopia, Ghana, Uganda, and Zanzibar were trained in *Musa* nematology, banana streak virus (BSV) diagnostics, breeding and biotechnology. Five manuals on black sigatoka disease, tissue culture, and banana streak virus in germplasm exchange were produced and disseminated to NARS.

Project 8. Integrated Management of Striga *and Other Parasitic Plants*

Goal

To reduce infestations of parasitic plants with a focus on *Striga* spp. The project is implemented in collaboration with NARES. Through integrated management practices, emphasizing cereal rotations with selected nitrogen-fixing cultivars of legumes, crop yield losses due to parasite infestations are reduced while soil conditions are improved.

Highlights

- Posting of IITA's "*Striga* Research Methods: a Manual" on our web site resulted in over 222 'downloads' of the 1.34 Mb file in the first two months.
- Demonstration of an integrated *Striga* management program was conducted for the second season in the moist savanna of Nigeria. As a result over 35 farmers have requested to participate in implementation of integrated *Striga* control on their own fields.

- Several soybean breeding lines with good agronomic characteristics from a wide range of maturities were identified that will be effective in provoking suicidal germination in the soil, of seeds of *S. hermonthica*, which parasitizes maize. These are available for testing.
- Studies on offspring of crosses involving several high- and low-stimulant producing soybean lines showed that production of germination stimulant of *S. hermonthica* seeds by soybeans is highly heritable for the isolates of *S. hermonthica* tested.
- Early-maturing white-endosperm maize varieties and intermediate-duration maize hybrids showed high level of tolerance to *S. hermonthica* and high grain yield in Côte d'Ivoire and Burkina Faso.
- Test crosses, extracted from a backcross population derived from *Zea diploperennis* and three IITA inbred lines, revealed a large number of experimental hybrids that outperformed the standard tolerant hybrid both for yield and reduced *S. hermonthica* emergence. Similar results were obtained using new inbred lines derived from tropical populations.
- Chromatographic analyses of root exudates of different plant species and cultivars showed four common chemical compounds and a number of plant-specific compounds active in stimulating germination of *S. hermonthica* seeds. Similarly, seeds of *S. gesnerioides*, which parasitizes cowpea, exhibit a plethora of specific stimulant receptors towards different isolates of *Striga* spp., and specific germination stimulants towards host and non-host plants.
- Studies, in collaboration with the University of Virginia, resulted in identification of a common molecular marker for *S. gesnerioides* susceptibility in four unique cowpea lines.
- Use of a simple screening procedure for ethylene-producing bacteria resulted in isolation of several non-pathogenic strains that are competent with both legume rhizospheres and nitrogen-fixing bacteria.

Project 13: Improvement of Yam-Based Systems

Goal

To ensure that farmers achieve sustainable increase in the productivity of yam-based systems through adoption of improved technologies. The project develops relevant technologies targeted at enhanced productivity in partnership with NARES.

Highlights *(Only plant protection related results are reported here)*

- Surveys on the geographical distribution of yam nematodes revealed that in Ghana and Nigeria the dominant species is *Scutellonema bradys*. In on-farm trials in Kwara, Oyo (North), Ebony and Rivers States in Nigeria, plants established from hot-water treated seed yams performed better compared to those established from standard farmers' planting material.
- In a survey for viruses infecting yams in the major yam growing areas of Ghana, yam mosaic potyvirus (YMV) was the most commonly found virus, followed by *D. alata* potyvirus (DAV). YMV was found more often in *D. rotundata* than *D. alata*. The latter was more susceptible to DAV.
- One new virus has been fully characterized and diagnostics to it have been established to facilitate indexing for germplasm movement. Three new isometric virus isolates from yam, *Dioscorea* mottle virus, *Dioscorea* mild chlorosis virus and *Dioscorea* necrosis virus were studied.
- A total of 1091 trainees (782 women and 309 men) comprising farmers, women groups, agricultural extension workers, grass root opinion leaders and politicians participated in the training activities on yam production at IITA/ESARC, Uganda. At every training session farmers received planting materials of both local and introduced yams for planting on their farms.

Project SP-IPM: System-wide Program on Integrated Pest Management

Goal

To enhance the effectiveness of integrated pest management research at the international agricultural research centers so that it contributes fully to sustainable agricultural development. This program seeks to encourage better communication and closer coordination among the centers and their partners, the development and adoption of more effective, client-orientated approaches to IPM, and a broader awareness of the benefits of IPM, leading to a policy environment more favorable to its widespread implementation.

Highlights

- A project database has been established which provides information on current and planned IPM projects of the System-wide Program on IPM (SP-IPM), as well as on those of individual centers across the CG system. This database provides an invaluable resource for IPM research planning, coordination, and monitoring, available to the participating centers, their partners, and the interested public. Extracts from the database, along with a wealth of other information about the SP-IPM, are accessible through the Program's newly refurbished website (www.cgiar.org/spipm).
- Individual SP-IPM Task Forces are also finding that the WorldWideWeb provides an excellent medium to reach out to new partners and a wider public. The website of the Beneficial Microorganisms Task Force, led by IITA, can be found at www.cgiar.org/spipm/tf/bmo; and that of the Farmer Participatory Research Task Force, led by CIAT, can be found at www.ciat.cgiar.org/fpr-ipm. Others are under development.
- The first full-scale research project launched by the SP-IPM, on Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics, is completing its first phase of work, under the leadership of CIAT. Over 1000 citations of relevant "gray literature" have already been gathered for the project's literature database and the details of nearly 400 whitefly professionals working in the tropics have been entered in the project's human resource directory. Diagnostic surveys carried out in 12 countries in Latin America and 10 countries in Africa are providing a completely new picture of the distribution and importance of whitefly-transmitted viruses, and of the strategies that farmers are using to address them. Numerous maps of vector and disease incidence, as well as a variety of other survey outputs, are now available in the project's first annual report.
- The positive impact of other Task Forces is already evident in closer intercenter collaboration in a number of fields. Joint proposals have recently been completed and submitted to donors for collaborative research on Rice Weed Management (an initiative led by WARDA), Soil-borne Pathogens (led by ICARDA), Parasitic Flowering Plants (led by IITA) and Cereal Stem Borers (led by CIMMYT).

P. Neuenschwander

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DONORS

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Research achievements and activities

Project 3

BIOLOGICAL CONTROL AND BIODIVERSITY

by K. Cardwell, A. Cherry, S. Dara, H. De Groote (project coordinator), G. Goergen, B. James, J. Langewald, P. LeGall, C. Lomer, D. Müller, P. Neuenschwander, M. Tamò
assisted by O. Ajuonu, S. Attignon, H. Davies, C. Gbongboui, F. Hountoundji, O.K. Douro-Kpindou, G. Heviefo

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 different 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), 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

3.1. 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.

On-going and future studies

3.1.1. Mass production of spores and product development

by C.L., J.L., A.C. - in collaboration with R. Bateman, N. Jenkins, D. Moore

1997 saw the LUBILOSA Metarhizium mass production plant in continuous production with a final annual yield of 175 kilos of conidia. Of these over 100 kg were destined for LUBILOSA's field trials in Mali, Ghana, Benin, Togo, South Africa and including the first large-scale aerial application trials in Niger. The remainder was supplied to the Plant Protection Departments of

West African national programs, which are conducting field trials of Metarhizium in collaboration with LUBILOSA.

The production process has been optimized and figures for output and cost compare very favorably with experimental units elsewhere. Analysis of production data for the last 2 years reveals while that yield is characterized by high variation in the short term, in the long term average yields are very consistent. This consistency combined with a shelf life of over one year at ambient temperatures allows a relatively small unit to produce and store conidia for control of a seasonal pest in a defined niche market without risk of underproduction or loss of viability. Imposition of strict quality control procedures has ensured that our conidia are consistently of very high quality, meeting our own self-imposed technical specifications.

Modeling of system parameters suggests an estimated maximum annual capacity of 350 kg conidia at a cost of just over US $20 per 100 g (the standard dose for one hectare). LUBILOSA recognize 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.

3.1.2. Insect-fungus interaction - ecological studies

*by J.L., C.L. - in collaboration with M. Thomas, S. Blanford**

A spread-sheet model which allows us to describe the various factors influencing the treatment efficacy in the field compared with the mortality of caged samples is being improved and will be presented in a more user friendly way. Mortality due to direct spray impact and secondary impact can be distinguished, and the effect of immigration modeled. The remaining discrepancy, labeled 'incubation delay factor' appears to be due to grasshoppers' capacity to thermoregulate in sunlight and bring their body temperature above the permissive range for fungal growth.

3.1.3. Development of use strategies

by J.L., D.M., H.dG., C.L. - in collaboration with R. Bateman

A Participatory Rural Appraisal in 5 villages in the Mono province of Benin revealed that the variegated grasshopper was the major agricultural pest, although a fairly recent one, so farmers have little knowledge of their biology and have not developed indigenous control methods. Villagers were keen on a collaborative program, which started with a demonstration and a training of six farmers per village, a group who will be in charge of the biocontrol of grasshoppers in their village. Groups in three villages tested several strategies: the preventive control by treating the young larvae stages, the curative control strategy of treating adult grasshoppers, with three different doses and two types of sprayers. The results show that farmers prefer the preventive approach and that the application dose can easily be reduced from 100 g/ha to 20 g/ha, without loss of efficacy (although decreasing dosages did have a major impact on the efficacy of the spore residue). This brings the cost of the product ($20 per 100 g) within easy reach of the farmer. The participatory tests also showed that treating the bush is not a practical strategy. Finally, the tests showed that battery powered spinning disk sprayers are more efficient than cheaper hand pump sprayers, justifying the higher costs. The villagers propose that the grasshopper biocontrol be organized by village teams, in close collaboration with the village association of cotton growers, to assure self-financing of the action. For the 1998-1999 season, this strategy was proposed to 18 new villages. They all organized a control team, which was trained by the project. Women, who have their own fields, prefer a separate control team. Three women teams have been trained so far.

In Ghana cadavers of *Z. variegatus* were distributed in infested cassava fields. The treatment appeared not to be efficient. The introduction of the data set into the M. Thomas model revealed the time to sporulation and the time of transmission of the disease from the cadavers to the life grasshopper to be the major constraint. Also in Ghana, trials on *Zonocerus variegatus* demonstrated that the effort of application could be reduced to ten minutes per ha, without reducing treatment efficacy, when space between the spray tracks is increased up to four times.

In Niger *M. anisopliae var. acridum* was compared with a new organic insecticide fipronil on 50ha plots. *Metarhizium* was applied at half the standard dose and a quarter of the standard volume application rate (50g/ha x 0.5l) Grasshopper densities were very low in the area chosen for the 1998 trials, and the data on population reduction are not representative for grasshopper control operations. Collaborative field trials with farmers in Mali were carried out against Sahelian grasshoppers using hand held ULV sprayers at large scale (50ha plots). Due to the scale, population reduction and highly reduced crop damage could be demonstrated. Combining several

village brigades in such a large scale operation, in combination with the use of *Metarhizium*, proved to be a powerful tool for the control of Sahelian grasshoppers.

The trial in Dogon country, Mali in collaboration with the NGO Pampad, tested dose rates of 100g, 50g, 20g and 0g against an outbreak of Sahelian grasshoppers, 85% in August 1998. Application was by hand-held ULVA+, one liter per ha on 5 ha plots. While the mortality due to direct impact of the spray application was similar for all three doses, the persistence of the spray deposit was reduced for the lowest dose of 20 g/ha. In field counts of populations, there were no significant differences in the efficacy of the three doses.

Currently recommended dose rates for *M. anisopliae var. acridum* IMI 330189 for use against Sahelian grasshoppers and all locust species is 100g/ha. However, at current production prices of about $200/kg, the cost of the active ingredient would be in excess of currently used chemical pesticides. In order to investigate ways of reducing costs, we tested the efficacy of several lower doses of spores.

3.1.4. Environmental impact

by J.L., C.L. - in collaboration with I. Stolz, R. Peveling*

In Niger three replicated 50 ha plots were treated with Metarhizium sp. and the organic insecticide fipronil. Hymenopteran abundance was monitored over the whole rainy season. Hymenoptera were caught using flight interception traps (Malaise traps) and yellow sticky traps. The insects were collected over time intervals, 4 times before and 20 times after treatment. Significant impact on Hymenoptera was observed only in the plots treated with fipronil.

3.1.5. Implementation and farmer participatory trials

by J.L., C.L., H.dG. - in collaboration with A. Diarra,

During an annual NARES meeting in Niamey LUBILOSA collaborators were encouraged to search for clients of the novel technology on the NGO level. The national programs of Mali and Gambia succeeded in raising funds for demonstration trials from northern NGOs active in rural development projects. Farmer participatory trials were carried out in Mali (with SECAMA) and in Niger (with BIT). National programs were supported to carry out trials in Burkina Faso, Ghana, Senegal, Chad and Mali. Regional training and information seminars were organized in Mali and Niger. The objective of these meetings was to spread information and increase public awareness. Not only technical staff of NGOs and government agencies but also decision-makers were invited. The response to these meetings was in most cases very positive, especially in Chad. Interviews were given on radio and TV and articles published in local newspapers.

3.1.6. Socioeconomic analysis of the potential of mycopesticides

H.dG., D.M., C.L. - in collaboration with V. Houndekon

A survey in southern Niger estimated the impact of pesticide use on human health, losses of domestic animals, and costs of destroying obsolete pesticides. A significant effect of the length of pesticide use on respiratory diseases was shown. Similarly, participating in the village brigade, who organizes the treatments against locusts, has a significant effect on neurological and dermatological disorders. Health costs, calculated as medical expenses and lost work time were found to increase significantly with the length of time pesticides had been used on the farm. With every year pesticides were used, an extra US$0.50 of medical costs per household per year was associated. Extrapolation over the number of hectare treated per family results in an estimation of the human health costs at $US 0.15/ha. The survey results also indicate a loss of domestic animals of 0.5% for small ruminants and 0.2% for cattle. At market value, extrapolated over the concerned area and distributed over the surface area treated against locusts and grasshoppers, the external cost to domestic livestock could be estimated at US $1.50 for each ha treated. Costs of destroying obsolete pesticides were estimated at $0.10 per ha treated, bringing the total health costs and externalities to $1.75. The externalities quantified so far are significant and important. The results suggest that there are substantial reasons to decrease subsidies for chemical pesticides, and guide donor support towards biological control methods.

The Niger Plant Protection Service's direct measurements of yield loss from locusts were compared to estimates by farmers, through group surveys in 25 villages, and individual surveys in 18 villages. For 1989-1993, the direct measurements estimate crop loss at 15%, group estimates average 35%, and individual estimates 53%. These values were also compared to farmers' declared willingness to pay for locust control. Values obtained in different villages ranged from $8 to $ 25

for head of households, $4 to $23 for dependent men, and $2 to $4 for women. On average, this value is 60% of the estimated value of the crop loss, and this average is very stable between districts and individuals. These numbers indicate that farmers are more willing to contribute to locust control than usually assumed. More participatory research is indicated to take advantage of this

A survey of 96 households in the Mono province of southern Benin shows that women are farmers in their own right. Although traditionally, men inherit land from their father to farm it with his wives, women have now obtained the right to farm their own plot. Most men (95%) live in their native village, while more than half the women came from elsewhere. Men cultivate on average 1.6 ha, of which 1 ha is inherited, 0.5 ha bought and 0.1 ha rented. Women only cultivate 0.6 ha, most of which is rented (52%) or borrowed (40%), and a small part bought (6%) or inherited (2%). Two women inherited land from their father. Men use more inputs than women, but fertilize about the same proportion of their land (86% for men, vs. 77% for women), resulting in an almost equal fertilizer dose for men and women (186 vs. 150 kg/ha). Similarly, they treat about the same proportion of land with pesticides (77% vs. 70%), resulting in an equal pesticide dose of 4 l/ha. These numbers indicate that land tenure is the major factor in the use of modern agricultural technology. Research into new agricultural technology should address women as farmers in their own right, and not reinforce the bias caused by unequal access to land.

LUBILOSA is also studying the institutional aspects of biological control, and surveys were conducted in Zinder, Niger and in the Mono, Benin. In both countries, extension services suffer from a severe lack of operational funds, and depend on external funding for almost all activities. The survey showed that in Zinder, extension or plant protection services rarely visit villages located more than 10 km away from their office. In the Mono, some projects and NGOs are active, but very few in agricultural extension or plant protection. In general, NGOs are interested in biocontrol of locusts and grasshoppers and the PPS can provide them with training.

3.2. 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 necessary 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 overseas centers of expertise.

On-going and future activities

3.2.1. Capacity building for faunistic studies
by G.G.

Infrastructure upgrading, adequate collection management and the steady incorporation of new acquisitions are factors that significantly contribute to the institute's capacity building for biosystematic capabilities to international standards. Following the institute's recent shift to a more widely accepted computer system the electronic collection catalogue has been transferred to a new indexing system. Updated in pace with the current identification work the collection database comprises to date over 2,100 identified species from 242 families. Thus the reference collection holds presently at least one named representative of about half of the 568 recognized insect families for West Africa. The new taxonomic additions provide enough biological data to plan a revised collection checklist. Conversion work to the new computer environment for further electronic indexes such as the museum's specimen-level database and the updated taxon catalogue of West African insects is now being implemented. In the course of this year the taxonomic

bibliography has increased to more than 4,300 publications of specific insect groups thus adding another 1,100 new records to the literature database. Further important source of information has been made available with the recent access of the museum to the Internet's World Wide Web pages.

To meet the current supply rate of prepared insects the repository capacity for stage mounted specimens was increased to 104 metal cabinets enabling thus the accommodation of a total of 1250 Cornell insect drawers. This represents only 40% of the museum's total storage capacity designed for long-term security and the steady acquisition of considerable reference material. Accordingly a revised design of the main collection set-up has been initiated. Similarly the need of adequate preservation devices for microscopic preparations of insect groups of agricultural importance led to the supply of 52 new slide cabinets creating thus a storage capacity for 21,000 mounts on anodized aluminum trays. The museum has also been expanded to include phytophagous and predatory mites, the integration and management of identified plant material, the systematic collection and maintenance of live collections of beneficial microorganisms and other pathogens of agricultural importance. These additions notably further the development of a regional capability for biodiversity studies.

3.2.2. Biodiversity studies

by G.G.

As in the previous year collecting activities with emphasis on pest and beneficial insects of IITA's mandated crops were pursued in different ecological areas in West Africa. Important insect material preserved in alcohol was obtained from light trap catches at 6 sampling sites chosen at regular distances along a 700km transect from south to north Benin. In addition, regular sampling was effected at the agricultural research station Niaouli, Benin, where crops are cultivated next to a protected humid forest. Likewise, numerous samples were supplied from the dry savanna area at Kano, Nigeria in close collaboration with IITA's cowpea scientists. Collection activities are being intensified in the humid forest zone at Mbalmayo, Cameroon, where permanent light and diverse bait trap monitoring have started with the assistance of scientists of IITA's Resource and Crop Management Division. New arthropod material was also steadily sampled in the mid altitude zone in Togo, which is renowned for the specific endemism of its arthropod fauna. In all sampling sites special care was devoted to also include agriculturally important reference material that needs to be preserved by slide mounting techniques.

IITA project 1 is investigating alternatives to natural bush fallow for sustaining soil fertility under tropical conditions. In a study initiated in 1990 in Ibadan, the forest-savanna transition zone of Nigeria, is compared simultaneously several land used systems such as continuous cropping (maize-cassava intercropping), natural fallow, covercrop fallow (*Pueraria, Chromoleana*) after an initial forest clearing.

For this year another 7,000 voucher specimens were stage mounted and labeled with their concomitant data in addition to the preparation of 400 microscopic slide preparations. The large amount of insect accessions to be processed led to the training and appointment of a new technician. During the period under review about 400 samples representing roughly 3,000 insect specimens originating from many African countries and IITA's own research activities were submitted and identified mostly to a satisfactory level (Table 1). Partially resolved requests were directed to groups specialists when needed. A large part of the identification work derived from the taxonomic support rendered to in house studies such as the examination of insects associated with the larger grain borer in woody host plants, the research on the parasitoid fauna of maize stemborers, ant biodiversity in banana cropping and environmental safety evaluation of biopesticides. The assistance provided to IITA scientists is being jointly published. Further support was provided in carrying out the unit's macro and microphotography service, by which another 150 slides of scientific interest were realized. In addition to its potential use in the elaboration of identification keys and monographs, this work serves as a valuable source in the documentation of the reference collection by digital means.

Table 1 - Identification requests handled in 1998

Origin	Number of samples	Insects	Col.[1]	Dip.	Hom.	Hym.	Lep.	Others	level identified Sp.	Gen.	Fam.
IITA	63	1054	937	19	50	28	10	10	1032	22	0
Benin[2]	11	68	24	29	0	0	15	0	45	23	0
B. Faso[2]	3	31	0	0	20	0	11	0	10	0	21
Cameroon[2]	10	53	0	25	10	18	0	0	42	11	0
Ghana[2]	22	48	0	6	0	42	0	0	30	17	1
Mgascar[2]	9	35	1	0	33	1	0	0	32	3	0
Niger[2]	1	10	0	0	10	0	0	0	0	10	0
Nigeria[2]	34	55	24	1	7	3	1	19	31	10	14
Togo[2]	1	10	0	0	10	0	0	0	0	10	0
Uganda[2]	46	307	0	0	0	307	0	0	42	265	0
Zambia[2]	14	128	10	0	0	0	0	118	10	100	18
TOTAL	214	1799	996	80	140	399	37	147	1274	471	54

[1] Col.= Coleoptera; Dip.= Diptera; Hom.= Homoptera; Hym.= Hymenoptera; Lep.= Lepidoptera; Sp.= Species; Gen.= Genus; Fam.= Family
[2] requests from NARES

3.2.3. BioNET coordination
by G.G.

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, created in 1993, is aimed at mobilizing and pooling worldwide biosystematics resources to the benefit of developing countries. With the establishment of the subregional network, WAFRINET, assistance will be provided to interested countries to achieve adequate self sufficiency in biosystematics for sustainable use of natural resources and to fulfill their commitment to the convention of biological diversity.

In the past two years, the relatively slow process of official endorsement of the project proposal by individual governments has delayed the activation of WAFRINET. New perspectives for final fund eligibility were recently opened with CORAF's (Conférence des Responsables de la Recherche Agricole de l'Afrique de l'Ouest et du Centre) recent grouped approbation representing the council of the minister of agriculture for West and Central Africa. Assistance to foster the implementation process is been provided by the temporary appointment of an additional staff so to better assume IITA's network coordinating function. Anticipating the near release of operative funds by the technical secretariat steps are now being initiated to organize a workshop to discuss practical issues of the work program. In the first facet of the workplan an extensive analysis of existing resources with concomitant assessment of the requirements for the subregion is programmed. The second phase will emphasize information and communication services, training in biosystematics, rehabilitation of existing collections and other resources and development and use of new technologies especially electronic aids to identifications. Preliminary achievements will be reported on the second BioNET-International Global Workshop planned for August 1999.

3.2.4. *Zonocerus* research
by P.LG

Studies of the diet of populations of *Z. variegatus* have been carried out at different locations in Benin and Togo during the wet season. The results confirm the previous study carried out at one site in Benin. They confirm that cassava is the major component of the diet also during the wet season. Recent observations showed that cassava is also eaten by very young stages and not only by the lasts nymphal stages and adults. The consumption of cassava by first and second stages was regularly observed at the beginning of the 98/99 dry season. This behavior needs to be explained, because it goes against what is generally observed.

The general survey on the grasshopper fauna from Benin is nearly completed and 127 species are now recorded from the country. Some of those species were previously known only from one or two localities. The reference collection of plant epidermis has been extended outside the cassava system. Now, it comprises more than 150 plant species. The collection permits the study of the diet of many phyllophagous insects living in the agrosystems from the moist savanna area.

3.2.5. Beneficial micro-organism collection

by A.C., C.L., K.C.

Plant and arthropod (insects and mites) 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. At present there is no coherent framework within IITA's PHMD to house these samples and consequently they are mostly are held in diverse collections under varying conditions, and which are not always readily accessible. Establishment within the CG system of the Systemwide Genetic Microbial Resources Database during 1997 provides a framework for development of the centralized IITA long-term microbial pathogen storage collection and database which sits alongside and enhances the existing biosystematic capacity. The collection will house lyophilized and cryopreserved samples arising from IITA's own projects and also, acting within CGIAR system, it will accept samples from its mandated area of over 25 African countries. Important samples are duplicated at collaborating institutes in North America and Europe. The collection is being fully databased and descriptors are being standardized with other centers participating in the SMGRD.

3.3. 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 can be 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 *M. anisopliae*.

On-going and future activities

3.3.1. Maize stem borers

by A.C., C.L.

Primary screening of dead stem-borer larvae from 1997 and 1998 field surveys in Benin, Nigeria, Ghana, and Cameroon and from experimental trials in Benin, Nigeria has continued, and to date, approximately 1400 samples have been examined for pathogens. The list of candidate biological control agents isolated from screening larvae now comprises pathogens from all major groups: *M. anisopliae* and *Beauveria* sp. active against stemborer larvae by topical application, isolates of *B. bassiana* with systemic activity against *Sesamia calamistis* Hampson (Lep., Noctuidae) in maize plants, a cytoplasmic polyhedrovirus (CPV) and a microsporidian from *S. calamistis*, a granulovirus of *Busseola fusca* (Fuller) (Lep., Noctuidae), and several isolates of *Bacillus thuringiensis*. Both the CPV and the microsporidian show promising characteristics for development as classical biological control agents. The CPV is widespread among samples of *S. calamistis* from Benin, though apparently rare in Nigeria. In sequential planting trials in southern Benin, the naturally occurring CPV was responsible for a peak of 25% mortality among introduced *S. calamistis* larvae.

Experimental work in 1998 concentrated on field and green house investigations into the systemic capacity of locally isolated *B. bassiana* samples. Earlier work demonstrated the ability of *B. bassiana* isolates to develop within maize plants and to provide a measure of protection against stem-boring larvae. Trials in 1998 were designed to investigate the relative efficacy of several isolates, the different routes of plant infection, the effect of spore formulations on seed penetration, and their activity against both *S. calamistis* and *Eldana saccharina* (Walker) (Lep., Pyralidae). 1998 was a year of low rainfall in southern Benin and also of low natural stem-borer attack. Nevertheless, preliminary analyses show that mean tunnel length in *Beauveria*-treated field plants was less than in control plants, although the difference was not significant. Recovery of endophytic *B. bassiana* from maize stems was low at less than 10% of treated plants. A positive effect of seed dressing formulation on fungal recovery from maize stems was demonstrated but the levels of infection were low, based on recovery of *B. bassiana* from stems. A short project has

been awarded from DFID to allow us, in 1999, to refine fungus detection assays and to better understand the plant penetration process.

3.3.2. *Neozygites floridana* as a classical microbial control agent for cassava green mite, *Mononychellus tanajoa*

*by S.D., C.L. - in collaboration with J. Gnago**

Surveys on the seasonal incidence of *Neozygites floridana* conducted during 1996 and 1997 were analyzed and submitted for publication. Surveys confirm the low incidence of *N. floridana*, and will help to pinpoint optimum release sites for the exotic isolates. Bioassays conducted in 1997 were analyzed and submitted for publication. One of the Brazilian isolates was significantly more virulent than the local Benin isolates. Experimental releases were made at two locations in Benin in replicated trials with five treatments and four replicates. Preliminary observations on pest population and fungus incidence were made.

A technique for the mass production of *N. floriana in vivo* inoculum was developed, and releases were made in replicated field experiments in February and June 1998. A description of the release technique has been submitted for publication. However, preliminary indications are that the releases have only caused a minimal increase in fungus incidence in two plots out of 16. Further work is needed to establish a better release technique; also to coordinate the release with favorable climatic conditions and high mite populations.

Imidacloprid is a chloronicotinyl insecticide that is reported to have synergistic effect, at sublethal levels, on the germination and/or infection process of some entomopathogenic fungi and nematodes. In our tests, with four concentrations of imidacloprid, it was found that the insecticide had adversely affected the germination of primary conidia and the formation of infective capilliconidia of *N. floridana*. These observations have been submitted for publication.

A similar fungal pathogen is *Entomophaga grylli on Z. variegatus* populations; PhD thesis research on this topic was concluded and has been written up as a PhD thesis.

3.3.3. Use of pathogens against Banana weevil; development of robust isolates

*by C.L., J.L. - in collaboration with I. Godonou**

Work in Ghana on field application and at IITA Benin on mass production has continued in 1998 and is reported in detail under Project 7. Very promising field results have been obtained by dipping banana suckers in spores. This application technique protected the suckers throughout the first growing season, a critical time for banana weevil attack. Application of spores in this way offers a ready-made implementation route and coordinates well with proposed dissemination of superior, clean, planting materials. Paring and hot-water treatment destroy nematodes and banana weevil, while the applied Beauveria inoculum provides continued protection against weevils.

One of the principal constraints found by the LUBILOSA project was the need to protect fungus during production from faster-growing contaminants. In selecting pathogens for use against banana weevil, the ability of the proposed microbial control agent to resist invasion by contaminating microorganisms was assessed. The selected isolate was demonstrably better than two other isolates at resisting contaminants. This has a significant effect on the eventual economics of production and re-opens the possibility for local production of such isolates.

3.3.4. Use of *Metarhizium* against termites

*by C.L., J.L. - in collaboration with M. Oke**

Termites often cause problems in maize and cassava. A new project in collaboration with ICIPE, IIBC, KARI and the Plant Protection Agency of Benin started in 1998 funded by the DfID Competitive Research Facility. A project-planning seminar was held in October in Nairobi, in order to coordinate, focus and streamline the future activities of this project. A first rapid rural appraisal was organized in Southern Benin to better understand the problem. Surveys are being carried out to collect local Metarhizium strains and socioeconomic data.

Highly significant mortality effects were found when dry spores were applied directly to termite mounds. When the spore dust was applied through artificial holes into the center of *Macrotermes* mounds, the activity of the colonies was reduced over six weeks.

3.3.5. Evaluation of viral and microsporidian pathogens of *Maruca vitrata*.

by A.C., M.T.

Viruses and a microsporidian isolated from field collected *Maruca vitrata* Fabricius (Lep., Pyralidae) in southern Benin are being reproduced in vivo, purified and assayed against *M. vitrata* larvae in the laboratory. Initial results demonstrate that there are two morphologically distinct isolates of occluded virus. A second microsporidian species was isolated from larvae in laboratory culture and is also under investigation as a possible biological control agent. Biological control of *M. vitrata* is further reported under project 4, Integrated management of legume pests and diseases.

3.4. 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., Pseudococcidae), 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, *A. dispersus*, 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

3.4.1. Mango mealybug

by P.N.

The two exotic parasitoids are being kept in culture at IITA, but no requests were received in 1998. Regular surveys were carried out in Benin to document the distribution and the impact of the natural enemies. In 1998, damage due to mango mealybug was localized. Among the marked mango trees, damage scores 3 and above (1=low to 5=high) were only found in Aplahoué (Mono province) in the South as well as Kouandé, Djougou, (Atacora province) and Parakou, Niki (Borgou province) in northern Benin. Both parasitoids were found in all localities.

This monitoring needs to be continued and already received requests for help from Côte d'Ivoire, a major producer and exporter of mango, need to be satisfied.

3.4.2. Spiraling whitefly

by P.N.

Since 1993, seven national surveys had been conducted by IITA to evaluate the distribution and spread of *A. dispersus* and the impact of the two parasitoids in Benin. During the continuing northward spread of the pest insect, the two parasitoids were following their host. First, *E. ?haitiensis* was far more abundant than *E. guadeloupae*, but recently the second parasitoid has increased in abundance. In 1998, *E. ?haitiensis* continued to dominate in the south, while *E. guadeloupae* was more frequent than *E. ?haitiensis* in the north. Both parasitoids have now reached the spreading front of *A. dispersus*. At the same time, pest frequencies and densities declined.

3.4.3. Control of water hyacinth

by H.dG., P.N.

As water hyacinth continues to spread in Africa, the previously available control agents were again requested by NARES (Table 2). In Benin, we released these weevils in a new infestation in the Mono province. In addition, the specific antagonist *Eccritotarsis catarinensis* (Carvalho) (Het., Miridae) was imported from the Plant Protection Research Institute, South Africa, in April 1998 and is now being maintained in the laboratory.

The two weevils are firmly established and in 1998, their impact was continued to be monitored. Water hyacinth densities are slowly decreasing, and this control is being felt by the affected population. During an interview of the fishermen in Tevedji, Sagon, and Kafedji, the reduction in water hyacinth coverage was put at between 60 to 90 %. In Sagon, a fisherman can now earn 2000-3000 cfa per day, against about 1000 cfa per day when water ways were completely covered by water hyacinth. In Kafedji, he earned 2000 cfa in 1998, against 800 cfa in the previous years.

Table 2. Shipment of the two weevils *N. eichhorniae* and *N. bruchi,* and the moth *S. albiguttalis* from IITA Benin, during 1998.

Species	Date	Number	Country
N. eichhorniae	03/05/98	300	Burkina Faso
	25/06/98	350	Benin
N. bruchi	03/05/98	300	Burkina Faso
	25/06/98	350	Benin
S. albiguttalis	16/08/98	350	Côte d'Ivoire

3.4.4. Control of water lettuce

by P.N.

Regular surveys were conducted to determine the spread, distribution and the impact of the weevil *N. affinis* on water lettuce. In the North of Benin (Borgou province), the weevil spread to Sori, 60km from the 1995 release site (Banikoara) despite the very sparse and erratic occurrence of water lettuce in widely spaced water holes.

In the South of Benin, the weevil spread 70km from Cotonou, upstream on the Ouémé river. In the two 1995 release sites, Sé and Adjaha, percentage coverage of the lake by *P. stratiotes* declined within one year (from 1997 to 1998) from 25 to 2% and from 64 to 50%, respectively. Overall, this species, which had been released in the Mono province in 1995, has now spread on its own to the Atlantique, Ouémé and the Zou provinces. In 1998, no further releases were therefore made. The weevil is, however, kept in culture for delivery to other countries.

Completed studies

Journal articles and book chapters

Blanford, S., M.B. Thomas & J. Langewald, 1998. Behavioural fever in a population of the Senegalese grasshopper,* Oedaleus senegalensis, *and its implications for biological control using pathogens. Ecological Entomology, 23:9-14.

Thermoregulatory behaviour of the Senegalese grasshopper, *Oedaleus senegalensis* (Krauss), was investigated in the field following a spray application of an oil-based formulation of *Metarhizium flavoviride* Gams and Rozsypal in Niger, West Africa.

Measurements of environmental temperature, wind speed and solar radiation were made in conjunction with measurements of internal body temperatures of grasshoppers from a control (unsprayed) and treated plot using microthermocouples and hand-held thermometers. Grasshoppers were monitored for 4 days from the third day after application.

Oedaleus senegalensis utilized a range of thermoregulatory behaviours to maximize body temperatures during periods of low insolation and ambient temperature, and to minimize excessive heat loading during the hottest periods. Preferred body temperature of uninfected grasshoppers was 39°C, with a range from 24°C in the early morning to a high of 46°C during periods of high insolation and ambient temperature.

Infected grasshoppers altered their thermoregulatory behaviour and showed a behavioural fever response to the pathogen. Preferred body temperatures of infected individuals were raised to a new set point of ≅ 42°C. This is believed to be the first evdience for a behavioural fever in response to a microbial infection for any

natural population. In the present study, its effects appeared to provide little therapeutic advantage to hosts infected following application. Preliminnary evidence from other studies, however, indicates that modifications to host thermoregulation could be a signicant constraint to the pathogen and may limit its impact under certain conditions

Borgemeister, C., G. Goergen, S. Tchabi, A. Awande, R.H. Markham & D. Scholz. 1998. Exploitation of a woody host plant and cerambycid associated volatiles as host finding cues by the Larger Grain Borer,* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae). Annals of the Entomological Society of America 91: 741-747.

We collected twigs of *Lannea nigritiana* attacked by the girdling cerambycid *Analeptes trifasciata* F. in the Lama forest of central Benin, West Africa. Emergence data from *A. trifasciata* wood samples revealed a diverse insect fauna, which consisted of 27, primarily coleopteran species of 8 different families. More than 70% of the identified insects were bostrichids. We report for the first time in West Africa, an association of the exotic larger grain borer *P. truncatus* and one of its introduced natural enemy, the histerid predator *T. nigrescens*, with twigs girdled by an indigenous cerambycid. We found more *P. truncatus* directly above the girdling site than elsewhere. *P. truncatus* is not attracted to volatiles emitted by adults or larvae of *A. trifasciata*, but is significantly attracted to odors of cerambycid frass, as well as to girdled and mechanically damaged *L. nigritiana* twigs. We discuss these results with regard to the host finding behavior of *P. truncatus*.

Borgemeister, C., K. Schäfer, G. Goergen, S. Awande, H.-M. Poehling & 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. Annales of the Entomological Society of America (submitted)

In cassava chips, sampled on a local market in Cotonou, Republic of Benin, West Africa, *Dinoderus bifoveolatus* (Wollaston) was the most 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 at 2 locations in southern Benin, caught consistently considerable numbers of beetles. The sex ratio of the trapped *D. bifoveolatus* was significantly female-biased. Low numbers of 2 further Bostrichinae, i.e., *Prostephanus truncatus* (Horn) and *Rhyzopertha dominica* (Fabricius), were also recorded in the traps.

Cherry, A.J., N.E Jenkins, G Heviefo, R.G. Bateman, C.J. and Lomer, 1999. Operational and economic analysis of a West African pilot scale production plant for aerial conidia of Metarhizium spp. for use as a mycoinsecticide against locusts and grasshoppers. Biocontrol Sci. Technol. 9:35-51.

Aerial conidia of *Metarhizium anisopliae (flavoviride)* var. *acridum* strain IMI 330189 used for inundative biological control of grasshoppers and locusts in sub-Saharan Africa are produced in a purpose-built facility at IITA Benin using a standard two stage mass production system. Yields average 31.1 g dry conidia powder per kg rice substrate, production capacity is 300-350 kg conidia per year and production costs are estimated at $21 per 100 g (the recommended dose for 1 ha). Production process parameters vary within narrow limits established during optimisation but yield is characterised by a high level of variation over time. Incubation period and temperature are identified as key factors, although they account for less than 40% of yield variation. Variation in conidial viability and contamination are correlated with several parameters but none can adequately explain variation. Handling time, a principal limiting factor, could be reduced by increasing substrate quantity per unit of production. An awareness of these factors presents the opportunity to fine tune production although options for increasing or improving production efficiency are limited within the constraints of the system.

D'Almeida, Y.A., J.A. Lys, P. Neuenschwander & O. Ajuonu, 1998. Impact of two accidentally introduced* Encarsia *species (Hymenoptera: Aphelinidae) and other biotic and abiotic factors on the spiralling whitefly* Aleurodicus dispersus *(Russell) (Homoptera: Aleyrodidae) in Benin, West Africa. Biocontrol Science and Technology 8: 163–173.

De Groote H., 1998. Increasing Women's Income through Credit in Southern Mali. Quarterly Journal of International Agriculture, 37:72-87.

In this paper the impact of access to credit on women's income is studied, by examining a credit program targeted at rural women in southern Mali. Several women from 200 households were interviewed thee times over the course of one year to compare those who have access to the program with those who do not. It was shown that the program does reach its target population, rural women, and the access to credit does increase their income by significant and relatively important amounts. Given the small incomes of women, these increases are small in absolute terms. The operating costs of the project are very high compared to the amount of credit provided, and the program can only recover a very small amount of its costs through interest payments. Therefore, the program is not likely to be sustainable under its current form, and a further study of alternative organizational structures for providing credit to women is indicated.

De Groote H. & N. Coulibaly, 1998. Gender and Generation: an Intra-Household Analysis on Access to Resources in Southern Mali. The African Crop Science Journal, 6:79-95.

This paper analyzes the differences of access to productive resources within the household of southern Mali. Information was collected through separate group discussions with older men, younger men, and women from six villages. This information was complemented with a formal survey of 96 households in 12 villages. It was found that the essential differences between individuals related to access are gender, age, marriage and being the head of the household. The head of the household, always a man, manages the common fields, but otherwise men have less access than women to private plots and to the gathering of forest products. They have, however, more access to animals, and own all equipment. Differences between ethnic groups are very important. Methodologically, an effort has been made to reduce age into categories of generation and relation to the head of the household, but generally these variables did not perform very well. For future intra-household surveys following strata need to be distinguished for sampling: heads of household, dependent men and women. need to be maintained as sampling strata. Other influential variables to be included in the survey are age, ethnic group, mariage and participation in field work.

Defoer, T., H. De Groote, T. Hilhorst, S. Kante & A. Budelman, 1998. 'Participatory action research and quantitative analysis for nutrient management in southern Mali: a fruitful marriage?' Agriculture, Ecosystems & Environment, 71:215-228.

A farmer participatory action research process was developed by the Malian farming Systems Research team to assist farmers improving the practices of soil fertility management. The process is based on a relatively simple and quick analysis of farm diversity regarding soil fertility management, followed by resource flow models made by test farmers. These models are farmers' major tool to diagnose the way they manage soil fertility, and to plan and evaluate improvements over time. To avaluate the process, an analytical framework has been developed, using the data from the resource flow models. Both management performance indicators based on famers' perception of good soil fertility management and farm level nutrient flows and partial balances have been monitored. It allowed assessment of differences between farm classes and changes over time, and comparison of farmers' performance with standard references. The results show that resource flow models are an operationally useful tool. They assist farmers in analysing their soil fertility strategies, and in planning step-wise improvements. The visualisation of flows also allows for reliable and complete data collection, because omissions and mistakes are directly visible. Moreover, farmers not only provide information, but actively participate in the analysis itself. Evidence is given that information obtained through quantitiative analysis based on data gained from resource flow models can improve knowledge and perception of the major actors involved in the process: researchers and farmers. Examples are given that show that marrying participatory action research and quantitative analysis can lead to planning, experimenting and adapting ways to improve the use of scarced local resources.

Gauhl, F., C. Pasberg-Gauhl & G. Goergen, 1988. Report of an insect pest on* Calliandra calothyrsus *Meissen in Cameroon. Agroforestry Systems 41: 213-218.

A beetle pest, *Tragocephala guerini* White (Col.: Cerambycidae) was observed for the first time damaging the branches of *Calliandra calothyrsus* Meissner in Cameroon, Central Africa. Details of its biology and damage on the host plant are described.

Jenkins, N.E., G. Heviefo, J. Langewald, A.J. Cherry & C.J. Lomer, 1998. Development of a mass production technology for aerial conidia of mitosporic fungi for use as mycopesticides. Biocontrol Information and News Service, 19:21-31.

In any microbial control programme, production of sufficient quantities of good quality inoculum becomes essential to its success. The inoculum produced must be both consistent and compatible with the intended formulation and applicaltion technology. Each of the stages in the development and optimisation of a mass production technique for the production of aerial conidia of Mitosporic fungi is discussed. Full details of the LUBILOSA mass production system for aerial conidia of Metarhizium flavoviride are given, along with recommended contamination and quality control procedures. This technique has been used successfully to develop the specifications for a commercial product for the biological control of locusts and grasshoppers.

Schäfer, 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 Product Research (submitted).

Shah, P.A., O.-K. Douro-Kpindou, A. Sidibe, C.O. Daffè, H. van der Pauuw & C.J. Lomer, 1998. Effects of the sunscreen oxybenzone on field efficacy and persistence of* Metarhizium flavoviride *conidia against* Kraussella amabile *(Orthoptera: Acrididae) in Mali, West Africa. Biocontrol Sci. Technol 8:357-364.

Shah, P.A., C. Gbongboui, I. Godonou, A. Houssou, & C.J. Lomer, 1998. Survival and mortality of grasshopper egg pods from semi-arid cereal cropping areas of northern Benin. Bull ent Res. 88, 451 – 459.

Shah, P.A., C. Gbongboui, I. Godonou, A. Houssou, & C.J. Lomer, 1998. Natural incidences of* Metarhizium flavoviride *infections from two grasshopper communities in northern Benin. Biocontrol Sci. Technol. 8 335-344.

Thomas, M.B., S. Blanford, C. Gbongboui & C.J. Lomer, 1998. Experimental studies to evaluate spray applications of a mycoinsecticide against the rice grasshopper,* Hieroglyphus daganensis, *in northern Benin. Entomologia Experimentalis et Applicata 87:93-102.

Conference papers, workshop proceedings, abstracts, newsletters

CIRAD & IITA, 1998. Reconnaissance des Hyménoptères Parasitoides d'importance économique: clé iconographique pour l'identification des genres. Part I (Clé iconographique): 372 pp.; Part II (Introduction & Supplements): 72 pp.

A dichotomous identification key with pictured diagnostic characters is provided for the determination of 186 genera of parasitic Hymenoptera of economical importance occurring in the field and in post-harvest systems in West Africa. The training manual includes more than 300 scanning electronic pictures and nearly as much hand drawings enabling the identification of all currently known genera of Ceraphronoidea, Cynipoidea, Chalcidoidea, Platygastroidea, Proctotrupoidea, Ichneumonoidea and Bethyloidea relevant to agriculture in West Africa. This document was jointly produced by CIRAD & IITA in the frame of a 3 weeks IPM training course (Delvare, G. & G., Goergen) carried out during 5-23th October 1998.

Dara, S. K., C.J. Lomer & F.C.C. Hountondji, 1998. Lutte microbiologique contre l'acarien vert du manioc: Une approche de lâcher expérimentaux de champignons pathogènes et la participation des paysans. 'Gestion biologique des nuisible: Pour une stratégie Africaine intégrée en matière d'introduction et de gestion des agents de lutte biologique', Workshop organized by IITA and CPI-OUA, Lomé, Republic of Togo. October 13-15, 1998.

Defoer, T., S. Kante, T. Hilhorst & H. De Groote, 1998. Towards integrated soil fertility: Experiences from Southern Mali. in Bezuneh, T., S. Ouedraogo, M.J. Menyonga, J-D. Zongo & M. Ouedraogo (eds) Towards sustainable farming systems in Sub-Saharan Africa, Scientific papers presented at the Second International Symposium of the African Association of Farming Systems Research-Extention and Training (AAFSRET) 21-23 Aug. 98, pp. 27-48. Ouagadougou, Burkina Faso.

Gérard S., 1998. Le foncier, le travail agricole et la lutte contre les ravageurs: une analyse genre dans le département du Mono. Mémoire pour l'obtention d'un Diplôme d'Enseignement Approfondi en Environnement Temps, Espaces, Societes. Institut National Agronomique Paris-Grignon.

Houndekon, V., H. De Groote & C. Lomer, 1998. Health costs and externalities of pesticide use for locust and grasshopper control in the Sahel. Paper presented at the Annual Conference of the America Agricultural Economics Association, August 2 - 5 Salt Lake City, Utah, USA.

To measure the full costs of locust control, the side effects of chemical pesticides need to be measured and quantified. Based on literature, secondary data and a preliminary survey in Benin and Niger three factors were included in the study: human health, losses of domestic animals, and costs of destroying obsolete pesticides. A formal survey was undertaken in southern Niger, and a logit analysis shows a significant effect of the length of pesticide use on respiratory diseases, and a significant effect of participating in the village brigade, which organizes the treatments against locusts, on neurological and dermatological disorders. Health costs, estimated from the household medical expenses and a valuation of lost work time, were found to increase significantly, by US$0.50 for every year pesticides were used, or $US 0.15/ha treated. The survey results also indicate a loss of domestic animals of 0.5% for small ruminants and 0.2% for cattle due to intoxication. At market value, extrapolated over the concerned area and distributed over the surface area treated against locusts and grasshoppers, the external cost to domestic livestock could be estimated at US $1.5 for each ha treated. Based upon costs of destroying obsolete pesticides, divided by the area spread over the last 15 years, these costs can be estimated at $0.10 per ha treated. The externalities quantified so far, $1.75/ha treated, are significant and important. The results suggest that there are substantial reasons to decrease subsidies for chemical pesticides, and guide donor support towards biological control methods.

Johnson, D.L., Y. Bousquet, M. Cammer, K. Clayton, E. Cruz, D. Forsyth, B. Hill, C. Lomer, P. Martin, P.Mineau, J. Schmutz & J. Smits. Grassland insects and bird: the importance of insects as food, and careful choice of insect control methods. Poster presented "4th Prairie Conservation and Endangered Species Conference", Saskatoon, Saskatchewan, Feb 1998.

Langewald J., S. Ouambama, R. Bateman, A. Mamadou, R. Peveling., S. Attignon and C. Lomer, 1998. Comparison of an organic insecticide with a mycoinsecticide for the control of* Oedaleus senegalensis *Krauss (Orthoptera: Acrididae) at an operational scale: the importance of the spray residue and immigration. Society for Invertebrate Pathology, 31st Annual Meeting, Sapporo, Japan, 25 - 30 Aug. 1998.

Operational scale field trials were conducted in 1996 and 1997, in the east of the Niger Republic, on 50 and 800 hectare plots, to compare the efficacy of an oil based formulation of the entomopathogenic fungus, *Metarhizium anisopliae* (*flavoviride*) var. *acridum* (Deuteromycotina: Hyphomycetes) with fenitrothion for the control of Sahelian grasshoppers. The Senegalese Grasshopper *Oedaleus senegalensis* Krauss was the most abundant species in the trials. *M. anisopliae* was applied at 5 x 10^{12} spores per ha, at volume application rates of 2l and 0.5l per hectare in successive years. Fenitrothion was applied at 220g per hectare,

at 1.25 and 0.22 litres per hectare volume application rates. Ultra Low Volume equipment mounted on a vehicle (1996) or a fixed wing aircraft (1997) was used for application. The *M. anisopliae* treatment reduced the grasshopper population significantly after 7 days and by 93% within 16 days. Fenitrothion caused a population reduction of more than 90% shortly after application, but due to immigration, the grasshopper population recovered to the initial level within 16 days. Grasshoppers treated with the fungus and given the opportunity to thermoregulate in the sun died more slowly than grasshoppers incubated in the shade. The survival of spores in the spray residue of the *M. anisopliae* plots assessed by exposing grasshoppers to the sprayed vegetation at intervals and monitoring disease levels during subsequent laboratory incubation, showed the spray residue to remain highly infective, for three weeks after spraying. At the end of the 1997 season, egg pod density and viability in the plot treated with the fungus was reduced compared with both untreated and the fenitrothion plots. Compared with the existing practice of large-scale treatment of grasshopper infestations with fenitrothion, use of *M. anisopliae* would not only be safer to mammals and less damaging to non-target organisms, but also be more effective in the long-term control of grasshoppers.

Lomer C., H. De Groote, J. Langevald & S. Attignon. 1998. Potenciel d'utilisation d'un mycopesticide contre les Locustes et Sauteriaux en Afrique. Poster presented at "VIII^{emes} Journées Scientifiques de l'Université du Bénin,Lomé", May 11 to 15, 1998

Lomer, C. J., 1998. Microbial control of migratory pests. Paper presented at the Society for Invertebrate Pathology, 31st Annual Meeting, Sapporo, Japan, 25 - 30 Aug. 1998.

Microbial control agents generally kill insects more slowly than chemical pesticides, and fast-moving migratory pests may not at first sight appear to offer the most promising targets for microbial control. Operators responsible for control may need to have recourse to chemical control agents in case control fails, either through a lack of prediction of outbreaks or because of the failure of control operations. Nevertheless, there are many occasions when pests breed and feed outside the crop and a microbial control agent can be used. Similarly, immature stages may cause little damage and early treatment in the crop can avoid damage. Microbial control agents are particularly likely to be favoured if the pest breeds in a conservation area, and if a publicly-accountable agency is responsible for control. Other key points of importance are the IPM context, in particular detection, planning and forecasting of outbreaks and the role of natural enemies. With these points in mind, we identify several locust and grasshopper systems where microbial control is becoming established; additionally, Sunn pest of wheat and Armyworm are identified as promising situations for microbials.

Olichon S., 1998. Etude de l'application au champ de mycopesticides contre* Zonocerus variegatus *au Benin. Mémoire de stage pour l'obtention d'un Diplôme d'Etudes Supérieures Spécialisés (DESS) en Gestion des Systèmes Agro-Sylvo-Pastoraux en zones Tropicales. Paris, Université Parix XII

Project 4

INTEGRATED MANAGEMENT OF LEGUME PESTS AND DISEASES

by S.K. Asante, O. Coulibaly, K.E. Dashiell, C.A. Fatokun, W.N.O. Hammond, J.d'A. Hughes, L.E.N. Jackai, L. Lajide, B.B. Singh, M. Tamò (project coordinator), K. Wydra
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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.

In soybean, two diseases are key production constraints: frogeye leaf spot caused by *Cercospora sojina* Hara (Deuteromycotina, Hyphomycetes) in West Africa, especially in Nigeria, and red leaf blotch caused by *Dactuliochaeta glycines* (Stewart) Hartman & Sinclair (Deuteromycotina, Coelomycetes) in Zambia and Zimbabwe. 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 16.

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

4.1. 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 two 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 1998.

On-going and future activities

4.1.1. Evaluation of cowpea breeding lines under no insecticide spray.
by C.A.F., L.E.N.J.

Mokwa: Twenty five cowpea breeding lines selected from crosses between some improved varieties and cowpea wild relatives were evaluated in Mokwa for Maruca damage during the 1998 main cropping season (August to October). The lines were tested in sole crop with or without

insecticide application. Some of the cowpea lines used as parents were also tested as checks. Grain yield ranged between 1,044 kg and 1,243 kg/ha among the best six lines when protected with insecticide. When the plants were not protected with insecticide sprays grain yield ranged from 1,031 kg to 1,159 kg/ha. The harvested seeds were sorted into two groups of damaged and good non-damaged. The yield of good non-damaged seeds in the best six breeding lines ranged from about 881 kg to 930 kg/ha when plants were not protected with insecticide (Table 1A). Pod evaluation index (IPE) values ranged between 18.8 and 28.0 among the best six cowpea breeding lines.

Ibadan: The same cowpea breeding lines that were evaluated in Mokwa were also tested at Ibadan during the second cropping season (September to November) under sole crop and with or without insecticide application. Grain yield obtained from the best ten lines ranged from 1121.5 kg to 1479.5 kg/ha when no insecticide was applied (Table 1B). All the best ten breeding lines gave higher good non-damaged grain yield than the best among the checks under no insecticide spray treatment (TVu14476 with 915.6 kg/ha). The incidence of Maruca on the field was relatively low during this season at Ibadan. Pod evaluation index values were therefore, generally high among the breeding lines and checks. The 'ipe' values ranged from 23 to 35.5 among the best ten breeding lines and from 20 to 30 among the four check varieties.

Table 1. Performance of Cowpea Breeding Lines in 1998 (IPE = Pod evaluation index)

Cowpea Line	Spray		No Spray		IPE
	Total seed yield (kg/ha)	Good seed yield (kg/ha)	Total seed yield (kg/ha)	Good seed yield (kg/ha)	
A) Mokwa					
IT95M-268-1-4	1242.7	1065.2	1159.0	929.8	19.5
IT95M-17	1210.2	1099.8	1142.7	992.3	28.0
IT95M-268-1-6	1166.1	1047.3	1134.8	929.8	18.8
IT95M-303	1233.2	1171.9	1057.7	999.4	24.3
IT95M-311-1	1076.5	1031.9	1046.9	964.4	22.8
IT95M-278	1043.5	986.9	1030.6	880.6	24.5
IT91K-180 (CK)	999.4	955.6	978.9	896.0	22.5
TVU 14476 (CK)	1062.7	996.9	828.5	758.1	23.5
IT86D-715 (CK)	939.4	805.2	801.4	611.8	15.8
LSD 5%	326.9	294.4	239.3	239.0	5.5
CV %	20.2	19.8	16.1	18.5	17.0
B) Ibadan					
IT95M-268-1-4	1530.7	1377.4	1479.5	1350.8	25.0
IT95M-118-1	1406.9	1350.7	1359.4	1270.7	30.5
IT95M-305-1	1479.5	1313.6	1328.6	1190.2	26.5
IT95M-190-4	1539.1	1348.2	1303.2	1123.6	26.8
IT95M-7	1567.0	1520.7	1256.1	1192.7	35.5
IT95M-190-1	1349.0	1233.6	1192.7	980.2	26.8
IT95M-309-1	1490.3	1450.3	1177.3	1091.5	23.0
IT95M-278	1303.2	1168.6	1172.7	1054.0	31.0
IT95M-249-1	1502.8	1425.7	1127.7	935.6	27.5
IT95M-303	1306.9	1234.8	1121.5	1051.0	25.8
TVU14476 (CK)	1207.3	1120.2	994.8	915.6	30.0
91K-180 (CK)	1176.9	1144.8	702.2	662.2	22.8
IT86D-715 (CK)	1034.4	876.8	673.1	574.3	20.0
IT86D-719 (CK)	1012.3	821.4	614.3	457.6	22.5
LSD 5%	310.4	303.3	380.8	355.2	6.8
CV %	16.1	17.1	24.1	25.1	17.7

It is interesting to note that three of the best six performing lines (IT95M-268-1-4, IT95M-303 and IT95M-278) in Mokwa were also among the best ten performers at Ibadan.

4.1.2. Grain yield reduction in elite cowpea cultivars due to natural infestation by major insect pests in northern Nigeria

by S.K.A., B.B.S., L.E.N.J., M.T.

The interaction of elite cowpea cultivars with the natural populations of major insect pests namely, *A. craccivora*, *M. sjostedti*, *M. vitrata*, *C. tomentosicollis*, and the resulting grain yield reduction were studied during three consecutive years (95-97) at the IITA Minjibir Experiment Station, near Kano, northern Nigeria. and the data are now being analyzed. The cowpea cultivars used were IT86D-719, IT90K-277-2, IT89KD-374-57, IT93K 452-1, IT86D-721 and a commonly grown local cultivar, Dan Ila. This year, IT89KD 389 which performed badly in 1995 and 1996 was replaced by a high yielding and short duration variety, IT93K 452-21. They were planted on 29 June and 11 July, in 1997 as sole crop and intercrop (with millet and sorghum, respectively). There were two treatment regimes; protected and unprotected. Yield loss was significantly higher for cowpea planted in July than when planted in June. Also, similar to the previous years, there was less yield reduction (44 %) when these cultivars were intercropped either with millet or sorghum as compared with monocrop (52%). Dan Ila consistently suffered the highest loss in grain yield both under sole crop (81%) and intercrop (74%). On the other hand, the least amount of yield loss (33%) was recorded on IT93KD 452-1 under solecrop and 24% on IT90K277-2 under intercrop. Across cultivars and sowing dates, average yield loss was 46% and 38% for sole crop and intercrop, respectively for the elite cowpea. Whereas mean yield loss in the local cultivar (Dan Ila) was 81% (monocrop) and 74% (intercrop). Land equivalent ratio indicated that it is more productive to intercrop cowpea with sorghum than with millet, and IT90K277-2 performed better under both millet and sorghum intercrop than the other elite cultivars.

4.1.3. Screening breeders' lines for resistance to virus infection

by J.d'A.H., B.B.S.

In 1998, 236 *Vigna unguiculata* lines from the cowpea breeder were screened for resistance to three cowpea viruses commonly occurring in Nigeria. The three viruses were cowpea aphid-borne mosaic virus (CABMV), genus Potyvirus - Onne strain, blackeye cowpea mosaic virus (BlCMV), genus Potyvirus – IT-16 strain and cowpea mosaic virus (CPMV) (synonym: cowpea yellow mosaic virus), genus Comovirus. Five seedlings of each line were by mechanically inoculated with each virus. The plants were scored for incidence and severity of symptoms after inoculation.

Fifty-three lines were found to be resistant to CPMV by mechanical inoculation. This represents 22.9% of the lines tested. Fourteen of them were resistant to infection while 39 lines showed a hypersensitive reaction with the production of necrotic lesions at the site of infection. Eight lines were found to be resistant to BlCMV. These lines were IT95K-1543, IT95K-214-2, IT96D-357-31, IT95K-1534, IT96D-659BT, IT96D-660, IT96D-793 and IT96D-794. One hundred and twelve lines were resistant to CABMV by mechanical inoculation.

Segregation was observed among the lines that were screened for resistance. The segregation was observed most often in the screening for resistance to CPMV and included segregation of extreme susceptibility and resistance. For example IT94K-2023-3 segregated with one highly susceptible plant, two showing some mild symptoms and one giving only a hypersensitive reaction. Other lines showing marked segregation of resistance to CPMV were IT95K-1095-2, IT95K-222-14, IT96D-772, IT89KD-349, IT96D-550BT, IT96D-553BT and IT96D-584BT.

4.1.4. Screening cowpea lines for multiple virus resistance

by J.d'A.H., B.B.S.

Out of 236 lines screened for resistance against CABMV - Onne strain, BlCMV– IT-16 strain and CPMV, thirty-two lines exhibited resistance against two viruses. Five of the lines had resistance against BlCMV and CABMV; the remaining 25 were resistant to CPMV and CABMV. Only two lines were resistant to all three viruses: IT96D-660 and IT96D794. In both cases the resistance to CPMV was in the form of a hypersensitive reaction.

4.1.5. Cultivar x strain interaction: Studies on existence of races of *X. campestris* pv. *vignicola* (*Xcv*)

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

Nine cowpea genotypes obtained from IITA, Ibadan, Nigeria showing differential reactions in field experiments in different ecozones were tested against 15 *Xcv* strains for the study of existence of bacterial races. To confirm results of the first genotype/strain interaction experiment, 6 selected

genotypes were again tested against 5 selected *Xcv* strains. When 9 cowpea genotypes were inoculated with 15 *Xcv* strains, considerable differences in virulence of the strains and in susceptibility of the genotypes were observed. The strains could be arranged in order of decreasing ability to produce symptoms, and the genotypes in order of increasing resistance. The resistant cowpea genotypes exhibited resistance and the susceptible genotypes susceptibility to most of the strains. Only a few pairs of genotypes and bacterial strains showed strong differential reactions, where one strain was highly virulent on the genotypes A and B and the other strain was highly virulent on genotype A but avirulent on genotype B. Reciprocal reactions were rarely observed. When 6 cowpea genotypes were inoculated with 5 *Xcv* strains in a repeated study, a gradual pattern in virulence of the strains and in susceptibility of the genotypes was observed as before. Because of a continuous pattern of virulence and susceptibility of most of the strains and genotypes, respectively, and due to fluctuation in virulence of some strains in some genotypes between the 2 interaction studies, a clear differentiation of races could not be achieved. The clear differentiation of weakly and highly virulent strains and susceptible and resistant genotypes suggests that the different aggressiveness of the 17 strains on the 11 genotypes is related to different degrees of virulence, i.e. to quantitative factors, but not so much to qualitative factors which would otherwise indicate the existence of races.

4.1.6. Resistance of cowpea genotypes to *X. campestris* pv. *vignicola*

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

The genotypes IT 84E-124 (No. 1), IT 86D-472 (No. 2), IT 84S- 2246-4 (No. 3), IT 81D-1137 (No. 4) and IT 84D-449 (No. 5) were identified as the most susceptible ones (in decreasing order), since they were diseased by some of the weakly virulent strains, too. Susceptibility decreased on the genotypes IT 86D-715 (No. 6), IT 86D-719 (No. 7), IT 84D-666 (No. 8) and the genotype IT 81D-1228-14 (No. 9) clearly showed the highest degree of resistance. The genotypes IT 86D-472 (No. 2), IT 86D-715 (No. 6), IT 86D-719 (No. 7) and IT 84D-666 (No. 8) showed atypical reactions characterized by a brown-red discoloration on the inoculated areas 14 days after inoculation. The discoloration appeared even on non-inoculated leaves and stems on genotype No. 7. Hypersensitive reaction (HR) was not observed on any genotype tested. Fifty-four cowpea genotypes obtained from IITA, Ibadan, Nigeria were tested in glasshouse experiments against 3 highly virulent strains of CoBB originating from different geographic areas. The genotypes varied highly in reaction against all 3 strains of *Xcv* and could be divided into 6 resistance/susceptibility classes. Three genotypes (IT 90K-284-2, IT 91K-92-10 and IT 91K-118-20) were not attacked by any strain and were classified as highly resistant. Four genotypes (IT 81D-1228-14, IT 86D-719, IT 82E-16 and IT 92KD-170-1) showed a moderately resistant reaction, since they were weakly susceptible against only the strain 28a1g and not susceptible at all against the other 2 strains. Sixteen, 8, 11 and 12 genotypes were classified as weakly resistant, weakly susceptible, moderately susceptible and highly susceptible, respectively. There was no correlation between resistance and origin or agronomic characters of the genotypes.

4.1.7. Resistance of cowpea genotypes to *Macrophomina phaseolina*

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

Susceptibility/resistance of 3 cowpea cultivars was assessed at two inoculum levels of *M. phaseolina*, causal agent of charcoal rot of cowpea (OD = 0,8 and OD = 1,6 at 660 nm). The varieties IT 93 K-734 and TN 5-78 showed high disease incidence of 54% and 71% in first week, reaching 70% and 95 %, respectively, at the end of the third week. In the variety Kpodji 5 % of plants where infected at the end of the first week, and 7% at the end of the third week The reaction of the variety Kpodji to the infection of *M. phaseolina* was further tested with increasing inoculum doses (up to OD = 6,4 at 660 nm) and over a period of 4 weeks. Germination was good at all inoculum concentrations; most of the plants were in class 1 (visually healthy looking plants) at the end of the fourth week and disease incidence as well as morality did not exceed 14 % for any of the relatively high inoculum concentrations.

Enzymatic activity (cellulase and 1,3 β glucanase), an indicator of fungal presence in the plants, was studied in 4 weeks-old plants infected with *M. phaseolina* and in plants infected with *M. phaseolina*, where seeds were treated with an antagonist (A9) before sowing. There was no significant cellulase or glucanase activity in either of the variants, K^- (not inoculated control), K^+ (inoculated control) and A9. Germination of seeds and fresh weight of the plants were similar in all variants.

4.2. *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 15 for details).

On-going and future activities

4.2.1. Screen the IITA cowpea germplasm of cultivated cowpea for resistance to Maruca pod borer and pod sucking bugs.

*by L.E.N.J, M.T. - in collaboration with Q. Ng, J. Asiwe**

IITA has the world cowpea collection most of which has been screened for various pests and diseases over the past several years. A number of things seem to have happened in the interim. Pest profiles have changed downwards between 1980 and 1995; also new germplasm has been added to the collection, and there is a growing need to get more information for GIS studies. We therefore decided to screen all of the cowpea germplasm whether or not it has been screened before.

Table 2.Cowpea germplasm accessions with high pod evaluation index (Ipe*) under natural field infestation with *Maruca vitrata*. Mokwa, Nigeria, 1998.

Ipe = 49:	TVu nos 7427, 7635, 7640, 7657, 7656, 7658, 7659, 7660, 7664, 7686, 8130, 12808, 12809
Ipe = 40-42:	TVu nos 1886, 1892, 7321, 7330, 7608, 7680, 8151, 8466, 13097.
Ipe = 32-36:	TVu 1147, 1641, 2377, 3085, 4578, 7364, 7748, 8154, 12193, 13381, 13386.

*Ipe range is 0 - 72.

Table 3. Cowpea germplasm accessions with low damage scores (<5*) for damage and infestation by *Clavigralla tomentosicollis* under natural field conditions. Mokwa, Nigeria. 1998.

Score = 3:

i. Early maturity group - TVu nos. 1052, 1068, 7321, 7330, 7425, 7427, 7601 7635, 7640, 7657, 7656, 7657, 7658, 7659, 7660,7664, 7680, 7748, 8151, 8154, 8286, 8467.

ii. Medium maturity group - TVu nos 185, 203, 275, 1147, 1186, 2000,

iii. Late maturity group: TVu 8702.

Score = 4-5:

i. Medium maturity group - TVu nos 139, 166, 296, 811, 1023, 1155, 1469, 1631, 2184, 2200, 3008, 3113, 3029, 8839, 10876, 11620, 14716, 14729.

ii. Late maturity group - TVu nos 655, 1780, 2123, 2246, 5123, 7240.

* range is 1 - 9.

Approximately 11,000 accessions were planted in Mokwa, (Southern Guinea Savanna zone) Niger State in Nigeria under no protection except with monocrotophos if necessary, after scores had been taken for aphid and flower thrips infestation. Mokwa has served as the "hot spot" for MPB and PSB evaluation in the past. Although generally low, infestation by aphid (*A. craccivora*), and floral bud thrips (FTh) (*M. sjostedti*) were also assessed using scores (1-9), as well as disease incidence (reported in a different section of this report). Planting was segregated according to the maturity groups of the cowpea accessions -- early, medium (2 groups) and late.

Infestation and damage by MPB was assessed in situ by examination of flowers (RVE) and scoring for pod load (1-9) and pod damage (1-9). A pod evaluation index (Ipe) was calculated using this information. Pod bug infestation and damage was evaluated using a 9-point scale where lower scores are better. A summary of the results follows.

Flower infestation by *M. vitrata* was generally heavy, with the highest levels observed in the early and late maturity groups. All groups had very poor Ipe values (0-10) with a few exceptions in the early maturity accessions (Table 2). This confirms the presence of heavy larval infestation during flowering. Some of the early maturing accessions may have escaped damage, but those accessions with Ipe 25<50 deserve further evaluation. Infestation by the PSB, *C. tomentosicollis*, was also heavy, with most accessions having the maximum score (9) for damage. Any accessions with scores <5 (Table 3) will be evaluated further. Infestation by aphids was low, and FTh low-moderate (highest score 5/9).

Every accession was scored for the various pests; this information will be added to the database for GIS studies. We hope to discover new sources of resistance to MPB and PSBs from the accessions selected for further evaluation. This will be ascertained during the 1999 season.

4.3. 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

4.3.1. Impact assessment of locally available natural enemies of major legume pests

by M.T.- in collaboration with A. Cherry, D. Arodokoun

The survey to monitor the presence and impact of the local strain of the thrips parasitoid *Ceranisus menes* Walker (Hym., Eulophidae) on cowpea was continued in 1998 in the Forest Margins Benchmark Area of southern Cameroon, both on selected legumes to be used as cover crops, and also on the natural vegetation. As already observed in Benin, only low numbers of *C. menes* could be observed. However, these surveys allowed the discovery of another thrips parasitoids, tentatively identified as *C. femoratus* Gahan (Hym., Eulophidae) (see 4.3.3).

Surveys for *M. vitrata* larval pathogens on different cultivated and wild host plants in Benin also continued in 1998, and allowed to ascertain the presence of various micro-organisms, among them different microsporidia, and two different viruses (see 4.3.5.).

4.3.2. 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.

4.3.3. Foreign exploration and quarantine testing of larval parasitoids of *M. sjostedti*

by M.T., W.N.O.H. - in collaboration with K. Diop, A. Loomans, T. Shanower*

Early January 1998, foreign explorations were continued around Hyderabad, (Andhra Pradesh state), focusing on the 'black abdomen strain' of *C. menes* discovered in 97. This time, collections were made from pigeonpea (*Cajanus cajan*) flowers, from which 29 adults could be obtained for inoculation. Because of sub-optimal condition for thrips rearing, one generation only could be obtained from the original collected material, after which the colony got extinguished.

During systematic surveys on both cover crops and wild vegetation in the Forest Margins Benchmark Area of southern Cameroon, the 'black abdomen strain' of *C. menes* was discovered around Yaoundé early February. By April it had moved already to Mbalmayo, and by the end of the year it could be reported also from the West along the road to Bafoussam. It was collected in high numbers from the most common road-side weed, *Centrosema pubescens*, which is also used as a cover crop, but also from trees such as *Milletia* spp., and, more importantly, from cowpea flowers. Investigations on the spread and impact of this parasitoid are still on-going in Cameroon.

In the meantime, over 450 adult specimens of the parasitoid could be introduced with regular import permits for experimental rearing in our labs in Cotonou. After some initial difficulties with the raring of the main host, *M. sjostedti*, a regular production could finally be established. After completion of biological and behavioral studies, experimental releases are planned both in Benin and Ghana during the second half of 1999.

Specimens of the 'black abdomen strain' from India, Cameroon, and Kenya (collected by S. Mickalik, GTZ project on IPM in beans, Nairobi) were sent to S. Triapitsyn, UC Riverside, for identification. They all seem to belong to the same species and were tentatively identified as *Ceranisus femoratus* Gahan (Hym., Eulophidae).

4.3.4. 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.

In conclusion, this study 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.

4.3.5. Entomopathogenic viruses for the control of *M. vitrata*

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

The original sample of a presumed baculovirus contained too little material for RFPL identification techniques and was accordingly semi-purified by differential micro-centrifugation and fed to mid-instar *M. vitrata* from the IITA laboratory colony to increase the amount of pathogen available. Inoculation led to expression of a previously unidentified protozoan pathogen in the assay larvae, and which inhibited viral multiplication. Examination of the *M. vitrata* colony demonstrated endemic infection with a putative microsporidian protozoa (possibly a *Vairimorpha* sp.) and which necessitated the complete destruction of the colony and sterilization of laboratory and all associated equipment. A new, pathogen-free, colony has been established, following standard isolation and procedures, from single gravid females imported from IITA, Nigeria, under import license.

As a result of this endemic infection, the original virus inoculum was used up without production of progeny. This required a month of intense field surveys in southern Benin to search for new isolates. Three viral and two microsporidian protozoa isolates (possibly *Nosema* sp.) were identified from single larvae. These have been partially purified as above and assayed as above. Preliminary results indicate we have two viral morphologies (possibly a NPV and a CPV), but further rounds of replication will be needed before sufficient material is available for RFLP analysis of viral DNA/RNA or for electron microscopy.

4.3.6. 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 *Trissolchus* 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.

4.3.7. Taxonomy of antagonists effective against M. phaseolina

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

The antagonists, which controlled efficiently *M. phaseolina* in the greenhouse were identified and are being characterized. Antagonist were bacteria, belonging to the genus Bacillus: *Bacillus subtilis, B. spaericus* and *Paenybacillus polymixa*. Strains of fungal antagonists of the genus Trichoderma (*T. harzianum*), isolated previously, were also tested and controlled *M. phaseolina* in pot experiments.

4.4. 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

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

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

On-farm trials in Benin, Ghana, Niger, Mali, Nigeria, Burkina and Senegal revealed 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.

Extracts from the forest trees *Khaya anthotheca* and *K. grandifolia* proved to have same insecticidal and anti-feedant properties as neem on *M. vitrata*

4.5. 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

4.5.1. Investigate mechanisms and basis of resistance to *M. vitrata*

*by L.E.N.J., - in collaboration with S. Nokoe, F. K. Ewete and JAN Asiwe**

During the past 3 years, experiments were conducted to determine the effect of different plant spacing on the population fluctuation of the major cowpea pests, especially *Maruca vitrata* and *Clavigralla tomentosicollis*. Although farmers are known to use a wide range of spacing in different ecological zones, we do not know whether spacing *per se* affects the incidence and severity of the pest populations.

The experiments were designed following Neddler's arc method, and they were carried out in Ibadan during the first and second seasons of the years in question. Two cultivars were used, IT 86D-715 an early erect cultivar, and Moussa local, a spreading medium maturing cultivar. Although the results have not been fully examined or analyzed, we can give you a summary of the preliminary findings

- Borer infestation (measured as flower infestation and damage - RVE) decreased with increase in spacing. This resulted in increasing overall plant productivity (measured as pod evaluation index -- Ipe) from low (0.55m) to wide (1.5m) spacing.
- A spittle bug,(probably *Locris* sp.) encountered in high frequency on cowpea during the study followed a different pattern. Populations were lower at narrow spacing and increased with increasing in plant spacing.

- Pod sucking bug infestation did not seem to follow any specific trend during the first season but during the second season infestation increased with plant spacing. The bug population during the second season was predominantly *C. tomentosicollis*.
- In 1996 when the population was very low, aphid infestation on both varieties increased with spacing up to a certain point and then appeared to decline, giving a normal curve. When infestation was higher and more normal in 1997, there was a decrease with wider spacing.
- Flower thrips caused slightly more damage at narrow spacing than at wider plant spacing.
- In general, grain yields during all years were higher in wider spaced cowpea, for both varieties, and followed the same trend as for Ipe. Final results of this study will be made available after proper analysis.

Wider spacing is usually accompanied by lower plant populations. This goes against current recommendations for planting improved cowpea varieties, especially early varieties with erect plant type (such as IT86D-715, one of the two cultivars used in this study). Based on these results, a logical conclusion would be that large plant populations are not necessarily optimal for non-chemical crop protection in cowpea. It is not certain whether these findings can be extrapolated across ecological zones without further modification. Further validation studies are necessary. However, the concept has been incorporated in a doctoral research thesis in Ibadan.

4.5.2. Testing synthetic pheromones for *M. vitrata*

by M.T. – in collaboration with A. Cherry, D. Hall, M. Downham

Four different pheromone blends, each at two different loadings in two different types of dispenser were field tested by Dr Cherry of NRI, on secondment to IITA in Benin. The experiment, in cowpea fields, lasted two months. For the first time ever, significant catches of male moths were obtained. Key results were: the three component blend that performed best in laboratory bioassays caught significantly more moths than any two- or single-component mixture; traps baited with the three-component blend caught significantly more than traps baited with virgin female moths; pheromone loading and dispenser type had no significant effect on catches over the two-week period each lure was tested; catches did not obviously decline over the two-week period each lure was tested; catches in pheromone traps in the fields showed little or no correlation with catches in a light trap a few hundred yards away; low but significant numbers of female moths were also caught in the traps baited with synthetic pheromone. Further experiments are under-way in collaboration with IITA, Benin to compare varying amounts of the two minor blend components and test three different types of trap.

4.5.3. Survey on the occurrence of *M. phaseolina* in the major cowpea growing regions in Niger

*by K.W. - in collaboration with L. Afouda**

During the growing season 1998 an unusually high rainfall quantity was recorded in Niger. In order to assess the impact of climatic change on the occurrence of *M. phaseolina*, which is believed to cause problems only in dry areas, a field survey was conducted in September 1998 in the major cowpea growing areas of Niger, the regions around Niamey and in the South-West and South-East of the country. Survey data of 1996 and 1998 in the area around Niamey were compared. In general charcoal rot of cowpea occurred with low severity in 18 of the 50 surveyed fields. Climatic conditions may have contributed to the low overall incidence and severity, though some sites were highly infected. In 1996, high infection levels were found in various stages of plant growth in most fields. Seeds bought from the market in Maradi showed 39 % infection with *M. phaseolina*.

4.5.4. Characterization of strains of *X. campestris* pv. *vignicola* (*Xcv*) by metabolic fingerprints, virulence and symptom development

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

Metabolization patterns of 95 carbon sources by 55 Xcv strains originating from different geographic areas, virulence groups and symptom types was studied by Biolog System. The strains varied considerably in the utilization of carbon sources. Nineteen substrates were used by all the strains, 47 not by any strain and 29 were used by some strains and not by the others. No considerable difference was found between strains isolated from blight symptoms and pustules originating from Nigeria, Niger, Cameroon and Benin or between strains in 3 virulence classes. A difference was observed between 2 strains isolated from pustule symptoms originating from Mozambique and 53 strains originating from other countries. Gentiobiose was not used by the 2

strains, but by all the others, while lactulose was used by the 2 strains but not by the others. A specific difference was observed between strains according to their geographic origin. The strains originating from Benin, Thailand and Uganda appeared similar, but different from the rest. Dextrin, glycogen and succinamic acid were not used by strains from Benin, Uganda and Thailand, but by all the other strains (excluding 2 pustule strains from Mozambique), whereas N-acetyl-D-glucosamine and malonic acid were used by all the strains from Benin (malonic acid only by 66% strains), Uganda and Thailand and not by the others (except 1 strain from Sudan and Brazil for N-acetyl-D-glucosamine). The strains originating from Benin, Thailand and Uganda were also clustered together, but separate from the others in a dendrogram and 2 dimensional plots. The strains from Mozambique were also clustered separately from the others, but together with the strains from Venezuela and Brazil. The Biolog data base identified all the strains as *Xanthomonas campestris*, however belonging to 8 different pathovars: *carotae* (38% of the strains), *manihotis* (20%), *vignicola* (18%), *alfalfae* (9%,), *campestris* (7%,), *vesicatoria* (4%,), *phaseoli* (2%) and *begoniae* (2%,). Only the strains originating from Benin (8 of 9 strains) and Thailand (both strains) were identified as *X. campestris* pv. *vignicola*. None of the strains from other countries and also of the 4 reference strains had been identified as Xcv. Among the highly virulent strains, about 44%, 31% and 6% of the strains were identified as X. c. pvs. *carotae*, *manihotis* and *vignicola*, respectively. From the medium virulent group, about 32% of the strains were identified as the pv. *carotae* and 26% as *vignicola*, whereas from the weakly virulent category, about 33%, 28% and 17% of the strains were identified as the pvs. *carotae*, *manihotis* and *vignicola*, respectively.

4.5.5. Assessing latent virus infection in cowpea

by J.d'A.H.

Seed-borne virus infection of cowpea is usually accompanied by conspicuous symptoms on the primary and first trifoliate leaves. Screening for seed-borne virus and resistance to virus infection has therefore relied on symptom expression. However, some cases of symptomless (latent) infection were recorded during screening experiments. This phenomenon is being studied to determine its potential consequences on the current screening methods for cowpea viruses. Symptomless infection of three cowpea lines, TVu 11979, SuVita-2 and TVu 1272, had been observed after inoculation with southern bean mosaic virus (SBMV), genus Sobemovirus, cowpea mottle virus (CPMoV), genus Carmovirus, cucumber mosaic virus (CMV), genus Cucumovirus and cowpea golden mosaic virus (CpGMV), genus Geminivirus. These lines, in addition to two other improved cowpea lines, IT82D-889 and IT90K-277-2 were found to have symptomless infection after inoculation with CPMoV. The proportion of symptomless infection was highest in IT82D-889 (27.4%), 9.5% in Tvu11979 and lowest in TVu 1272 (9.0%). No symptomless infection was found in IT90K-277-2 whereas all plants of SuVita-2 expressed conspicuous symptoms after inoculation.

4.6. 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

4.6.1. 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.

4.6.6. 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.

4.7. 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

4.7.1. 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, A.B. Salifu, D. Seck

After several seasons trials by researchers, on-station promising technologies that were identified for transfer to farmers fields for validation, varied from one country to another and included: (i) cultivars with multiple resistance/tolerance and therefore require minimum or no insecticide treatment; (ii) cultivars expressing strong resistance to Striga and/or Alectra; (iii) the use of natural plant extracts as insecticides, (iv) use of solarization, double or triple bagging, metallic drums, and natural plant powder or extracts for storage. In a few cases some of the above components were already integrated to form an 'IPM basket'.

Several cultivars were confirmed to demonstrate multiple resistance in Burkina Faso (IT 85D-3516-2, KVx 414-22-2, KVx 414-22-72, KVx 404-8-1, KVx 404-22-2). These cultivars are being released to farmers. Also on-farm minimum insecticide trials were conducted in Benin, Mali, Nigeria, Ghana, Mozambique and Senegal. Striga/Alectra resistant varieties were confirmed on farmers fields in Burkina Faso (KVx 61-1, Waongo-1, and Gorom local); Nigeria (IT90K-76, IT 90K-867-11 and IT 90K-82-2); Niger (IT89KD-374-57, IV 92-E3, VMI, and HTR); and Senegal (IT93K-596, IT95K-1088-4, IT95K-1090-12, and IT95K-1091-3).

In Ghana and Senegal, synthetic insecticides were replaced by neem extracts from leaves and particularly seeds, with very promising results on farmers fields. Similar results were obtained with the use of *Carica papaya* in Benin. Preliminary on-farm testing of neem extracts was also conducted in Nigeria and Niger. For the transfer of storage technologies, on-farm testing was quite advanced in many countries; Cameroon, Benin, Senegal, Burkina Faso, and Ghana, and to a less extent in Nigeria.

In Senegal a demonstration of the 'IPM basket', comprising improved variety, planting distance, use of neem extract as insecticide, harvesting at the appropriate period, and a combination of the use of metallic drums and extracts from the plant *Boscia senegalensis* for storage, increase grain yield by 37-1150%. The on-farm validation of most of the above technologies will continue for another 2-3 years.

4.7.2. Investigation of the effect of resistant cultivars, natural plant extracts, intercropping and planting date, on pest abundance and grain yield.

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, A.B. Salifu, D. Seck, M. Toure

From on-station trials in 8 countries, several lines of cowpea were identified to show single or multiple resistance to a number of insects pests and diseases. Very good levels of resistance to flower thrips and Striga/Alectra were confirmed in Burkina Faso, Nigeria, Ghana, Senegal and Niger, resulting in higher grain yield. In most of the countries, trials on the use of neem and to a lesser extent, papaw leaf extracts, were concentrated on fine-tuning the appropriate dosages and frequency of application.

The multilocational international trials across various ecological zones using planting dates to control pod sucking bugs continued in Benin, Burkina Faso, Ghana, Niger, and Nigeria. Planting cowpea at different times of the season again showed that different population levels of PSBs and other insect pests were attracted to the crop. Thus confirming previous findings in Burkina Faso and Nigeria. However, intercropping trials gave inconclusive results in most countries.

4.7.3. Socioeconomic studies: baseline farmhousehold surveys

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. Toure

Baseline farmhousehold surveys have carried-out in at least 72 households in the benchmark sites of Cameroon, Benin, Burkina Faso, Mali and Ghana. The first step of the surveys consisted of an extensive preliminary investigation in the sample villages through a rapid appraisal. The questions are related to key issues on pests and diseases knowledge and management. The second step is the

intensive survey trough a structured questionnaire which resulted from the rapid appraisal. The intensive survey has focused on the household and field level data collection. Primary data were collected on the household characteristics: farm size and gender composition, age of household members, level of schooling, major household decision making process, areas cropped, types of crops grown, pests and diseases management, farmers' varietal choices and benefits from adopting technologies.

4.7.4. Socioeconomic studies: marketing surveys and data collection

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. Toure

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 subsector analysis of cowpea has been completed in Cameroon, Benin, Burkina Faso, Mali 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 subsector analysis is marketing which is supposed to provide the links between producers and consumers through a process of buying, storing, transporting, processing and selling cowpea. The subsector analysis helps also in setting initial technical and socioeconomic research priorities to improve cowpea production, storage and marketing performance.

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.

Bottenberg, H., M. Tamò & B.B. Singh, 1998. Cowpea pest dynamics on wild* Vigna *sp. and cultivated cowpea in monocultures and mixtures with millet: a comparison of the relative importance of host plant resistance and mixed cropping in cowpea pest management. Agric. Ecosyst. Envir., 70:217-229.

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. (submitted).

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 inefficacy of *O. albidipennis* as biological control agent for *M. sjostedti*.

Verdier V., K. Assigbétsé, G. Khatri-Chhetri, K Wydra., Rudolph K. & J.P. Geiger, 1998. Molecular characterization of the incitant of cowpea bacterial blight and pustule* Xanthomonas campestris *pv.* vignicola. *European Journal of Plant Pathology, 104: 595-602

Conference papers, workshop proceedings, abstracts, newsletters

Afouda, L., K. Wydra & G. Wolf, 1998. Development of serological methods for the detection of* Macrophomina phaseolina *(Tassi) Goid, incitant of ashy stem of cowpea (*Vigna unguiculata *(L.) Walp). Int. Congress of Plant Pathology, Edinburgh 9-16 August 1998, abstr. 3.4.46

Macrophomina phaseolina is a worldwide distributed seed and soilborne pathogen with a wide host range. Infected plants show various symptoms as damping off of young seedlings, stem and root fissures, ashy stem, leaf blight and wilt, and sudden death of mature plants. Apparently healthy plants can carry the fungal infection in a latent form. Yield loss can be high, particularly in regions with high temperatures and pronounced water deficit. The production of clean seeds is a prerequisite for a healthy plant stand and can reduce the damping off in early stages of plant growth as well as the latent development of the mycelium in growing plants. To develop integrated methods to control the disease, an accurate knowledge on the biology of the fungus in infected plants and seeds is necessary. Therefore, a sensitive method was developed to detect the fungus even at latent stages in the plant and in seeds.

Antigens were prepared from mycelium and cultural liquid medium of *M. phaseolina* and injected into rabbits. Four polyclonal antibody fractions were purified and tested in a DAS-ELISA (Double Antibody Sandwich Enzyme-Linked Immunosorbent Assay) for their ability and sensitivity to detect *Macrophomina phaseolina* in infected plants. Fractions with high sensitivity in the DAS-ELISA were selected to study the biology of *Macrophomina phaseolina* in plants.

Three from the four tested antibodies allowed the detection and quantification of *Macrophomina phaseolina* in different parts of infected plants with symptoms as well as in symptomless plants. In infected plants, *Macrophomina phaseolina* was found to be mainly located in the roots and in the hypocotyl and to a small extent in the epicotyl. There was no evidence of fungal presence in the leaves. The latent occurrence of *Macrophomina phaseolina* was confirmed by detecting the fungus in inoculated but healthy looking plants.

Afouda, L., K. Wydra & G. Wolf, 1998. Approach to biological control of* Macrophomina phaseolina *(Tassi) Goid, causal agent of charcoal rot, and development of serological methods for its detection in cowpea (*Vigna unguiculata *(L.) Walp). Mitteilung Biolog. Bundesanstalt 357:251-252

Macrophomina phaseolina is a worldwide distributed seed and soilborne pathogen with a wide host range. The affected plants show various symptoms, but the fungus can also be present in the plants in a latent form and cause high yield loss, particularly in regions with pronounced water deficit. Polyclonal antibodies were raised against *Macrophomina phaseolina* and allowed, in a direct, double antibody sandwich DAS-ELISA (Enzyme-linked immunosorbent assay) detection and quantification of the fungus in different parts of infected plants showing symptoms as well as symptomless plants. Fungal and bacterial antagonists were isolated from soil samples originated from different regions in Niger. These antagonists were tested in vitro and in the growth chamber for their ability to inhibit the growth of *Macrophomina*.

Assigbétsé, K., V. Verdier, K. Wydra, K. Rudolph & J.P. Geiger. Molecular characterization of the incitant of cowpea bacterial blight and pustule,* Xanthomonas campestris *pv.* vignicola. *IX Int. Conf. Plant Path. Bacteria, Madras, India, August 26-29, 1996 (in press).

Khatri-Chhetri, G., K. Wydra & K. Rudolph. Development of a semi-selective medium for quick and easy detection of* Xanthomonas campestris *pv.* vignicola*, incitant of cowpea bacterial blight. IX Int. Conf. Plant Path. Bacteria, Madras, India, August 26-29, 1996 (in press).

Khatri-Chhetri, G., K. Wydra & K. Rudolph. Variability of strains of* Xanthomonas campestris *pv.* vignicola*, incitant of cowpea bacterial blight and bacterial pustule, collected in several African and other countries. IX Int. Conf. Plant Path. Bacteria, Madras, India, August 26-29, 1996 (in press).

Khatri-Chhetri, G., K. Wydra & K. Rudolph, 1998. Characterization of* Xanthomonas campestris *pv.* vignicola *strains by metabolic fingerprints (BIOLOG system). . Int. Congress of Plant Pathology, Edinburgh 1998. abstr. 2.2.103.

Cowpea bacterial blight caused by *Xanthomonas campestris* pv. *vignicola* (*Xcv*) is common worldwide, whereas cowpea bacterial pustule has been reported only from Nigeria and West Africa where mixed symptoms of blight and pustules were often observed. The pathovar vignaeunguiculatae proposed for pustule causing bacteria has not been accepted internationally. For both bacterial variants differences in aggressiveness have been reported, but the existence of races has not been clearly established. It is still an open question whether blight and pustule causing bacteria belong to the same pathovar *vignicola*. Therefore, the objectives of this study were to characterize blight and pustule causing strains by analyzing their capability to metabolize 95 organic substrates.

Fifty-five strains of *Xcv* (36 from blight, 13 from pustules, 6 reference strains) originating from 11 countries, were studied for their metabolization pattern of 95 carbon sources using the Biolog GN Microplate System.

The strains varied considerably in utilization of the carbon sources. Twenty-seven substrates were used by all the strains, 48 not by any strain and 20 were used by some strains and not by the others. Although the strains isolated from pustules differed to some extent from strains isolated from blight in the metabolization of N-acetyl-D-glucosamine, D-galactose, cis-aconitic acid, malonic acid and succinamic acid, no specific difference could be observed. Only 2 pustule strains originating from Mozambique differed highly in the utilization of gentiobiose, lactulose, D-melibiose, D,L-lactic acid, glycerol and D,L-α-glycerol phosphate. No considerable difference was observed between reference strains and fresh isolates.

A specific difference could be observed between strains according to geographic origin. Dextrin, glycogen and succinamic acid were not used by strains from Benin and Thailand, but were used by all the others, whereas N-acetyl-D-glucosamine, malonic acid and L-proline were used only by strains from Benin and Thailand. The strains from Venezuela differed considerably in the metabolization of cis-aconitic acid and α-hydroxybutyric acid from the other strains.

Identification: Ninety-one percent of the strains from Benin and Thailand (18% of all the strains) were identified as *Xanthomonas campestris* pv. *vignicola*. None of the other strains was identified as *Xcv*. The Biolog data base identified 80% of the strains as Xanthomonas campestris, however belonging to 7 different pathovars . Twenty percent were identified as *Pseudomonas cissicola*.

According to the variations in substrate utilization (but similarities within a group) the strains could be categorized into 4 groups:1. Cameroon, Nigeria, Niger, Sudan and Uganda, 2. Benin and Thailand, 3. Venezuela and Brazil and 4. Mozambique. The Biolog System revealed a considerable variation in metabolic fingerprints of the strains which were more or less correlated with their origin and identification, but not to blight or pustule development and pathogenicity. It is concluded that the strains isolated from blight and pustules from West Africa belong to the same pv. *vignicola*.

Khatri-Chhetri, G., K. Wydra and K. Rudolph 1998: Isolation, virulence analysis and genotype/pathogen interactions of* Xanthomonas *campestris pv.* vignicola *strains, incitant of cowpea bacterial blight and pustule, from different geographical areas. DPG Working Group 'Bacteriology', Geisenheim, September 1997. Phytomedizin 28:60-61.

From cowpea leaves with symptoms of bacterial blight and/or pustules, obtained from Benin, Cameroon, Mozambique, Niger, Nigeria, Uganda and Venezuela, 97 strains of *Xanthomonas campestris* pv. *vignicola* were isolated. Twenty reference strains were received from Brazil, Burkina Faso, India, Sudan, Thailand, USA and Zimbabwe, including one strain causing only pustule symptoms from Mozambique. The strains varied highly in virulence after spray infiltration on cowpea genotype IT 84D-449 in glasshouse experiments. Blight was the dominant symptom produced by all strains. Only in a few cases, brown, minute pustules developed on inoculated leaves. Development of small, brown pustules depended mainly upon temperature, virulence of strains and susceptibility of genotypes. Highly virulent strains evoked systemic infections on non-inoculated leaves and stem canker, while weakly virulent strains produced symptoms mostly on inoculated leaves only. Fresh isolates were usually more virulent than reference strains. Four ICMP reference strains (333, 334, 3389 and 5855) were avirulent on this genotype. The difference in virulence and development of minute pustules between strains was not related to their origin. Only 3 strains originating from Mozambique produced pustule like structures without typical blight on this genotype. Therefore, the differentiation of a second pathovar "*vignaeunguiculatae*", appeared unjustified. When 9 cowpea genotypes were inoculated with 15 bacterial strains of different origin, a gradual increase/decrease in virulence of the strains and in susceptibility of the genotypes was observed. Therefore, bacterial races could not be clearly differentiated.

Khatri-Chhetri, G., K. Wydra & K. Rudolph, 1998. Development of a semi-selective medium for quick and easy detection of* Xanthomonas campestris *pv.* vignicola *, incitant of cowpea bacterial blight and pustule. Mitteilung Biologische Bundesanstalt 357:247.

A semi-selective medium (SSM) for an easy isolation of *Xanthomonas campestris* pv. *vignicola* (*Xcv*), incitant of cowpea bacterial blight and pustule, was developed. Twelve carbon and 5 nitrogen sources were tested for selectivity towards *Xcv*, and 25 antibiotics were screened for inhibitory effects on *Pseudomonas fluorescens, Erwinia herbicola, Bacillus subtilis* and 4 other saprophytes isolated from cowpea leaves. D-cellobiose and ammonium chloride were found to be optimal carbon and nitrogen sources, respectively. Among the antibiotics, cefazoline inhibited the growth of most of the saprophytes with little effect on some pathogen strains. DL-methionine enhanced the growth of *Xcv* strains to some extent. Boric acid along with the selected carbon and nitrogen sources and DL-methionine suppressed the growth of the saprophytes *P. fluorescens*, SP2 and SP3. The SSM designated as "Cefazoline-Cellobiose-Methionine Medium" (CCMM) contained: dipotassium hydrogen phosphate 0.8 g, potassium dihydrogen phosphate 0.8 g, magnesium sulphate 0.3 g, boric acid 0.2 g, ammonium chloride 1.0 g, D-cellobiose 10 g, cycloheximide 0.2 g, DL-methionine 1.0 g, cefazoline 10 mg and agar 14 g per liter of water, pH adjusted to 7.2. Colonies of *Xcv* on CCMM were whitish, round, raised and ca. 0.2 to 1.8 mm in diameter 96 h after streaking. CCMM inhibited the growth of *E. herbicola, B. subtilis* and 3 other saprophytes isolated from cowpea leaves. *P. fluorescens* and SP 3 (isolated from a cowpea leaf), which could not be completely inhibited by CCMM, could be differentiated from *Xcv* by their smaller size and different color of colonies. The SSM may be useful for quick and easy detection of *Xcv* from contaminated cowpea plants and soil.

Sikirou, R., K. Wydra & K. Rudolph, 1998. Inoculum sources of* Xanthomonas campestris *pv.* vignicola, *incitant of cowpea bacterial blight and pustule, and identification of other hosts besides* Vigna unguiculata. *Int. Congress of Plant Pathology, Edinburgh 9-16 August 1998, abstr. 6.67

Cowpea bacterial blight caused by *Xanthomonas campestris* pv. *vignicola* (*Xcv*) is widespread in most areas where cowpea (*Vigna unguiculata*) (L.) Walp) is cultivated. It causes heavy losses, when the infection comes in an early stage of crop growth. Losses range from 2.66 to 92.24% according to cultivar and stage of infection. Besides the use of resistant varieties, the knowledge on inoculum sources is important to develop control methods. The objectives of this study were to find out the major inoculum sources of cowpea bacterial blight and to determine other possible hosts of *Xcv* besides *Vigna unguiculata.*

In the field, cowpea leaves infected with a marker strain resistant to rifampicin and streptomycin were mixed with soil and kept on the soil surface or buried at 10 cm and at 20 cm in the soil. In the greenhouse, 40 g of leaves with symptoms were mixed with soil and subjected to 4 different water regimes: pots without watering, pots watered every 2 weeks, pots watered every 3 days during two months, pots watered every 3 days. Residual bacteria were determined every 2 weeks in field trials and every month in the greenhouse trials.

In field experiments, un-weeded cowpea plots were inoculated by spraying with a marker strain resistant to rifampicin and streptomycin. Leaves of the dominant weeds were collected every 5 days for detection of *Xcv* bacteria. The same weed species were inoculated by leaf infiltration in the greenhouse and leaves were collected for determination of bacterial numbers every two weeks. Twelve legume species were tested by leaf infiltration to identify the host range of *Xcv*. Symptom development was recorded every 3 days to 5 days.

The results showed, that in the field no bacteria could survive more than 2 months in the top soil layer or buried at a depth of 10 and 20 cm in the soil. In the greenhouse, the bacteria were also detected only up to 2 months under various water regimes.

The epiphytic bacteria obtained from 6 weed species collected from the field and from leaf infiltrated plants from the greenhouse progressively decreased in number. In the field, bacteria were not found from 10, 15, 25 and 45 days after inoculation (dpi) and in the greenhouse from 45, 90 and 105 dpi, according to weed species.

From 12 legume species leaf-infiltrated with *Xcv*, only *Stenophylis sternocarpa* (African yam bean) showed clear and typical symptoms of cowpea bacterial blight.

According to the fast decreasing number of the pathogen on weeds and the short survival of *Xcv* in crop residues in the soil, weeds and plant debris are not regarded as principal sources of inoculum, but may contribute to the spread of *Xcv* during the cropping season. However, *Stenophylis sternocarpa* can be considered as a host plant of *Xcv*.

Sikirou, R., K. Wydra and K. Rudolph, 1998. Survival of* Xanthomonas campestris *pv.* vignicola *, incitant of cowpea bacterial blight and pustule, on weeds and in soil and identification of other hosts besides* Vigna unguiculata. *Mitteilung Biolog. Bundesanstalt 357:223

Reducing the level of initial inoculum is important to control bacterial blight and pustule of cowpea caused by *Xanthomonas campestris* pv. *vignicola.*(*Xcv*). The objectives of our studies were to identify the principal source of inoculum under the conditions of Benin and to determine other possible hosts of *Xcv* besides *Vigna unguiculata* . Marker strains, resistant to rifampicin and streptomycin were screened for similarity to natural isolates and used for field studies of cowpea bacterial blight. Un-weeded cowpea plots were inoculated by spraying with the Rifampicin-Streptomycin resistant strain and the development of epiphytic *Xcv* populations on 6 dominant weed species was studied. The survival of *Xcv* on cowpea plant debris (leaves with

symptoms) and in soil was investigated. The results showed, that epiphytic bacteria obtained from 6 weed species collected from the field and from leaf infiltrated plants from the greenhouse progressively decreased in number. In the field, bacteria were not found from 10 to 72 days after inoculation (dpi) and in the greenhouse from 45 to 105 dpi, according to weed species. No bacteria could survive more than 2 months on the soil surface or buried at a depth of 10 and 20 cm in the soil.

From 12 legume species leaf-infiltrated with *Xcv*, only *Stenophylis sternocarpa* (African yam bean) showed clear and typical symptoms of cowpea bacterial blight.

According to the fast decreasing number of the pathogen on weeds and the short survival of *Xcv* in crop residues, weeds and plant debris are not regarded as the principal sources of inoculum, but may contribute to the spread of *Xcv* during the cropping season. Moreover, *Stenophylis sternocarpa* could be considered as a host plant of *Xcv*.

Wydra, K., G. Khatri-Chhetri & K. Rudolph: Pathological and physiological characterization of the incitant of cowpea bacterial blight and bacterial pustule,* Xanthomonas campestris *pv.* vignicola*, from different geographic origin. National symposium on recent developments in plant pathology, Chennai, India. (in press).

Cowpea leaves with symptoms of bacterial blight and bacterial pustule were collected in Niger, Nigeria, Cameroon and Venezuela. The isolated bacterial strains showed considerable differences in colony morphology and virulence. Although the incitants of the blight and pustule symptom have been described elsewhere as different pathovars (pv. *vignicola* and pv. *vignaeunguiculatae,* respectively), blight was the dominant symptom evoked by all pathogenic isolates, however, differing in strength. Only minute pustules developed in few cases. Highly virulent strains systemically invaded the stem where fissures and cankers developed resulting in withering of the whole plant. The observed high degree of pathogenic variability was independent from the geographic origin of the strains. When 9 cowpea genotypes were inoculated by 15 bacterial strains of different origin, marked differences in virulence were observed which did not justify, however, the designation of different races. Physiological studies on the metabolization of organic substrates using the Biolog system revealed a considerable variability between strains in metabolic fingerprint patterns which were not correlated to the pathogenic behavior. It was concluded from these results that a thorough knowledge of the naturally occurring variability of the pathogen is a prerequisite for testing and selecting resistant genotypes.

Project 5

INTEGRATED MANAGEMENT OF MAIZE PESTS AND DISEASES

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

Outputs

5.1. 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 5.3.). 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.

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

5.1.1. 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. Kalabane, M. Koubé, R. Ndemah, Z. Ngoko*, R. Olatinwo*, W. Marasas, M. Poehling, M. Setamou*, S. Weise*

In 1997, in Cameroon, questionnaires were administered, field maize health assessed, and stored grain sampled with 12 farmers per village, in six villages, in each of two agroecological zones. Sub-samples of the grain will be analyzed for mycotoxins. These data have been analyzed assessing the relationships of field variables with stored grain degradation and with management practices as described by the farmers. A first analysis which encompasses biotic and abiotic as well as socio-economic data was done in 1998.

In Uganda, the country-wide surveys are completed and work will concentrate in benchmark sites set up by socio-economists based on biotic data obtained from the surveys (see under 5.4.5.). First diagnostic work in the benchmark sites was done end 1997/beginning 98 with emphasis on GLS, stemborers and their natural enemies (especially *Telenomus* spp. and *Cotesia* spp.) of stemborers. At Namulonge, labs for rearing of stemborers and natural enemies have been completed. First releases of *Cotesia flavipes*, larval parasitoid of *C. partellus*, were be carried out

by ICIPE in late 1997. Pre-release and follow-up studies will be carried out by NARO scientists backstopped by the IITA/IFAD project and TT&TU.

In Ghana, the choice of these benchmark areas have been backed up by macroeconomic statistics on population, access to roads, maize areas, production and yields assembled from the University of Ghana at Legon. They comprise the Ashanti Region representing the Transitional agroecological zone lying between the forest and the Guinea Savannah; the Eastern Region which is the forest zone with medium population density; and the Volta Region characterized by a coastal Savannah with degraded forest agroecology, and low population density. A first diagnostic survey with emphasis on pests has been carried out in late 1997. The benchmark sites will be used test hypotheses created via survey data and for R&D of IPM technologies.

5.1.2. *M. nigrivenella*: an ear-feeding pest of maize in western Africa

*by F.S. - in collaboration with M. Sétamou**

In the Guinea savanna of many western African countries, the most damaging lepidopteran pest of maize is the relative poorly known *M. nigrivenella*. It has been found across ecological zones in Benin, Ghana, Nigeria and Côte d'Ivoire. In Benin, several country-wide surveys were carried out between 1991-97 to assess the pest status, host plant range and natural enemy complex of this species. *M. nigrivenella* was found on several plant species from various plant families: Malvaceae (i.e. cotton), Fabaceae (e.g. *Phaseolus lunatus*, mucuna), Caesalpiniaceae, Rubiaceae, and Sterculiaceae. Cover crops such as the *Canavalia ensiformis* and *Mucuna pruriens* have been found to be excellent hosts for maintaining relatively high *Mussidia* populations during the off season. Generally, infestations and damage levels of *Mussidia* in maize fields varied with abundance of alternate hosts, i.e., pods or fruits suitable for survival and development of the pest, and thus with ecological zone.

In Benin and Nigeria, no larval or pupal parasitoids, and low egg parasitism (<0.01%) was found on maize, cotton, Canavalia and Phaseolus bean. On *Gardenia* spp. only, mean parasitism of 12.4% of *Mussidia* pupae by *Antrocephalus crassipes* was found in Benin. In Cameroon, parasitoids were often found on maize with *Tetrastichus atriclavus* as the most common species followed by *Antrocephalus* sp. and *Bracon* sp.

M. nigrivenella is only known as a field crop pests from some western African countries, although it was reported from non-cultivated hosts in eastern and Southern Africa, and it is hypothesized that in the latter regions *M. nigrivenella* is under natural control on wild hosts. This opens possibilities for the re-distribution approach (See 5.4.1.). Given sufficient funding, exploratory work will be done in East and Southern Africa. In 1998, emphasis was given to compiling, analyzing and publishing results.

5.1.3. Studies on the penetration and establishment of downy mildew in maize seeds and correlation with seed transmission

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

Earlier downy mildew workers in Nigeria all stated that *P. sorghi* (maize strain) did not form oospores, and seed transmission of the disease through internally seed-borne mycelium or oospores was thus unlikely. They concluded that *P. sorghi* perenniated because of continual maize cultivation with dry season survival on maize grown in inland valleys. But there was an indication and possibility of seed- transmission from histological work, which showed mycelia and oospores of *P. sorghi* in maize kernels of systemically infected plants. Thus we decided to identify other potential modes of transmission of maize-infecting strain of *P. sorghi*. Transmission by market seeds from the three DM-endemic states, seed from systemically infected plants, and seed from silk-inoculated plants, and 'crazy top' tissue were investigated.

Downy mildew symptoms developed from market seeds within seven days of emergence, and treatment with Apron plus® did not significantly alter the infection percentages. Both are a good indication that infection was seed borne.

Seed transmission from nubbins of systemically infected plants was highly significant in the different locations where seeds were collected ($F = 7.64$, $P = 0.0001$). Occurrence of infected plants from crazy-top amended soil was significant, in 1998 screenhouse and field experiments. Crazy-top tassels from infected plants were plowed into the field and planted up with susceptible variety (pool-16). The plots amended with infected tassels gave a mean of 35% downy mildew systemically infected maize plants while the control plots showed no infection.

Downy mildew infected seeds from the artificial silk-inoculation when planted after a month of storage at 9% moisture content failed to transmit the disease. Therefore we conclude that mycelium of *P. sorghi* in dry seed may not be of much significance but oospores in mature kernels and in crazy tops should be viewed seriously. Seed transmission of *P. sorghi* has so far been a subject of speculation for many years. But in this study seed transmission has occurred from market grains, in nubbins and in crazy tops in the glass house and field.

5.1.4. Modeling of development of *P. sorghi* resistance to Apron plus ®

by K.F.C., V.A. - in collaboration with L. Ayinde, D. Onukwu, K.M. Chin, K. Müller

Studies were conducted to determine under which conditions *P. sorghi* populations in southern Nigeria would lose sensitivity, and these conditions were related generally to the agricultural conditions in the country. In contained trials, it was shown that loss of sensitivity could be induced with sub-optimal dosage and that it would be stable if there were a constant supply of susceptible hosts. In general, though, when the seed dressing was applied in appropriate doses. There were no incidents of breakthrough. Risk of breakthrough of resistant fungal strains was further lowered when the host plant had moderate resistance. The potential for catastrophic breakthrough of resistant pathotypes is mediated by numbers of infective inocula in the environment, and this parameter is strongly influenced by how successfully integrated pest management tactics are deployed in the zone. To assess liklihood of breakthrough, i.e. loss of sensitivity of the *P. sorghi* population to Apron plus® in a region, a stochastic model can be used based on estimated probability of encounter of at-risk plants (susceptible not treated, susceptible sub-optimally treated, resistant sub-optimally treated) and regional effective inoculum concentration at a given time.

5.1.5. 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 *M. nigrivenella* and *E. saccharina*, and known storage pests such as *S. zeamais* and *Carpophilus spp.* have been found in higher numbers when the fungus is present. Work in 1997 and 1998 has revealed that stem borers can also be found in higher numbers in plants with endophytic *F. moniliforme* than plants without. Greenhouse and lab experiments showed that on plants inoculated with *F. moniliforme, E. saccharina* laid significantly larger egg batches and had considerably higher survival of offspring than on plants treated with fungicide (once only) or where seeds underwent a hot water treatment. No differences were observed with *S. calamistis*. A one-time fungicide or hot-water treatment, however, did not keep the plants Fusarium-free for the entire growth cycle, indicating that infection may also occur at a later stage.

In field trials, covering the ear significantly reduced F. moniliforme incidence. Borers often move from stem to ear, and tunnels in the stem are often associated with fungi such as *F. moniliforme*, therefore we were interested to know if stem borer levels in the field had any impact on post-harvest quantities of *F. moniliforme* and fumonisin contamination of the ear. In a field to store study of maize in Cameroun from 1996 until 1998, no field factor was found to be significantly related with post-harvest contamination with the fungus and its toxin.

5.1.6. Biology and ecology of *P. truncatus* with particular reference to its natural habitat (i.e. as a wood-feeder)

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

Screening of the principal tree species in the Lama Forest was conducted in order to characterise the woody substrate range of *P. truncatus*, and only a few species have been found susceptible to *P. truncatus*. Woody substrates are being collected monthly at locations around the south and mid Benin in order to evaluate the importance of collection time and site on the *P. truncatus* reproductive success. Reproduction has not yet been obtained on wood, which was dead at the time of collection, and completely fresh wood is as well not acceptable. Reproduction of *P. truncatus* on woody substrates has only been obtained from fresh wood which has been dried to a moisture content ranging from 15% to 50%. Moisture content but especially collection time has been found to be important for the reproductive success. The importance of collection time is probably associated with biochemical changes in the wood composition, so wood samples have been saved and will be subjected to biochemical analyses. Flight activity is being monitored with pheromone traps in the Lama Forest (80 km North of Cotonou), Pennesselou Forest (400 km North West of

Cotonou), Toui Forest (330 km North of Cotonou) in Benin and in the Yendi area in northern Ghana. On all sites, forest trap catches are linked to traps placed in the vicinity of grain stores just outside studied forests, and grain stores are sampled monthly to monitor insect densities and grain damage. Previously published trap catches of *P. truncatus* in the Mono Province (South of the Lama Forest) showed a gradual decline during the period of 5 years (1992 to 1997), which was interpreted as a sign of impact (control) of the natural enemy. However, trapping in the Lama forest in the following years have shown, both inside the forest and adjacent to grain stores just outside the forest, the trap catches exceeded 700 *P. truncatus* in some of the weekly samples in May and June 1998. In the same traps the number of *T. nigrescens* exceeded 200 per week adjacent to grain stores, but it did not exceed 60 in the forest. In the Pennesselou forest more than 1200 *P. truncatus* have been caught in a weekly sample with only 3 *T. nigrescens* present in the same trap. These results suggest that, especially in certain savanna areas, *T. nigrescens* may not play a significant role in the ecology of *P. truncatus*. Especially in southern Benin the distribution of *T. nigrescens* and *P. truncatus* catches seem to have similar spatial/ecological distribution, but *T. nigrescens* may be constrained in the most remote parts of the studied forest. Seasonal changes in trap catches are evident but the patterns are still not fully understood. Climate, storage practices and woody composition are being evaluated as potential driving factors for the trap catch patterns. Substantial differences in average trap catches among traps from each forest have been obtained and strongly indicate that the *P. truncatus* distribution in the forests is not homogeneous but associated with presently unknown ecological variables. Efforts are being made to relate this variation in spatial distribution of *P. truncatus* to vegetational heterogeneity (a vegetation survey was conducted last year). GIS and image processing analyses will be conducted in order to generate maps of seasonal flight patterns and vegetational composition.

Arthropods living on poor substrates, like wood, are known to benefit from endosymbiotic interactions with microorganisms. Histological studies of *P. truncatus* enabled the detection of intracellular endosymbionts, and they are in the process of being described. Lab experiments have shown that the development of the organs harboring these endosymbionts (mycetomes) in *P. truncatus* females reared at 37 ^{o}C were significantly smaller than mycetomes in females reared at 30 ^{o}C. The Guinea Savanna areas of West Africa are major maize growing areas, and the average daily temperatures can reach levels which may affect the mycetomal development. These mycetomes may not be eliminated completely, but it can be argued that high temperatures affect the mycetomal size and that development time, survival, and reproduction rate are influenced by mycetomal size. It is presently being examined under lab conditions how mycetomal size affects the reproduction of *P. truncatus* on both woody substrates and maize.

5.1.8. Modeling of storage pest population dynamics and grain losses

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

A demographic, distributed delay population model of *S. zeamais* in West African grain stores was published, and a model of *T. nigrescens* developed, in object-oriented C++, jointly by workers at IITA and the Danish Institute of Agricultural Sciences. As with the *P. truncatus* population simulation model the model is driven by grain moisture content and minimum and maximum daily temperature, and uses grain store size (in kg maize) and initial density as additional parameters. For both models the developmental rates, larval survivorship, age-specific fecundity and density-dependent emigraton rates were obtained from experiments done at IITA Calavi or from published articles. Field experiments done at IITA Ibadan and in the Mono Province of Benin provided the validation data. The *S. zeamais* model was used to evaluate the effects of varietal resistance and interspecific competition on population dynamics. With respect to varietal resistance, the model indicated that a resistance factor that affected reproductive success of the beetles would play a large role early in the season but a decreasing role as the season progressed and as other factors, in particular intraspecific crowding, became more important. Interestingly, that differences among varieties in terms of *S. zeamais* density tend to be greatest at the beginning of the season but also tend to decrease over time had been previously reported, so the simulation modelling provided a theoretical mechanism for an observed phenomenon. The *P. truncatus* model and the *S. zeamais* model have been linked to a 'grain store' environment, which contains weather files and parameter settings for initializing and driving the simulation models and keeps track of the damage state of the maize. The damage state of the maize is being linked to map-based data on maize market prices (see below). Using this structure, the modelling work will focus on the links between the pest models and between the pests and the predator, *T. nigrescens*. The grain store model is being

refined further, and is intended as a user-friendly tool to help analyze the effects of different management strategies and different agro-ecologies on pest density.

Iterative statistical techniques are being used to estimate the daily per capita rate of maize damage for *P. truncatus* and *S. zeamais*. Ten data sets, from Nigeria, Benin and Mexico, are being used to estimate grain damage rates in different ecologies, and under different management strategies. The per capita rates will be used to link the pest models to the grain store environment described above, and to link model output with economic analyses. The effect of maize damage on *S. zeamais* behavior showed that the strong effect of crowding on weevil reproduction is most likely due to the presence of other beetles, and not due to the damaged state of the maize, according to a student thesis. This suggests the role of a chemical inhibitor, perhaps combined with physical contact, in reducing beetle reproduction.

Data collected from the country-wide survey of 102 grain stores conducted last year was used to field validate sequential sampling plans, and to evaluate the economic efficacy of pesticide use. The sampling plans developed for *P. truncatus* were found to be adequate, and the sequential probability ratio test plan, with an assumed negative binomial underlying distribution, was the preferred plan. The sampling plans for *S. zeamais* need further adjustment, particularly with regard to the upper and lower threshold insect densities. With respect to pesticide use, a higher proportion of the farmers involved in our survey in the Mono and Zou provinces of Benin were found to treat their stores with field pesticides at the time of stocking than was observed in a similar survey conducted in 1993. Furthermore, using published data on the relationship between grain damage and market value, per kg market value of the grain from treated stores was not found significantly different than the value of the grain from untreated stores in the same area. This indicates that clear messages regarding the safety and utility of pesticide use need to be developed and communicated, and that sampling before making decisions about pesticide use can have economic benefits.

As part of an experiment to monitor store conditions as well as insect density and fungal infection and aflatoxin contamination, temperature and humidity probes were placed both inside and outside nine rural maize stores in southern Benin. The objective is to relate within-store and ambient weather conditions to the most important factors determining grain value and safety as a food. Stores were sampled to estimate insect density and samples brought to the lab for fungal and aflatoxin analysis. One objective is to observe whether insect density is in any way correlated with fungal attack, and how important pockets of moist maize are in supporting aflatoxin-producing fungi in the store. This link will be important in combining Geographical Information System approaches with simulation models as part of a decision-support tool.

5.1.9 Economic analysis of stored maize

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

Data on maize prices and quality are being collected every 3 months at several markets across Benin and this data will be combined with 4 years of market data on maize prices obtained from ONASA to generate a spatial data map of maize prices. Since maize quality tends to drop as the price rises (and as farmers' stocks of maize deplete during the course of the season), and since maize prices themselves tend to be functions of not only the season but also factors such as the quality of the transportation network and proximity of a major market to the farmers, these data will be useful in economic interpretations of farmer decisions. Maize price data will be used to evaluate the results of field trials using different varieties or using new control strategies, and they will be linked to grain loss output from the simulation modeling in a GIS platform

5.2. 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 multitrait 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 fungus, A. flavus, 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

5.2.1. Mass-rearing of *S. calamistis, E. saccharina, B. fusca* and *M. nigrivenella*, and development of field increase systems with NARES

by F.S. - in collaboration with A. Chabi-Olaye, R. Ndemah, M. Sétamou**

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. poe*phaga (occurring on sorghum in the northern Guinea savanna). These insects are also used for testing their suitability for indigenous and exotic natural enemies species and strains, and for massrearing natural enemies including entomophagous organisms. M. nigrivenella is reared on both artificial diets and pods of the Jackbean, Canavalia enseiformis.

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 NCRE/IRA 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. Further experiments will be carried out in the framework of the CIMMYT/IITA Project on breeding for stress resistant maize in Africa (AMS). Thus, in 1998, a first meeting with entomologist from AMS target countries was held in Ibadan to discuss techniques to increase uniformity of field infestations.

5.2.2. Improve stem borer resistant populations and lines

by S.O.A., J.G.K., F.S.

A cycle of recurrent selection was completed in TZBR Ses 3 C2 by the recombination of 35 selected S2 lines in 1998 to form TZBR Ses 3 C3.Recurrent selection for increased levels of resistance to stem borer attack continued in three maize populations (TZBR Eld 1 C7, TZBR Eld 3 C2 and TZBR Syn W/Y C1). S1 progenies from the three populations were evaluated in 1998 at two locations one of which was under artificial infestation with *S. calamistis* or *E. saccaharina* as appropriate. Corresponding S2s of the selected progenies from each of the populations will be recombined to form new cycles for the populations.

Furthermore, research effort initiated in 1997 to broaden the base and adaptability of TZBR Eld 1 C7, continued in 1998 with the isolation of S1 lines from the second backcross generation. These lines will be evaluated and selected progenies recombined to form TZBR Eld 4 C0. TZBR Eld 1C7 has a high level of resistance to *E. saccharina* and also moderately resistant to *S. calamistis* but was created more from unadapted genotypes thus making the population relatively unadapted itself.

A cycle of mass selection was completed in both Ama TZBR-W and Ama TZBR-Y in 1998. Both Ama TZBR-W and –Y are products of a collaborative breeding arrangement with Institute of Agricultural Research and Training, Moor Plantation, Nigeria being carried out in a stem borer hot

spot location of South-East Nigeria. Levels of resistance of selected individuals from the hot spot location were confirmed under artificial infestation with *S. calamistis* at Ibadan before recombination. Additionally, Ama TZBR W/Y was separated along color lines and product obtained crossed to selections from Ama TZBR-W or Ama TZBR-Y as appropriate to create two experimental populations namely Ama TZBR-W1 and Ama TZBR Y1, respectively. The new cycles and experimental populations together with the original populations will be evaluated in 1999 to estimate progress from selection.

A 10-parent diallel evaluation of maize populations having varying levels of resistance to Sesamia and/or Eldana sp. was conducted in 1998 at five locations, three of which were under artificial infestation with Sesamia, Eldana and Sesamia plus Eldana, respectively. Further evaluations of the diallel crosses are planned for 1999. Results obtained from these evaluations will allow the assignment of populations into two broad heterotic groups for future breeding purposes.

5.2.3. Evaluation of the effect of *Bacillus thuringiensis* (Berliner) δ-endotoxin on maize stem and ear borers with specific reference to *S. calamistis*, *B. fusca* and *E. saccharina*

by F.S. - in collaboration with L.E.N. Jackai

To investigate the activity of different *B. thuringiensis* Cry proteins against *B. fusca*, *E. saccharina* and *S. calamistis* larvae, different concentrations (0.016, 0.08, 0.4, 2, 10μg/ ml) of four Cry proteins (CryIAb, CryIAc, CryIC et CryIIA) were used. The larval feeding behaviors, larval survival and the larval growth on the artificial diet containing each of the 4 Cry proteins at different concentrations were studied. The results showed that at any concentration, the -endotoxin induced feeding inhibition. However, larvae recovered from this inhibition 24h after when they were exposed to Bt at concentrations below 0.4μg/ ml. All of the larvae species were susceptible to the Bt endotoxin but some specific activity of CryIAc, CryIC et CryIIA was noted. The CryIAc with the lowest toxicity on the larvae provoked, at 2μg/ ml, 93% of mortality on *E. saccharina* 42.4% and 35.6% on *B. fusca* and *S. calamistis* respectively. Only the CryIAb at 0.016μg/ ml. showed the high level of virulence on the three borers. The growth of survival larvae was negative affected by the toxins.

Cry toxins at sublethal concentrations had no effect on the acceptance of *S. calamistis* larvae by the larval parasitoid *C. sesamiae* but the number of parasites produced was positively affected while sex ratio was lower on *C. sesamiae* from larvae fed on Bt.

5.2.4. 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 Link:Fr. 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 cotamination in field and laboratory studies in the U.S.A. These genetic materials were increased and crossed to tropically adapted elite maize inbred lines at IITA. The resulting crosses and backcross populations are expected to be good sources of inbred lines and synthetic varieties with resistance to aflatoxin contamination. Furthermore, we have initiated a collaborative research work with USDA scientists to screen IITA inbred lines for resistance to aflatoxin contamination. A total of 80 inbred lines adapted to the savanna and mid-altitude ecological zones of West and Central Africa were sent to the US for screening.

5.2.5. 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. Although the lines were artificially inoculated with Cercospora

zeamays, the environmental conditions were not conducive for the development of the disease in Uganda and Cameroon. Thus, meaningful results were not obtained. This trial will be repeated in 1999.

A set of differential maize hybrids of proven susceptibility and resistance to grey leaf spot (GLS) was planted at two moist savanna locations (Ferkéssedougou, and Sinématiati) to monitor the presence of grey leaf spot in Cote d'Ivoire. None of the typical symptoms of grey leaf spot were observed on any variety at either location.

5.2.6. Compare old vs. new cycles in IITA maize breeding populations for improvements in ear characteristics and grain quality
by K.F.C., J.G.K., B.M.D. - in collaboration with O. Ayinde, S. Odubiyi

To achieve progress toward better grain quality and storability, passive selection for general ear appearance and improved husk cover were found to be inadequate. A more specific screening methodology will have to be used to make progress towards improving ear quality with respect to mycotoxin fungi. A manuscript corroborating this conclusion is in preparation.

5.2.7. Evaluation of maize inbred lines derived from adapted x exotic backrosses for resistance to downy mildew
by A.M., S.O.A., K.F.C.

Seven-day-old seedlings of 42 maize inbred lines derived from backcross populations of two downy mildew resistant, namely KU1414 SR and KU1403, and introduced inbred lines were inoculated with downy mildew suspensions of 2.2 x 10^5 to 7.1 x 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 1).

Table 1. Mean percent downy mildew incidence of five resistant and five susceptible inbred lines selected from a trial inoculated with spore suspension in the screen house in 1998.

Selected lines	%Downy mildew infection
KU1414xHI 28/86-667-1xKU1414-1	14
KU1403	17
KU1414xHI 28/86-667-1xKU1414-3	27
(ATP SR x KU1414 SR/SR) x ATP SR 2-4-1	30
KU1414 SR	33
(KU1414 SR/SR x 1368 STR)-2-1	84
KU1414 SR/SR x 1368 STR-2-1	87
KU1414 SR/SR x 1368 STR-1-1	87
(KU1403 x 1368)-1-1-2-1	90
(KU1403 x 1368)-8-1-2-1	97
Mean	55
SE	3
CV (%)	29
Probability of F	0.0001

Although more than 60% of the lines had 50 to 97% downy mildew infection, three inbred lines derived from KU1414 SR backcross populations had low (14-30%) disease incidence. On the other hand, none of the inbred lines derived from KU1403 backcross populations had lower disease incidence than KU1403. It is interesting to note that the two inbred lines with significantly lower disease incidence than KU1414 SR had a common introduced parental inbred line (Table 1). Incorporating these new sources of resistance into adapted populations can, therefore, enhance durability and level of resistance to downy mildew.

In 1998, corresponding S2s from selected S1 progenies of DMRESR-W1 and DMRESR-Y1 were recombined to form-DMRESR-W1 C1 and DMRESR-Y1 C1, respectively. Both populations are early maturing and downy mildew resistant genotypes created from the introgression of new sources of DM resistance from both Philippines and Thailand into DMRESR-W and DMRESR-Y, respectively.

8644-27, marketed under the brand name of "Oba Super 2" is a DMR hybrid formed in 1986 with about 60% level of resistance. It is however a very good hybrid being highly N-use efficient and has very broad adaptation. In 1998, research effort aimed at improving and/or developing better performing maize hybrids was intensified by the evaluation of new single- and topcross hybrids. Preliminary results obtained from these evaluations revealed the existence of a) DMR single cross hybrid with more than 15% yield advantage over Oba Super 2 in Saminaka, Nigeria and b) DMR topcross hybrids with at least 10% better yield than Oba Super 2 in trials conducted under artificial infestation with downy mildew in Akure, Nigeria.

5.2.8. Evaluation of efficacy of plant resistance 'inducer' against downy mildew.

by K.F.C. – in collaboration with J. Hughes, R. Asiedu, K. Dashiell, O.Ayinde

An experimental commercial inducer was tested on maize for the control of downy mildew. The inducer was applied to maize plants starting one week after emergence and repeated weekly for one month. *P. sorghi* inoculum was sprayed on to the induced and control plants in the evening of the 14th day. The inducer was ineffective in controlling this disease, as % disease on induced inoculated plants was not different from that on non-induced inoculated plants.

5.2.9. Evaluating post harvest resistance to maize pests

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

Eight varieties were received from CIMMYT collaborators for lab evaluation, and several varieties, received from CIMMYT in 1996, were multiplied in the field. One variety from Oaxaca, which exhibited promisingly low susceptibility to *P. truncatus* attack (measured as low larval survivorship) in 1996 also showed drought tolerance in the field, and will be evaluated for disease resistance in Ibadan. A number of varieties, from both IITA and CIMMYT, were evaluted in terms of physical and chemical characteristics. Several of these varieties have been evaluated in lab experiments with respect to their effect on *S. zeamais* life history parameters as part of a student thesis.

5.3. 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.

On-going and future activities

5.3.1. The evaluation of the efficiency of indigenous natural enemies and the feasibility of extending the geographic range of selected promising species in Africa

by F.S. - in collaboration with J. Hailemichael, W. Overholt, D. Conlong, J.H. Smith jnr., H. Smith, M. Poehling, 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. Studies carried out with IRA scientists in the rainforest of Cameroon showed that egg parasitism significantly reduced borer larva numbers per plant at harvest, but the reduction is not sufficient. This is probably due to the scarcity of wild host plants which serve as a refuge for both pests and natural enemies during the between and off-season. Whereas *T. busseolae* has been reported to exist across Africa, *T. isis* has not yet been found in the eastern African region. It will be introduced into Uganda once the natural enemies complexes are identified by a joint NARO/IITA project funded by IFAD.

In monthly surveys in southern Benin, sesamia egg batches yielding both *T. busseolae* and *T. isis* were not uncommon, and some yielded three parasitoid species. It is not clear whether this was due to parasitization of eggs not parasitized previously and/or superparasitism. Since both species are needed to keep *S. calamistis* under control in the Dahomey gap, and mixed parasitism also occurred during periods when discovery efficiency (percent egg batches with parasitoids) was low superparasitism is of no advantage to the individual species. Thus, a series of lab experiments were set up to study interspecies competition of the two *Telenomus* species. Selfsuperparasitism was 37.6% in *T. busseolae* and 21.5% in *T. isis*. Both *Telenomus* species were able to discern eggs already parasitized by a conspecific female. Parasitism of previous parasitized eggs was significant higher when they were offered immediately than exposed 24h and 48h later. When presented with an egg mass parasitized by *T. isis*, *T. busseolae* oviposited in 20.3% of the parasitized eggs compared to 82% of unparasitized eggs versus 15.8 and 65%, respectively, when T. isis was the second species. For fresh eggs in which multiparasitism involved both *T. isis* and *T. busseolae*, the latter emerged from 78.3% regardless of whether it was the first or second ovipositing female. But if *T. isis* attacked the host eggs 24h before *T. busseolae*, the former won the competion but with a high mortality. It was concluded that mixed parasitism was due to superparasitism of *T. busseolae* after *T. isis*. Thus, introducing *T. isis* into eastern Africa would not affect the biological efficiency by *T. busseolae*.

C. sesamiae is a common larval parasitoid of *S. calamistis* and *B. fusca* in East and Southern Africa, and according to some reports keeps *S. calamistis* under control in these regions. In western African countries repeatedly surveyed by PHMD, *C. sesamiae* was hardly ever found on *S. calamistis* and even rarer on *B. fusca*. It is concluded that the West African strain of this larval parasitoid is not adapted to the stemborer species attacking cereals or the known wild grass hosts. In 1994, lab colonies of East African strains of *C. sesamiae* and *Pediobius furvus* Gahan (Hym., Eulophidae) parasitizing *S. calamistis*, provided by the ICIPE/WAU biological control project in Nairobi, Kenya, were established at IITA-Benin. *C. sesamiae* was released in Benin in 1995 together with two other exotic *Cotesia* species. It is still being recovered in southern Benin but seems to spread very slowly. Subsequent releases in eastern Nigeria were not successful so far and it is speculalted that they were released too early, i.e., before they could mate. Future releases in Benin and Nigeria will be done via exposing cocoons in cages. In 1998, an Kenyan strain of *C. sesamiae* that successfully attacks both *S. calamistis* and *B. fusca* was established at the IITA-Benin laboratories.

Collaboration with the South African Sugar Experiment Station (SASEX), Durban, continued in 1998. Several consignements of *Sturmiopsis parasitica*, a tachinid pupal parasitoid attacking *S. calamistis* and *E.saccharina*, were sent to South Africa, and finally released in 1998. Another promising candidate for *E. saccharina* in SA is Arctia sp. another tachinid commonly found in Cameroon.

In 1998, further consignements of *S. calamistis* pupae parasitized by *Pediobius furvus* were shipped to Brazil to be tested on the sugar cane borer *Diatraea saccharalis*. Earlier tests in Texas showed that *D. saccharalis* is a suitable host but *P. furvus* did not establish for climatic reasons.

5.3.2. Microbial control of stemborers

by F.S., - in collaboration with C. Lomer, C. Kooyman, K. Djaman, 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. The goal of this project is to assess the potential of using insect pathogenic microbes as part of an integrated pest management program, incorporating insect predators and parasitoids, resistant varieties and the use of wild grass hosts as trap plants to control stem borers in West Africa. Collections of isolates in the various countries will be made within the framework of the IITA/IFAD project. For further details see Project 3: Biological Control of Pests in the farming systems.

5.3.3. The role of wild hosts as a trap plants or refuge of natural enemies in the stemborer ecosystem

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

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. Consequently, knowledge of the entire host range of stemborers is of utmost importance for the evaluation of the importance of natural enemies species which may be responsible for the fluctuation in pest densities between countries, ecozones and seasons.

Surveys results from Ghana, Cameroon and Côte d'Ivoire yielded strong negative relationships between abundance of wild hosts in the vicinity of a field and stemborer infestations in the field, suggesting that wild grass habitat act as buffers for stemborer attacks on maize. Studies in the greenhouse and field trials showed that both *S. calamistis* and *E. saccharina* prefer certain wild grasses, and especially *Pennisetum polystachion*, as well as young plants and plant structures for oviposition although pre-adult mortalities are between 95 and 100% as compared to 70% on maize. For *B. fusca*, the mortalities on wild grasses were generally considerably higher than for the other two species. It is concluded that many wild hosts species act as trap plants. On-farm experiments in Cameroon showed however, that, although receiving a high egg load, the commonly occurring *P. purpureum* is not an ideal trap plant because mortalities among first larval stages are too low and on especially tall plants the whorl feeding *B. fusca* easily disperses onto maize. Likewise, an experiment set up at IITA-Benin, using *P. polystachion* showed no significant reduction of stemborer in maize with grass border rows. Being highly attractive the grass harboured stemborers before maize was planted and also attracted stemborers to maize. It is concluded that an ideal trap plant would work on short-medium distance only, in terms of attractiveness would be superior to maize, and produce a high and fast mortality of first larval instars. In 1999, *Panicum maximum* and *Andropogon gayanus* will be tested in addition.

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

*by F.S. - 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 soil K, Na, and Mg. 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. Likewise, within a certain range, K had a negative effect on survival of larvae and pupae but not as striking as on fecundity. In the forest sites in Cameroon, a positive relationship was found between soil Mg, Ca, and *B. fusca* egg batch size and numbers, and consequently percent dead hearts. In contrast to *S. calamistis* in Benin, percent plant infested and damaged by *B. fusca* at harvest was positively related with soil Mg, whereas the Ca/mg ratio was negative. In 1998, emphasis was given to analyses and publishing results. This series of studies will be finished in 1999.

5.3.5. Soils characterizations for atoxigenic strains of the soil inhabiting fungus A. flavus
*by K.F.C. - in collaboration with P.J. Cotty, L. Ayinde, M. Sétamou**

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. Data analysis is under way.

5.3.6. 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 to verify the results obtained from the lab.

5.3.7. Development and testing of pathogen application techniques against storage pests
by W.G.M., R.H.M. - in collaboration with A. Cherry, C. Lomer

Recent surveys (see section 5.1.8) show that that many farmers treat their stores with highly toxic compounds intended for field pests, rather than pesticides designed for stored products. *T. nigrescens* has been shown to be a classical biological control agent of *P. truncatus* in many areas, but laboratory experiments (see 5.1.6) suggest that it may be less effective in savanna regions, for example in central and northern Benin. Laboratory and field experiments showed that the entomopathogenic Deutermycete fungus, *Beauveria bassiana*, may have potential as a biological alternative to chemical insecticides or adjunct to *T nigrescens*.

Laboratory last year showed that mortality rates of *P. truncatus* and *T. nigrescens*, and subsequent fungal sporulation on cadavers are being monitored under different humidities at PHMD to measure fungal transmission. The practical potential of fungal treatment was evaluated in a 7 month field experiment involving 20 -dispersed grain stores, with the fungi being applied to cobs using an ultra-low-volume applicator with a kerosene-peanut oil blend as a carrier for fungal conidia. Treatments included carrier with and without the fungal spores, maize stored with and without the husk, and controls. Stores were inoculated with laboratory reared *P. truncatus* and *T. nigrescens* so as to present a maximum challenge situation for the fungus. Cobs were sampled on a monthly basis, evaluated for insect density (*P. truncatus*, *S. zeamais* and *T. nigrescens*), grain loss and grain moisture content. Results did not show much control of stored product pests, and although some vertical transmission was observed, it was insufficient to be of much practical benefit. Additional lab trials are being conducted to determine the relationship between dose, carrier (water-based, oil-based, or powder), length of exposure time and beetle survivorship. At a joint IITA CABI workshop in December 1998 (see below) collaborative links between entomopathologists in West and East Africa were established and exchanges of isolates and application technology will be considered.

5.3.8 *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 has been able to establish well in some sites in East Africa, while not at all in others. Lab experimenets have shown that the beetles do well at temperatures of at least 28 to 30 C, and cease development entirely below 19C, while its prey, P. truncatus, can survive and develop at temperatures as low as 12C. In order to address East African NARES concerns, cold-adapted *T. nigrescens* were collected in Mexican highlands and are being stored at CIMMYT while appropriate administrative clearance is obtained for forwarding to CABI in the UK. The beetles will be quarantined at CABI, examined for pathogens and parasitoids, and eventually sent to African collaborators for release in the mid –altitude sites where *T. nigrescens* has thus far failed to establish. In Benin and Ghana, *P. truncatus* and *T. nigrescens* flight activity is being monitored using pheromone traps (in the the Mono province of Benin, trapping has continued since 1992). In collaboration with scientists at the Savanna Agricultural Research Institute (SARI) in Tamale, Ghana, a trapping and store sampling network has been established to examine the relationship between the wood habitat and the grain habitat for *P. truncatus* and *T. nigrescens*, and gather ground-truthing data on the role of weather and location in pest and natural incidence.

5.4. 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.

On-going and future activities

5.4.1. Assessment of impact DM eradication campaign

by V.A., S.O.A., K.F.C. - in collaboration with H. vander Maarel, P. Ikemefuna, S. Olafide, L. Ayinde

A coordinated effort to eradicate maize downy mildew from southern Nigeria began in 1994 in a joint IITA/FAO/Nigeria Federal Ministry of Agriculture campaign. IITA hosted a conference/workshop and a training workshop to initiate the campaign. The progress of the campaign was interrupted due to the fuel shortages, etc. in 1994. In 1995 a TCP program with FAO began, to implement an integrated management program to control the disease. The IPM includes the use of the chemical seed dressing, Apron plus®, the increase and distribution of IITA-developed downy mildew resistant materials (e.g. DMRESR-W), and a general information campaign telling the farmer to rogue infected plants and to buy certified seed. In 1997 an impact assessment survey was conducted to determine how well farmers understand the situation with downy mildew, which control technologies that they have adopted, and where they heard about it. Data analysis of frequency of farmer awareness of the disease and various control options is calculated by gender of the farmer, by state, and by distance from a primary market center.

More than 50% of the farmers in Osun and Oyo states knew the cause of downy mildew while only 25% of the Ondo state farmers were aware though the disease has been endemic in this state since 1975. The more remote the village from a major market center, the less their knowledge of the disease, e.g. on average across states, 44% awareness was recorded at 5 km distance, while at 15 km distance 38.4% knew. More women (12%) used DMR seed than men (8.4%). Awareness of downy mildew resistant (DMR) seed was highest in Ondo (24%) and lower in Osun (15%) and

Oyo (5%), and use of DMR seed was followed the same trend: Ondo (17.7%), Osun (6.25%), and Oyo (1.5%). Awareness and availability of DMR seed declined with distance from market center. Statistics on Apron plus utilization are proprietary. The most effective communications medium was radio with 40% of the farmers stating that they had heard about DM that way. The next most important source of information, cited by 32% of the farmers were the Agricultural Development Projects (ADPs). Farmers learned about it from other farmers 20% of the time, and field days, posters and TV were cited as the source of information for only 8%. Unfortunately, the technical message received by farmers was not as accurate as it could be. For example, 55% of the farmers using the seed dressing Apron plus® were using less than the commercially recommended dose of 10g/kg seed. This lapse increases the danger of loss of fungal sensitivity to the product.

The 781 farmers interviewed farmed over 1500 fields in 1997 representing over 1000 acres in the main growing season (April –August), 300 acres in the second season (August-December), and 820 acres during the dry season. Information was gathered on the cost of downy mildew related inputs, when farmers were likely to use them, and what the farmers expected to earn for their crop. Only 1 farmer said that he didn't buy DMR seed because it was too expensive, while 16 of the farmers that didn't use Apron plus® said it was because of the expense. The majority of the farmers that knew about DMR and Apron plus® but didn't use them, said that it was due to lack of availability. Thus, the technologies are adoptable, and farmers are interested to acquire them, but supply is still the bottle-neck to utilization.

5.4.2. 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.

5.4.3. 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/mm^2/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.

5.4.4. IPM of stored product insect pests

by W.G.M., C.N., R.H.M. – in collboration with N. Holst, D. Moore, S. Smith

A workshop was held at PHMD, in collaboration with CABI Bioscience, and attended by participants from 7 sub-Saharan countries, including West, East and Southern Africa. Presentations included technical accounts of lab and field experiments, as well as presentations of decision-support tools for NARES and NGOs. Resolutions developed on the potential of entomopathogens on post-harvest pests and on general IPM needs in stored products will be posted on the IITA web page. In addition, a course on post-harvest pest identification and sampling was offered to farmers and extension agents in the Zou and Mono provinces of Benin, in collaboration with a Danish-backed NGO, in December. The course will be refined in collaboration with other NGO's and NARES, and offered at other locations in Benin in 1999.

5.4.5. Database generation on economics of maize as a commodity in Ghana, Cameroon and Uganda and cost benefit analysis of IPM technologies

by O.C., K.F.C., F.S. - in collaboration with Z. Ngoko, G. Bigirwa*, M. Botchey, E. Darkwa*

For the development of sound IPM technologies, multidisciplinary research aimed to assess the biotic, economic and financial crop losses, the perceptions of farmers about pests, damages and the indigenous pest control measures, as well as the profitability of IPM technologies is needed. Socioeconomic surveys were carried out to complement the biological surveys in Cameroon, Ghana and Uganda. The specific objective of socioeconomic surveys were:

- To assess the economic and financial maize crop losses in different agroecological zones of Cameroon, Ghana and Uganda.

-To evaluate the economic and financial profitability of the existing and potential IPM technologies generated by the PHMD and to be recommended to farmers.

Cameroon: Farmers knowledge and perceptions of pests, diseases and control strategies play a key role in the acceptance of integrated pest management technologies by farmers. A multidsciplinary team including entomologist, pathologist, extension agents and social scientists has carried-out a survey to assess such perceptions on maize health management in three agroecological zones, the humid forest, the moist savannah and the highlands of Cameroon. The survey has been carried-out in benchmark sites or representative recommandations domains delineated in each agroecological zone and a sample of 178 farmhouseholds have been selected for formal interviews. Questions were related to farmers perceptions of the main pests and diseases, the farm resource endowments, the different pest control strategies and their effectiveness. Farmers report that borers (all types) are the main constraints to maize production in all of the agroecological zones, followed by grasshopers and rodents in the humid forest. Diseases are not known to most of farmers who however report signs like spots on leaves or dry leaves. Sitophilus are the main damaging insects reported by all farmers in storage. The common pest control techniques are applied in storage with the use of chemicals by some farmers in the highlands. The information on farmers perceptions on pests and diseases and control strategies guide biological scientists in the design and recommandations of cost effective and adapted integrated pest management technologies.

Uganda: The multidsciplinary study assesses farmers knowledge and perceptions of pests, diseases and control strategies used in three main maize production regions in Uganda. Benchmark sites or representative recommandations domains have been idenfied and in which 144 farmhouseholds have been sampled for formal interviews about farmers perceptions of the main pests and diseases, the farm resource endowments, the different pest control strategies and their effectiveness. The survey has been carried-out by a team of entomologist, pathologist, extension and agricultural economists. The results show that borers and termites are cited by farmers as the most damaging insects in the field. Streak virus disease is known to farmers and reported to be the main disease. Weevils attacks are reported to be the main constraint of storing maize over more than 6 months. Pest control strategies for seed conservation include drying the cobbs before hanging them in the kitchen and storing seeds with ash or Actellic 2% powder. The disease control in the field include the use of and improved open-pollinated maize variety Longe1 which is resiatant to streak visrus diseases. The pest control in the field commonly used is cultural practices of roguing sick plants and rotations. Chemical pest control against borers is used by some few farmers associated with the Uganda Seed Project. The main chemical used is Ambush. Storage pest

control include drying in the sun before storage and the use of Actellic 2% the most popular chemical provided by the Sasakawa 2000 extension program. The information on farmers perceptions on pests and diseases and control strategies is an important background for biological scientists who will design effective integrated maize pest management technologies to fit farmers objective and resource constraints.

Completed studies

Journal articles and book chapters

Ayertey, J.N., W.G. Meikle, C. Borgemeister, M. Camara & R.H. Markham. 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 (submitted).

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.

Bock C.H., M.J. Jeger, L.K. Mughoho, E. Mtisi, G. Kaula, D. Mukasambina & K.F. Cardwell. Variability of* Peronosclerospora sorghi *isolates from different geographic locations and hosts in Africa. Mycological Research (submitted).

Bock C.H., M.J. Jeger, L.K. Mughoho, E. Mtisi & K.F. Cardwell 1998. Production of conidia by* Peronosclerospora sorghi *on sorghum crops in Zimbabwe. Plant Pathology 47, 243-251.

Factors affecting the production orf conidia of Peronosclerospora sorghi, causing sorghum downy mildew (SDM), were investigated during 1993 and 1994 in Zimbabwe. In the field conidia were detected on nights when the minimu temperature was in the range 10-19°C. On 73% of nights when conidia were dedtected rain had fallen within the previous 72h and on 644% of nights wind speed was<2.0ms^{-1}. The time period over which conidia were detected was 2-9h. Using incubated leaf material, conidia were produced in the temperature range 10-26°C. Local lesions and systemically infected leaf material produce 2.4-5.7 x 10^3 conidia per cm^2. Under controlled conditions conidia were released from conidiophores for 2.5 h after maturation and were shown to be well adapted to wind dispersal, having a settling velocity of 1.5 x 10^{-4} m s $^{-1}$. Conditions that are suitable for conidia production occur in Zimbabwe and other semi-arid regions of southern Africa during the cropping season.

Bock C.H., M.J. Jeger, L.K. Mughoho, K.F. Cardwell, V. Adenle, E Mtisi, A.D. Akpa, G. Kaula, D. Mukasambina & C. Blair-Myers. 1998. Occurrence and distribution of* Peronosclerospora sorghi *(Weston and Uppal (Shaw)) in selected countries of West and Southern Africa. Crop Protection 5:427-439.

Surveys of sorghum and maize crops were undertaken in Nigeria, Zimbabwe, Zambia, Mozambique and Rwanda during 1991 and 1992. The occurrence and prevalence of sorghum downy mildew (SDM) caused by Peronosclerospora sorghi [Weston and Uppal (Shaw)] was assessed in rgions of each country. In Nigeria only maize was systemically infected in the southern humid zone, where rainfall was 1200-1800 mm and the altitude 300-1000 m. This epidemic zone appeared to be geographically isolated from other areas of Nigeria where SDM was observed. Within tyhe southern epidemic zone, yield loss was estimated to be 11.7%. Individual fields had up to 95% incidence of systemically infected plants. In the arid north of Nigeria (rainfall<1300 mm, altitude 600-1200m) both maize and sorghum were infected, and disease incidence was invariably low (<5%). Systemic SDM incidence on maize was nigatively correlated with growth stage (r= -0.7746, P = 0.01). In Zimbabwe, Zambia, Mozambique and Rwanda sorghum and maize were infected with SDM in areas with an annual rainfall of 600-1200 mm and an altitude rage of <300-1800 m. Incidence of infection within crops was generally low, and sites with infected crops were scattered in these countries SDM local lesion infevtion was observed only on sorghum. Yield loss due to SDM in Zambia, Zimbabwe and Rwanda at the time of the survey was negligible. However, SDM is widespread in Africa and occurs in many different agricultural areas, and thus remains a threat to sorghum and maize production. Management of the disease using resistant varieties, cultural and chemical control should reduce the risk of future epidemics.

Bolaji, O. O. & N.A. Bosque-Pérez, 1998.. Life history and mass rearing of* Mussidia nigrivenella *Ragonot (Lepidoptera: Pyralidae) on an artificial diet in the laboratory. African Entomology 6: 101-110

Life history of *Mussidia nigrivenella* Ragonot was studied at 26 ±2oC, 65±5% R.H. in the laboratory. When reared on artificial diet, larval period lasted 18.4 days, pupal period 10.2 days, and total development time (one-day-old larvae to adult) 28.7 days. On average, pupae of males weighed 80.7 mg and those of females 111.2 mg; adult males weighed 44.0 mg and females 65.2 mg. Mated females laid on average 268 eggs, while unmated ones laid 155. Adult females had a longer mean life span (6.1

days) than males (5.3 days). Individuals reared in batches of 30 larvae had significantly shorter larval and total developmental periods than those reared in batches of 60, 90 or 120. Pupal and adult weights decreased significantly as the population size increased. Development period was significantly shorter and weights of pupae significantly higher on a soyflour, wheatgerm based diet and a soyflour, maize flour, wheatgerm based diet than on most other diets. Seven oviposition substrates, including plastic mesh, wire mesh, brass screen, waxed paper and paper towel were compared for preference by *M. nigrivenella*. In both multiple and no-choice tests, paper towel folded diagonally and 21 x 21 units plastic mesh had significantly more eggs laid on them than other substrates.

Bonato, O., Schulthess, F. & J.U. Baumgaertner. A simulation model for carbon and nitrogen allocation and acquisition in maize. Ecol. Model. (in press).

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. Selecting a character for identifying larval instars of the stemborers* Sesamia calamistis *Hampson (Noctuidae) and* Eldana saccharina *Walker (Pyralidae) on maize. Insect Sci. and Appl. (in press).

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., G. Goergen, S. Tchabi, A. Awande, R.H. Markham & D. Scholz. 1998. Exploitation of a woody host plant and cerambycid associated volatiles as host finding cues by the Larger Grain Borer,* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae). Annals of the Entomological Society of America 91: 741-747.

We collected twigs of *Lannea nigritiana* attacked by the girdling cerambycid *Analeptes trifasciata* F. in the Lama forest of central Benin, West Africa. Emergence data from *A. trifasciata* wood samples revealed a diverse insect fauna, which consisted of 27, primarily coleopteran species of 8 different families. More than 70% of the identified insects were bostrichids. We report for the first time in West Africa, an association of the exotic larger grain borer *P. truncatus* and one of its introduced natural enemy, the histerid predator *T. nigrescens*, with twigs girdled by an indigenous cerambycid. We found more *P. truncatus* directly above the girdling site than elsewhere. *P. truncatus* is not attracted to volatiles emitted by adults or larvae of *A. trifasciata*, but is significantly attracted to odors of cerambycid frass, as well as to girdled and mechanically damaged *L. nigritiana* twigs. We discuss these results with regard to the host finding behavior of *P. truncatus*.

Borgemeister, C., C. Adda, M. Sétamou, K. Hell, B. Djomamou, R.H. Markham & K.F. Cardwell, 1998. Timing of harvest in maize: Effects on harvest losses due to insects and fungi in central Benin, with particular reference to Prostephanus truncatus (Horn) (Coleoptera: Bostrichidae). Agric. Ecos. Environ. 69: 233-242.

A storage experiment was conducted in Bante, central Benin between autumn 1994 and spring 1995. The maize was harvested 1, 3 and 7 weeks after physiological maturity and stored for up to eight months. The main results were: a) leaving the maize in the field for extended periods after physiological maturity resulted in severe gain losses after eight months of storage; b) Most of the grain losses were attributed to Prostephanus truncatus; c) Early harvested maize had a higher proportion of mouldy grain; d) Harvest data had no consistent effect on the level of aflatoxin contamination; e) Based on a participatory evaluation of maize quality by local farmers, the economic value of maize for eight months was highest in maize harvested three weeks after physiological maturity.

Borgemeister, C., A. Tchabi & D. Scholz. 1998. Trees or stores? The origin of migrating* Prostephanus truncatus *collected in different ecological habitats in southern Benin. Entomologia Experimentalis et Applicata 87: 285-294.

Migrating *P. truncatus* were collected weekly with pheromone-baited funnel traps at three different sites in southern Benin for 12 months. One site was located in a primary forest, one in a peri-urban area, and one in a region with intensive agriculture. The sex of the trapped beetles was determined. The gut-content of the specimens was analyzed for remains of lignin and starch, the former indicating recent feeding on woody, the latter on a starchy substrate, such as stored maize or dried cassava. At all locations, the sex ratio of migrating *P. truncatus* was significantly female-biased, with the greatest proportion of females trapped at the peri-urban

site. At the forest site, most beetles had lignin in their guts, while the proportion of beetles containing starch was highest in the peri-urban site. Approximately equal proportions of beetles with either starch and lignin were trapped in the region with intensive agriculture. The results are discussed with regard to the population dynamics of *P. truncatus* in different habitats and the flight activity of the beetles.

Borgemeister, C., K. Schaefer, G. Goergen, S. Awande, M. Setamou, H.M. Poehling & D.Scholz 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 (submitted).

In cassava chips, sampled on a local market in Cotonou, Republic of Benin, West Africa, 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 bostichids, i.e., Prostephanus truncatus (Horn) and Rhyzopertha dominica (Fabricius), were also recorded in the traps.

Bosque-Pérez, N.A., S.O. Olojede & I.W. Buddenhagen. Effect of maize streak virus disease on the growth and yield of maize as influenced by variety and disease infection time. Euphytica (in press).

Field experiments were conducted from 1989 to 1991 at Ibadan, Nigeria, to assess effects of maize streak virus (MSV) disease on growth and yield of maize varieties having different levels of disease resistance. MSV disease reduced yield and growth in all years, but varieties differed significantly in amount of loss, disease severity and incidence. MSV disease was negatively correlated with plant height and dry weight, grain weight per plot, 1000-grain weight, ear length and diameter. In 1989 MSV disease decreased yield of resistant variety TZB-SR by 1.5%, of resistant hybrid 8321-21 by 10%, and of moderately resistant hybrid 8329-15 by 17%. Yield of susceptible variety TZB Gusao was reduced significantly more, by 71%. Plant age at time of virus challenge had significant effects on yield and growth characters, with earlier infection resulting in greater disease severity and yield reduction. A significant interaction between variety x age at challenge was also detected, indicating that varieties were differentially affected by MSV in relation to the growth stage when challenged. Disease incidence after challenge was lower for the most resistant varieties. This property of lower disease incidence under equal challenge opportunities (tolremicity) is an important aspect of resistance. The resistant varieties discussed here were bred for tolerance – good yield performance when diseased –, but TZB-SR and 8321-21 also exhibited tolremicity. Tolremicity combined with tolerance constitutes the overall disease resistance of a variety to a systemic pathogen such as MSV.

Bosque-Pérez, N. A. & F. Schulthess. 1998. Maize: West and Central Africa. pp. 11-24 In: A. Polaszek (ed.). African Cereal Stem Borer: Economic Importance, Taxonomy, Natural Enemies and Control, CAB International, England, 530p.

Bourassa, C., C. Vincent, C.J. Lomer, C. Borgemeister & Y. Mauffette. Effects of* Beauveria bassiana *(Balsamo) Vuillemin and* Meharrrhizium 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 entomophatogenic fungi, three of Beauveria bassiana and one of Metarrhizium 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 bettle 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, 1998. 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 (submitted).

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.

Cotty, P.J. & K.F. Cardwell. West African and North American communities of* Aspergillus section flavi *are divergent. Applied and Environmental Microbiology (submitted).

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.

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).

Fifty-two maize varieties were screened for resistance to infestation by the maize weevil, *Sitophilus zeamais* Motschulsky, using assessment methods proposed by Dobie (1974) and Urrelo et al. (1990). The two methods gave similar assessments of maize susceptibility to S. zeamais. The Dobie method is preferred due to the lower total time required for assessment of relative susceptibility of maize varieties. The greatest disadvantage of the Urrelo method is the intensive labor requirements in early stages of a trial, when numbers of eggs have to be counted, although it has the advantage that the assessment may be terminated upon emergence of the first F1 adult. Two explanatory variables, kernel size and hardness, were investigated to determine whether they may be used as indicators of resistance. Results suggest kernel size is more important in determining resistance to attack by *S. zeamais*, with large kernels appearing to show greater resistance than small ones. Contrary to expectations, of the varieties tested, including local, hybrid and improved open pollinated (OP's) varieties, the local varieties were generally more susceptible. This may be related to kernel size, as all improved OP's and hybrids tested had large kernels, whereas the majority of the local varieties had small ones. However, it is possible that kernel size does not have a direct effect on susceptibility, but rather that it is related to other factors which influence it. No clear relationship between weevil susceptibility and kernel hardness could be detected, although there was an indication that differences associated with kernel size varied depending on kernel hardness. None of the varieties tested showed high levels of resistance to attack by *S. zeamais*.

Hell, K., K.F. Cardwell & M. Sétamou. Distribution of fungal species and aflatoxin contamination in stored maize in four agroecological zones in Benin, West-Africa. Plant disease (submitted).

This study assessed *Aspergillus* infection and aflatoxin contamination in stored maize in Benin, West-Africa. The aflatoxin load of farmers' stores in the four agroecological zones of the country were evaluated over a two year period. In the 1993-94 growing season at the beginning of the storage season (September - December), *Aspergillus* contamination was low (10 to 20%). Six months later (February - April) grain infection was higher than 55% in all ecozones. In the 1994-95 season, no increase in *Aspergillus* infection was observed at the beginning of storage and six months later. Aflatoxin contamination at the beginning of storage in 1993-94 was significantly higher in the Southern Guinea Savanna, than in the other agroecozones. In the same year, maize stored for six months in the Sudan Savanna showed high mean aflatoxin contamination of 125.5 ppb six months after storage. Overall of the 742 samples collected during the two survey years, 25% were aflatoxin positive, and out of the positive samples 60% were contaminated with levels higher than 20 ppb, the WHO-limit.

Hell, K., K.F. Cardwell, M. Setamou & H.-M. Poehling Production practices and their influence on aflatoxin contamination in stored maize in Benin, West-Africa. J. of Stored Prod. Res. (submitted).

This study related production factors to post-harvest quality of maize in Benin, West Africa. Aflatoxin levels of maize sampled from 300 farmers' stores in four agro-ecological zones were evaluated in two consecutive years, at the beginning of storage and 6 months later. Information on maize production factors, i.e.crop rotation, type of fertiliser used, field pest damage, variety used, quality of husk cover, and associated crops, was collected via a questionnaire administered to the farmers. The production factors were associated with aflatoxin levels using regression analysis. There was significant variation in the development of aflatoxin in stored maize across the agro-ecological zones of Benin. Maize in the southern Guinea savanna and Sudan savanna was more vulnerable to aflatoxin development, whereas relatively little aflatoxin was detected in maize cultivated in the forest savanna mosaic. Intercropping of maize with cowpea, groundnut, or cassava was associated with higher aflatoxin levels, whereas mixed cropping with vegetables was associated with reduced aflatoxin content. Aflatoxin development was negatively related to application of double ammonium phosphate fertiliser. In southern Benin, local varieties had significantly lower aflatoxin levels, whereas in the north improved varieties were more likely to have less toxin. Damage to maize plants in the field either from bird, animal or insect attack was associated with higher toxin levels.

Hell, K., K.F. Cardwell, M. Sétamou & H.-M. Poehling. Harvest practices and their influence on aflatoxin contamination in stored maize in Benin, West Africa. J. of Stored Prod. Res.(submitted).

Aflatoxin levels in farmers' stores in four agroecological zones in Benin, West-Africa, were determined in two consecutive years and related to harvest factors. Maize cobs were sampled at 3 and 6 months in storage. Information on maize harvest practices, i.e. harvest timing, sorting, drying period, shelling and dehusking was collected via a questionnaire administered to 300 farmers. Across the country 30 to 50% of the farmers harvest maize more than 1 month after physiological maturity. Only between 22.5 and 50% dried maize once it was harvested. Maize was sorted at several stages, either at harvest, or later when maize was dehusked, shelled, or shortly before storage. Maize was shelled before consumption or sale, except in northern Benin where maize was shelled before storage. The harvest practices were associated with aflatoxin levels (ppb) using regression analysis. Factors associated with increased aflatoxin were: harvesting that took more than 7 days, long drying periods in the field, delay in sorting, and drying of harvested cobs for 60 to 90 days. Practices associated with reduced aflatoxin contamination were drying without the husk and sorting out of poor quality ears, discolored grains or those with bad husk cover or husk damage before storage.

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.(submitted).

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.

Meikle, W.G., C. Adda, K. Azoma, C. Borgemeister, P. Degbey, B. Djomamou & R.H. Markham, 1998. Varietal effects on the density of* Prostephanus truncatus *(Col.: Bostrichidae) and* Sitophilus zeamais *(Col.: Curculionidae) in grain stores in Benin Republic. Journal of stored Products Research 34:45-59.

Maize varietal characteristics were evaluated in the field and in the laboratory for their efficacy in providing resistance to storage pests, in particular *Prostephanus truncatus* Horn (Col.: Bostrichidae) the larger grain borer, and *Sitophilus zeamais* Motsch. (Col.: Curculionidae) the maize weevil. Resistance appeared to be associated more with the husk than with the grain. Higher-yielding varieties, even with 'hard' flinty kernels, tended to suffer high *P. truncatus* damage, possibly due to variability in the quality of the husk cover. Varietal susceptibility to *S. zeamais* did not appear to be associated with husk cover. Most damage by storage pests occurred later in the season, and damage was most strongly associated with *P. truncatus* density. An ideal maize breeding program should include plans for developing maize varieties suitable for a long storage season, in addition to varieties with a high yield.

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

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, D. Scholz & R.H. Markham, 1998. A simulation model of* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae) in rural grain stores in Benin. Environmental Entomology 27:59-69.

A distributed-delay, demographic simulation model of *P. truncatus* populations in rural maize stores was developed and validated. Developmental and mortality parameters for eggs, larvae and pupae, and life span and fecundity data for adult insects, were estimated from published data and from laboratory experiments. The overall phenology of the simulated beetle dynamics reflected well that of field data, although the model output tended to overestimate beetle density later in the season. The model was developed to contribute to a low-cost tool for evaluating the major factors influencing population dynamics of stored-product pests and their natural enemies, and to provide a conceptual framework for evaluating different control strategies in an integrated control context.

Meikle, W. G., R.H. Markham, B. Djomamou, H. Schneider, K.A. Vowotor & N. Holst. 1998. Distribution and sampling of* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae) and* Sitophilus zeamais *Motschulsky (Coleoptera: Curculionidae) in maize stores in Benin. Journal of Economic Entomology 91: 1366-1374).

Proper sampling can be an effective tool in guiding Integrated Pest Management strategies during the course of a season. However, few plans have been developed for sampling agricultural pests under West African conditions. Among- and within-store population distribution characteristics are described here for two pests of field grain stores, P. truncatus and S. zeamais. An enumerative sampling plan to estimate sample size over different insect densities, and sequential sampling plans, using Wald's Sequential Probability Ratio Test and Iwao's confidence interval method, are developed and evaluated for West African field stores.

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

Olatinwo, R.O., K.F. Cardwell, A. Menkir, M.L. Deadman & A.M. Julian. Combining ability amoung selected maize populations for resistance against Stenocarpella macrospora (Earle) ear rot in the mid-altitude zone of Nigeria. Plant Breeding (submitted).

Olatinwo, R.O., K.F. Cardwell, A. Menkir, M.L. Deadman & A.M. Julian. Inheritance of resistance to Stenocarpella macrospora (Earle) ear rot of maize by generation mean analysis. Plant Breeding (submitted).

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 Science and its Application 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.

Scholz, D., C. Borgemeister & H.-M. Poehling, 1998. Electrophysiological and behavioural responses of the larger grain borer, Prostephanus truncatus, and its predator,* Teretriosoma nigrescens*, to the borer-produced aggregation pheromone. Physiological Entomology 23: 265-273.

Electroantennogram (EAG) and behavioural studies were conducted with *Prostephanus truncatus* (Horn) (Col.: Bostrichidae) and the predatory beetle, *Teretriosoma nigrescens* Lewis (Col: Histeridae) in regard to their responses to the components of the prey-produced aggregation pheromone. There were hardly any differences between species or sexes regarding perception thresholds. In field and olfactometer experiments, female *P. truncatus* were more responsive to the pheromone than males, and both sexes reacted more vigorously to the second pheromone component, T2, than to T1. Sex ratios among trap catches of *T. nigrescens* were slightly male-biased. The predator did not behaviourally differentiate between the pheromone components.

Scholz, D., C. Borgemeister, R.H. Markham & H.-M. Poehling, 1998. Physiological age-grading and ovarian physiology in* Prostephanus truncatus*. Physiological Entomology, 23: 81-90.

The reproductive systems of male and female *Prostephanus truncatus* were described for beetles between emergence and 30 days old in order to determine age-grading criteria. Seminal vesicles were bigger among non-mated males than among mated males due to accumulation of sperm; no age-specific differences were found for male *P. truncatus*. Ovaries (germarium size, number of follicles and follicle size) were similarly developed for females. Starved females were found to resorb follicles. Yellow body formation was strongly dependent on age, and was used as an age-grading criterion for female *P. truncatus*.

Females flying off maize cobs and caught with pheromone traps were of varying physiological age and mated, and their ovarian development was suspended. All migrating females were mated, indicating that lone females Maya act as colonizers, independently of males. The applicability of migration theories *to P. truncatus* and adaptive inter-reproductive dispersal as part of its life history strategy are discussed.

Scholz, D., C. Borgemeister, R.H. Markham & H.-M. Poehling, 1998. Flight initiation and flight activity in Prostephanus truncatus (Coleoptera: Bostrichidae). Bull Ent. Res. 88: 545-442.

In an outdoor experimental set-up, the number of Prostephanus truncatus (Horn) flying from maize cobs was recorded for 50 weeks with three pheromone traps, each placed at c. 100-300 m from the first experimental set-up. Multiple regression analyses revealed that both flight initiation and flight activity were partly influenced by mean temperatures, but were not directly related. Flight initiation was mainly dependent on population density. An additional experiment showed that sex ratios among pheromone trap catches were not correlated with the number of beetles caught; sex ratios were female-based throughout the year. Seasonal fluctuations in flight activity recorded with pheromone traps are mainly dependent on changes in the number and sizes of beetle populations in a given area, as well as on breeding site availability and suitability.

Setamou, M., K.F. Cardwell, F. Schulthess & K. Hell, 1998. Effect of insect damage to maize ears, with special reference to* Mussidia nigrivenella *(Lepidoptera; Pyralidae), on* Aspergillus flavus *(Deuteromycetes; Monoliales) infection and alfatoxin production in maize before harvest in the Republic of Benin. J. Econ. Entomol., 91:433-438.

Pre-harvest maize infection by *Aspergillus flavus* and subsequent aflatoxin contamination as affected by insect pests damage to maize ears was studied via surveys in farmers' fields and in a on-station trial, in the Republic of Benin in West Africa. The most important pest species was the lepidopteran earborer *Mussidia nigrivenella*. Percent of grain infected by *A. flavus* and of samples contaminated with aflatoxin as well as the mean aflatoxin content of samples increased with increasing borer damage. Ears with less than 2% insect damage, had an average of 11.7 and 43.6 ppb of aflatoxin in 1994 and 1995, respectively. Ears in the highest damage class, i.e., > 10%, had an average aflatoxin of 514.6 and 388.2 ppb in 1994 and 1995, respectively. In 1994 only, coleopteran species such as *Sitophilus zeamais* and *Carpophilus sp.* significantly increased aflatoxin production in grain samples. In a field trial using *M. nigrivenella* infestation and *A. flavus* inoculation treatments, the presence of the ear borer feeding resulted in increased kernel infection and aflatoxin contamination. Artificial infestation increased aflatoxin content of maize by an average of 45 ppb while inoculation increased the toxin level by 517 ppb. The significant interaction between infestation and inoculation indicated that higher levels of aflatoxin B1 were found when the fungus was associated with borers than with the fungus alone. Overall, these findings show that *M. nigrivenella* was the major field pest connected with *A. flavus* infection and subsequent aflatoxin production in preharvest maize in Benin.

Udoh, J.M., K.F. Cardwell & T. Ikotun. Storage structures and aflatoxin content of maize in five agro-ecological zones of Nigeria. J. Stored Prod. Res.(submitted).

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 µg/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.

Udoh, J., T. Ikotun & K.F. Cardwell. Use of pesticides in maize storage by gender and agro-ecological zones in Nigeria. Int. J. of Pest Management (submitted).

A survey was conducted to identify the maize storage pesticides used by male and female farmers in five agro-ecological zones in Nigeria. The zones were Humid Forest, Mid-altitude, southern Guinea savanna, northern Guinea savanna and Sudan savanna. Five villages within each agro-ecological zone were selected and five farmers per village were interviewed. The highest percentage of male (50%) and female (82%) of farmers who used pesticides were from the northern Guinea Savanna zone. Only 6% of the male farmers in the Humid Forest and 15% in the Mid-Altitude zone used Pirimiphos methyl (Actellic) in dust and liquid

formulations which is the recommended pesticide for admixture with grains. None of the female farmers across all the zones used Pirimiphos methyl as a storage protectant of maize.

Vowotor, K.A., W.G. Meikle, J.N. Ayertey, C. Borgemeister, C. Adda, B. Djomamou, P. Degbey, K. Azoma, A. Adda & R.H. Markham. Intra-specific competition between larvae of the larger grain borer,* Prostephanus truncatus *(Horn) (Col.: Bostrichidae) within maize grains. Insect Science and its Application (in press).

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 singel, 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 competion, 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. Theimplications of intra-specific competition under storage conditions are discussed.

Conference papers, workshop proceedings, abstracts, newsletters, thesis

Baba-Moussa, A.A.M.T. 1998. Microflora associated with maize stem and cob borers damages in Southern Benin with special reference of* Fusarium moniliforme *Sheld. Memoires Ing. Ar. Univ. du Benin, Togo

In a view of assessing the miccrorganisms associated with borers damages in Southern Benin, three have been conducted from April to July 1997. The first survey was conducted on maize plants at 2t to 3 leaves stage, the second one on plants at flowering stage and the third on maize cobs. In addition, a experiment was conducted at IITA Calavi Station to determine the nature of relationship existing between damages caused by *Sesamia calamistis*, *Eldana saccharina* and the associated microflora. Three other on-station experiments have been conducted: one aimed at understanding the mode of on farm infection of maize plants by *Fusarium moniliforme* and the two others conducted in greenhouse aimed at studying the impact of the fungus on oviposition and larval survival of *S. calamistis* and *E. saccharina*. Four treatments were used for that purpose: untreatd control plants, artificially infested plants by *F. moniliforme* using toothpicks, plants treated with benlate and finally plants steming from seeds treated with hot water at 60°C for 5 minutes.

Fusarium spp. were the most recorded pathogens among the fungi identified on stem and cobs; 71%, 69% and 83.7% during 1st, 2nd and 3rd survey, respectively. The incidence of the fungi, with the exception of some rare genera such as *Penicillium* spp. and *Mucor* sp., was higher in infested samples than in the non-damaged plants by borers. Moreover, these results showed that there is succession of the microflora in maize plants according to the vegetative growth stage of plant.

The results of experiments conducted on endophytism of *F. moniliforme* showed that artificial infection of stems by *F. moniliforme* caused an increase of the impact of fungus in the ear; it has also been noted that cob protection at flowering stage has resulted in a significant reduction of the incidence of the fungus in the grains. Moreover, the heat treatment of seeds at 60°C for 5 minutes efficiently reduced the incidence of the fungus in both stem and cob.

Results of greenhouse trials demonstrated that neither *S. calamistis* nor *E. saccharina* has preference for the oviposition on maize plants for the four treatments but for *E. saccharina* the number of eggs per mass was higher on *F. moniliforme* inoculated plants. *E. saccharina* larval survival was considerably higher on inoculated plants, whereas *S. calamistis* has not been affected by the fungus.

Agboka, K., 1998. Competitive behaviour of* Telenomus busseolae *Gahan and* T. isis *Polaszek (Hymenoptera: Scelionidae) two egg parasitoids of* Sesamia calamistis *Hampson (Lepidoptera: Noctuidae). Memoires Ing. Ar. Univ. du Benin, Togo

The goal of this work is to study some fundamental aspects of the behaviour of *Telenomus busseolae* et *T. isis* in a laboratory. This involved mating and oviposition behaviour; host discrimination and competition among the two coexisting species.

In the first step, a mating behaviour experiment showed that in both parasitoids there was competition between males for copulation with females upon emergence. In the second step, the ovipositional behavior (drumming, insertion of ovipositor, marking of eggs) of *T. busseolae* and *T. isis* using *S. calamistis* eggs as host was studied. Both *Telenomus* species could discern eggs already parasitized by a conspecific female but superparasitism was 32% and 15% by *T. busseolae* and *T. isis*, respectively. Both species could also discriminate eggs parasitized by the other species. When presented with an egg mass parasitized by *T. isis*, *T.*

busseolae oviposited in 20.3% of the parasitized eggs compared to 82% of unparasitized eggs. When the experiment was reversed, *T. isis* female presented individually with an egg mass parasitized by *T. busseolae*, it showed much discrimination and oviposited only in 15.8% of parasitized eggs compared to 65% of unparasitized eggs. For eggs in which multiparasitism involved both *T. isis* and *T. busseolae*, the latter emerged from 78.3% regardless of whether it was the first or second ovipositing female. It was concluded that mixed parasitism was due to superparasitism of *T. busseolae* after *T. isis*.

Borgemeister, C., C. Adda, R.H. Markham, R. Oussou, D. Scholz, H. Schneider, W.G. Meikle, & H.-M. Poehling. Advances in the understanding of the ecology of* Teretriosoma nigrescens *Lewis (Coleoptera: Histeridae), a natural enemy of the exotic larger grain borer* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae). Proceedings of the 50st German Plant Protection Conference, Münster, Germany, 23.-26. September 1996, abstract only (in press).

The accidental introduction of the larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), in the early 1980s resulted in destructive pest outbreaks in small-farm maize stores in both East and West Africa. Studies conducted in Central America and Mexico, the pest's neotropical area of origin, provided circumstantial evidence that the pest might be under the control of natural enemies and that classical biological control of the pest in Africa might be feasible. Among several potential candidate natural enemies, the predator *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae) was selected as the most promising and has now been released in four African countries: Togo, Benin, Ghana and Kenya. The establishment and rapid spread of the predator across Benin has been monitored using pheromone traps. Despite earlier concerns regarding host specificity, biochemical analysis indicates that the great majority of prey consumed are of the target pest, while laboratory life table studies have confirmed that the predator has appropriate biotic characteristics to act as a successful control agent. Analysis of the effect of meteorological factors on the flight activity of the predator revealed, that both in the Neotropics and in West Africa weather data alone can not sufficiently explain the flight cycle of the beetle. Follow-up studies are now being carried out to evaluate the actual impact of the predator on pest populations and damage in stores.

Bosque-Pérez, N.A. & I.W. Buddenhagen. Biology of* Cicadulina *leafhoppers and epidemiology of maize streak virus disease in West Africa. Proceedings Maize Streak Disease Symposium, September 1997, Hazyview, South Africa (in press).

Studies have been conducted in Nigeria on the biology of *Cicadulina* leafhopper vectors of maize streak virus (MSV), on the role of indigenous grasses as reservoirs of virus and vectors, and on incidence and severity of MSV in relation to maize varietal susceptibility/ resistance levels. *Cicadulina* populations peak before the rains end in the savanna and after the rains in the forest zone. The proportion of viruliferous leafhoppers increases as the season progresses. *C. mbila* is the predominant vector species; four other species are less common. *C. arachidis*, transmits MSV inefficiently and is believed not to be of importance in disease epidemics. Off-season survival of MSV and vectors occurs mostly in riverine areas in grasses and in areas with hydromorphic soils where maize is grown during the dry season. However, streak found in many grasses in Nigeria is not readily transmissible to susceptible field maize. The weeds most likely to be involved in perpetuating an epidemiologically-competent MSV maize strain are *Axonopus compressus* (an introduced perennial), *Brachiaria lata* and *Setaria barbata* (indigenous annuals). MSV epidemics occur only in years with favorable weather conditions which allow vector survival and build-up, and where maize-competent strains are present in grass hosts. MSV disease reduces maize yield, but varieties differ in amount of loss, disease severity and incidence. Resistant varieties exhibit tolerance – good yield performance when diseased – and lower disease incidence or tolremicity. Low disease incidence is partly due to insect resistance and the potential for disease spread is lower on varieties exhibiting this character.

Cardwell, K.F. 1998. Marasmiellus leaf disease on maize in West Africa. Plant Disease Note 1660. Vol 82:6.

A leaf disease of maize previously described as borde blanco or horizontal banded blight, and caused by *Marasmiellus paspali* was recently observed for the first time in three West African countries. The symptom was white (scorched), dry lesions on the edge of the leaf that grew phasically resulting in horizontal bands delineated by purple to brown margins. Minute basidiocarps (1 mm high) were seen in the white zone of the banded lesions, often arranged linearly. Out of over 100 fields visited in 1993 and 1994, the disease was seen in one site only in southern Cameroon in 1994. In 1997, it was found in all maize fields in four separate areas in the humid forest zone of that country. In Ghana in November 1996, it was prevalent during survey of 60 fields with leaf area losses from 30 to 40%. In August of 1997, the disease appeared in low incidence on maize in Nigeria. The appearance of the Marasmiellus disease in Cameroon, Nigeria, and Ghana in the last three years represents a geographic shift from where the pathogen has been previously reported. It is not known at this time if significant yield loss is being incurred.

Cardwell K.F., J.M. Udoh & K. Hell. Assessment of risk of mycotoxic degradation of stored maize in Nigeria and Benin Republic, West Africa. USDA Aflatoxin Elimination Workshop, Memphis, TN. Oct. 26-28, 1997.

An inventory of maize grain quality in West African peasant farming systems was conducted from 1993 to 1995. In Nigeria, around 25% of the stores were aflatoxin positive with an average of 292 ppb. In Benin, from 27-73% of the stores were contaminated with an average of 37 ppb aflatoxin during the 2 year period.

Maize in all zones was found to have risk of contamination, but the degree of risk by zone was not consistent between countries, indicating that farming practices had as much influence as climate. The Humid Forest zone had significant risk only in Nigeria when farmers stored maize on the floor of a room. The Southern Guinea Savanna had high risk in both countries, with 25-30% of the stores contaminated early in the storage period. Factors significantly related to high toxin levels in that zone were insect damage, crop system, prolonged field drying, and sorting practices. Maize stores in the Northern Guinea savanna of Nigeria had the lowest incidence and the least toxin contamination, while in Benin the highest incidence, 73%, occurred in this zone in 1994. Crop rotation, use of insecticide and fertilizer, field drying, and storage system were significant factors related to contamination. The Sudan Savanna, bordering the Sahel, had the most consistent risk of high aflatoxin contamination, averaging 305 ppb across years. In summary, maize is a primary staple for human consumption in Benin and Nigeria, and many people are being exposed to aflatoxin levels well above accepted standards. Little is known about the year to year variability of contamination in West Africa so it is unclear if the contamination levels during this sampling period were typical.

Cotty P.J., T. Feibelman & K.F. Cardwell. Insights into regulation of aflatoxin biosynthesis from an unusual Aspergillus* flavus *strain from Africa. USDA Aflatoxin Elimination Workshop, Memphis, TN. Oct. 26-28, 1997.

An unusual aflatoxin producing fungus was isolated from soils collected in the Republic of Benin. This fungus differed from other aflatoxin producing fungi in both sclerotial morphology and regulation of aflatoxin biosynthesis. The fungus (called Strain P) was assigned to *A. flavus* based on conidial morphology and polymorphisms in the Taka-amylase gene. Strain P produced aflatoxins B1 and B2 and elongate sclerotia up to 2 cm in length with a bulbous base and reduced melanin content. Only one fungal isolate like strain P was observed among several thousand that have been examined in North America and West Africa.

Meikle, W.G., N. Holst, C. Nansen, J.N. Ayertey, B. Boateng & R.H. Markham. Developing decision-support tools for post-harvest pest management in grain stores in West Africa. 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.(in press).

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., N. Holst, P. Degbey, R. Oussou, C. Nansen & R.H. Markham, 1998. Decision-making tools: An evaluation based on survey data from Benin. Presented at the joint IITA/CABI Workshop on Entomopathology and Stored Product Pest Management, Nov. 30 to Dec. 3 1998, IITA-PHMD, Calavi, Benin.

Information about the current status and prognosis of pest problems is important for proper decision-making by farmers. If a farmer can make an educated guess about the approximate density of the pests in his store, about how that density is likely to change given certain conditions (such as weather), and about the relationship between pest density and grain value, he or she will be in a good position to make sound economic decisions about pest management, in the same way a stockbroker needs good information about investments in order to effectively manage a portfolio. Farmers who assume a pest will be a problem, and treat their stores without bothering to look, may save time but waste money and risk their health for no reason, and those that assume a pest will not be a problem risk rapid economic loss if their store is infested by pests like *Prostephanus truncatus*, the larger grain borer. One way to provide the information is in the form of a decision-support tool. The tool we have developed at IITA and DIAS consists of population simulation models, map-based weather data and programs for developing sampling plans. Two surveys of farmers and grain stores, conducted in Benin in 1997-98, when combined with data from 1993, showed that a) pesticide use is probably increasing, in spite of the establishment of *T. nigrescens* as a biocontrol agent for *P. truncatus*, b) pesticide use was not associated with either lower overall insect densities or higher market value for the maize, and c) sequential sampling plans developed by our group would have successfully detected almost all *P. truncatus* infestations, usually with fewer than 20 cobs.

Meikle, W.G., N. Holst, & R.H. Markham, 1998. Developing computer-based modelling programmes to study the dynamics of maize pest populations in traditional African storage systems. In PostHarvest Systems. The Newsletter for Postharvest Systems Development in Africa (published jointly by IITA and GTZ). No.3.

Storage pests can cause considerable crop losses particularly in traditional storage systems where environmental conditions are uncontrolled and storage periods are variable. Studying the effects of environmental factors on pest population dynamics and storage losses will enable researchers to devise simple decision making tools designed to assist farmers in rational and economic storage management practices. Stored product systems are ideal for the application of simulation models to provide an understanding of observed changes in pest populations and evaluate the effects of different management strategies. Unlike field systems, the mass of feed substrate does not change over time, the system studied is largely limited to the room or container where the product is stored, the role of weeds is eliminated, and the most important variables that affect storage pest populations, temperature and grain moisture content are relatively simple to measure and control and are considerably simpler to investigate than interactions between sunshine, rainfall, temperature and humidity which effect field crops. One may therefore expect there to be extensive use of insect modelling for the management of stored pests. A population simulation model of S. zeamais, which incorporates varietal resistance, is discussed in light of the history of ecological modelling in stored product sytems and the role of such models as tools.

Oussou, R.D., P. Degbey, W.G. Meikle, B.A. Boateng & R.H. Markham. Vers des outils de prise de décision pour la lutte contre les ravageurs post-récolte du maïs. Premier colloque international du riseau Africain de recherche sur les Bruches, 10-14 Feb. 1997, Lomé, Togo. Organized in collaboration with the Conseil Phytosanitaire Interafricain (C.P.I. / O.U.A.). (in press).

In order to develop a decision support tool that would be useful to extension agents and eventually farmers, results from field and laboratory work at IITA need to be extended to different agro-ecologies and different socio-economic situations. Using survey and field trial results, we have developed sampling plans for stored product insects. Tools such as sampling plans will be modified with the help of farmers, extension agents and national research scientists. By developing simulation models, we intend to construct a framework for understanding insect ecology, maize varietal effects and price dynamics. The framework will be used both to help in understanding existing experimental results, and in determining those areas in which further research is needed.

Schulthess F. & S.O. Ajala. Recent advances in the control of stemborers West and Central Africa. WECAMAN conference, Cotonou, 1997 (in press).

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.

Project 6

INTEGRATED MANAGEMENT OF CASSAVA PESTS AND DISEASES

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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 *Colletotricum gloeosporiodes f. sp. manihotis*, cassava brown streak virus, and various root and stem rot pathogens. Less widely distributed pests include the spiralling 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 alleviating 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 1998, 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 1998 it has been reported established in 16 African countries, with the greatest spread occurring in Benin, Cameroon, Cote d'Ivoire, Ghana, Guinea Conakry, Togo, Nigeria, and Uganda. Limited spread has been reported from Kenya and Tanzania, and recent establishment has been reported from the Democratic Republic of Congo and Malawi. Establishment of *T. aripo* has been reported also from Burundi, Liberia, Rwanda, and Sierra Leone. *T. aripo* now covers an estimated 900,000 km^2 with most of the area covered occurring in West Africa and parts of East and Central Africa. In West Africa *T. aripo* has reduced cassava green mite populations by two thirds and increased cassava yields by 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*. In addition, laboratory and field experiments determined the seasonal variation in cassava in the diet of the variegated grasshopper. Several parasitoids associated with *B. tabaci* were identified on cassava and five termite species were identified in Zambia.

On the plant pathology front, 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 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. Yield loss trials of 22 local and improved cassava varieties in several ecozones were concluded. Biochemical techniques were developed for quick and easy detection of CBB, and a quick screening method was developed for root and stem rots. Sources of resistance were also identified against CBB, CAD and CMD from local clones and breeding lines in Benin and Nigeria. A new fungal disease, *Macrophomina phaseolina*, was found causing pre-harvest cassava root rot in Benin and Nigeria. Root-knot nematode was shown to be a potentially significant pest of cassava where it occurs in high populations in Uganda

In 1999, priority will be given to the continuation of the Africa-wide biological control of cassava green mite, CMD, root rot pathogens and CAD. CBB activities in West Africa will be reduced due to loss of project staff. The project will expand the work on nematodes and look for opportunities in cassava root scale, termites, and postharvest insects and diseases. Cassava green mite efforts shift to impact assessment and enhancement of biocontrol through cultural practices in the lowland humid tropics of West Africa and mid-altitude humid tropics of East and Central Africa. The project will resume foreign exploration for phytoseiid predators adapted to mid-altitude suhumid zones of Southern Africa. Efforts will continue to establish virulent exotic strains of the mite fungus, *Neozygites floridana*, to enhance cassava green mite control where exotic phytoseiids have not performed well. 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 investigating mechanisms of apparent geminivirus cross-ressistance. Cassava anthracnose disease (CAD) and root and stem rots, major problems in humid lowlands, will continue to be investigated for cultural control possibilities. Research on root rot epidemiology, yield losses and variety evaluations will continue, to develop sustainable control methods including the use of pathogen antagonists. Resistance of local and improved varieties to root-knot nematode in Mozambique and potential interactions with other cassava pests will be tested. The project will devote considerable amounts of human and material resources to training and supporting national programs through participatory evaluations of IPM technologies, enhancing action learning by establishing Farmer Field Schools, conducting on-site IPM training courses, 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 1999, 45% of project activities will be in the mid-altitude zone, while 39% and 16% of activities will be in the moist savanna and humid forest zones, respectively.

Outputs

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

Background

Country-wide diagnostic surveys were carried out in Malawi and Mozambique at the beginning of the long rainy season in November and December 1998 to determine the levels and distribution of cassava green mite and associated predator fauna. Preliminary examination of the data indicated that cassava green mite is most severe in Central and Southern Malawi and Central and Northern Mozambique. Cassava green mite was not found in Maputo and Gaza provinces in Mozambique, contrary to surveys conducted in December 1997 and August 1998, which showed the presence of cassava green mite at the INIA research station in Gaza province and at the University of Mozambique research fields. These diagnostic surveys were used to identify areas for concentrating initial biological control efforts and to identify appropriate sites for exotic phytoseiid releases. In addition to previously collected data from other countries, pre- and post-release data of cassava green mite and associated arthropod fauna will be used to evaluate non-target impact of exotic phytoseiids on cassava and surrounding vegetation.

On-going and future activities

6.1.1. Diagnostic surveys of cassava green mite in Malawi and Mozambique

by R.H., M.T. – in collaboration with J. Gwinner, A. Jones, I. Zannou

Country-wide diagnostic surveys were carried out in Malawi and Mozambique to determine the levels and distribution cassava green mite and associated predator fauna in November and December, at the beginning of the rainy season. Preliminary examination of the data indicated that cassava green mite is most severe in central and southern Malawi and central and northern

Mozambique. Cassava green mite was not found in Maputo and Gaza provinces in Mozambique, contrary to surveys conducted in December 1997 and August 1998, which showed the presence of cassava green mite at the INIA research station in Gaza province and the University of Mozambique research fields. These diagnostic surveys were used to identify areas for concentrating initial biological control efforts and to identify appropriate sites for exotic phytoseiid releases. In addition to previously collected data from other countries, pre- and post-release data of cassava green mite and associated arthropod fauna will be used to evaluate non-target impact of exotic phytoseiids on cassava and surrounding vegetation.

6.1.2. Assessment of the incidence and importance of cassava mosaic disease in countries within the east and central African region.

by J.P.L. – in collaboration with R. Mayala, S.C Jeremiah, G.W. Otim-Nape, J.M. Thresh, J. Kamau

An epidemic of unusually severe cassava mosaic disease (CMD) has expanded to cover most of the cassava producing areas of Uganda in recent years. This epidemic now threatens neighbouring countries in the region. Surveys were conducted during 1997 in western Kenya, Rwanda and in the Lake Victoria zone of north-western Tanzania to make a regional assessment of the CMD situation. Follow up surveys were conducted in western Kenya and the Kagera region of north-western Tanzania, two areas in which the CMD pandemic is actively expanding. During 1998, the pandemic expanded up to 80 km southwards into the northern part of Kagera Region and appeared to have crossed into southern Nyanza Province in western Kenya. Incidence of CMD in affected areas of Kagera Region ranged from 50 to 100%. Incidence in Western and northern Nyanza Provinces was 85%. Whilst incidence in southern Nyanza Province remained low at 15%, evidence for the incipient expansion of the pandemic into this zone was provided by the occurrence of severely diseased whitefly-infected cassava plants in the part of the zone nearest to the pandemic affected areas of northern Nyanza.

6.1.3. Diagnostic survey of whiteflies and whitefly-borne viruses of cassava and sweet potato.

by J.P.L., B.D.J. – in collaboration with A.R. Cudjoe, N. Ntonifor, T. Echendu, S. Ogwal, B. Odongo

In 1998, surveys of whiteflies and whitefly-borne viruses of cassava and sweet potato were completed in Kenya, Tanzania and Madagascar and initiated in Malawi. Database entry and preliminary analysis were done for survey results from Uganda, Ghana, Benin, Nigeria and Cameroon. Preliminary maps of whitefly abundance and cassava mosaic disease incidence were developed for the eight countries for which surveys were completed. Provisional identifications were done for whitefly nymphs and parasitoids collected during the surveys. In West Africa, whiteflies were generally more abundant in the higher rainfall areas towards the Atlantic coast, although this was not associated with a similar trend for CMD incidence. In East Africa, high CMD incidence was associated with the pandemic of severe CMD in Uganda and western Kenya. Whilst Bemisia tabaci, the recognised vector of cassava mosaic geminiviruses, was the most commonly occurring whitefly species on cassava, B. afer, also occurred widely, and was the predominant species in the southern countries of Malawi and Madagascar. Four species of whitefly parasitoid were identified, although only Encarsia transvena occurred throughout areas sampled.

6.1.4. The establishment and application of PCR-based diagnostics at IITA-ESARC.

by J.P.L., J.d'A.H. – in collaboration with G. Thottappilly, S. Winter

A PCR protocol for cassava mosaic virus diagnostics being used by the Biotechnology Unit of IITA was tested at IITA-ESARC with a view to eventually being used for the routine discrimination between the three cassava mosaic geminivirus forms currently recognised from Africa. Successful results were obtained from initial tests and the first practical application was the diagnosis of virus diseased cassava samples from Rwanda for which DNA was extracted in Rwanda and PCR analysis carried out at IITA-ESARC. Two primer pairs were used, one specific for ACMV (AL1/F with ARO/R), the other specific for EACMV-like viruses (EACMV and the Uganda Variant – UV) (primers CT/AL1/F with CT/AL1/R). Most samples collected from Rwanda provided amplification products with the ACMV primers, although a small number gave products with the EACMV/UV primer pair. Results therefore suggested the occurrence in Rwanda of both ACMV and EACMV or UV. In 1998, additional primer pairs were obtained and tested. These included an EACMV specific pair and a degenerate pair of universal geminivirus primers. PCR was used during 1998 to map the occurrence of cassava mosaic geminiviruses in 12 Districts of Uganda and the Lake Zone of Tanzania and as a routine diagnostic tool for the identification of

viruses in CMD diseased cassava used within experimental trials in Uganda. Beyond 1998, PCR based techniques should be routinely used for cassava virus diagnostics at IITA-ESARC.

6.1.5. Diagnostic survey of cassava diseases in Togo

*by K.W. – in collaboration with K. Kpémoua, A. Banito**

Data were collected on the distribution, incidence and severity of cassava diseases in Togo. Cassava fields were visited in the major cassava growing areas, but also in marginal areas as the dry savanna in North Togo. Special emphasis was on cassava bacterial blight and cassava mosaic virus disease. Bacterial blight was frequent in the North. Samples of bacterial blight and root rots were collected for further characterization. Agronomic and ecological data as well as plant characteristics were recorded in order to identify their influences on the diseases.

6.1.6 Collection and characterization of root rot pathogens in Nigeria

*by K.W.. – in collaboration with A.G.O. Dixon, J. Onyeka**

Root rot samples were collected in the sub-humid and humid areas of Nigeria and pathogens isolated and identified. The most frequently found pathogen was Botryodiplodia theobromae, others were Sphaerostilbe repens, Fusarium spp. and Phytophtora sp. Virulence of strains was variable, highly virulent strains were used for inoculation of cassava varieties.

6.1.7 Cassava diseases in Benin and Ghana and their interaction with environmental and agronomic factors and plant characteristic

by K.W.. – in collaboration with V. Verdier

Analysis of data on the interaction of cassava diseases with influencing factors was conducted. Among the seven cassava diseases observed in a survey in the cassava growing regions of Benin and Ghana in 1993, cassava mosaic disease occurred most frequently in all ecozones, with a higher incidence across all ecozones in Ghana (82.2%) than in Benin (48.1%). Cassava bacterial blight was particularly severe in all ecozones of Benin, but rare in Ghana. The savanna zones of Benin were heavily infected with an incidence of 34.5%-84.1%, and a high percentage of plants showing systemic symptoms, while cassava bacterial blight was not observed in the rainforest zone of Ghana. Anthracnose and leaf diseases caused by Cercospora spp. were of minor importance. Multivariate analysis revealed that high cassava bacterial blight incidence and severity were associated with increasing plant age and clay soils, whereas disease incidence was negatively correlated to the association of several crops and several cassava varieties in one field. Cassava mosaic disease appeared to be positively correlated to increasing weeds in a field and the association of several cassava varieties. The severity of the Cercospora diseases was positively correlated to profusely branching varieties. Cercospora caribaea was associated to increasing rainfall and suppressed by a mixture of varieties.

6.1.8. Yield loss due cassava bacterial blight in 22 varieties

*by K.W., A.G.O.D. – in collaboration with A. Fanou**

Yield loss and epidemiology trials with 22 varieties in 3 ecozones - rain forest zone, transition forest zone and dry savanna - over two years were finalized and data analysis performed. A detailed symptom evaluation, 6-weekly in the rainy season and less frequent in the dry season, was conducted and plant growth and root yield data and epidemiological parameters on CBB development were collected and analyzed. The yield of the varieties was variable due to environment. The most stable variety was TMS 30572, although it did not always have the highest yield. TMS 30572 was followed in terms of yield stability by I8800158, I8900854 and I8900914. However, up to 50% (DW) and up to 38% (FW) significant yield loss in TMS 30572 were recorded in the DS and in the coastal FST zones in 1994, respectively. Data analysis of yield loss trials with a susceptible variety (Ben 86052) and a resistant variety (TMS 30572) in 5 ecozones, partly over 3 years, was completed. Dry savanna 1994, 1995, 1996: significant losses of 50% were recorded in the resistant TMS 30572 and a susceptible variety in 1994; Forest savanna transition zone (coastal) 1994, 1995, 1996: significant losses of 38% in TMS 30572 in 1994, of 32% in the susceptible variety in 1996. No significant losses occurred in the forest savanna transition zone (in land), Rainforest zone and Sudan savanna.

6.2. *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

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

by J.S.Y. - in collaboration with A. P. Gutierrez, M. Sabelis

Several ecological questions concerning the interactions between cassava, *M. tanajoa* and the complex of established exotic phytoseiids predators is being investigated through a simulation model. A beta version of the model was made operational during the year by modifying an existing cassava simulation model. Predator and prey life table data determined in the laboratory at constant temperatures provided the functional parameters, while the population dynamics of *M. tanajoa*, interacting with the established predators *T. manihoti* and *T. aripo* in several locations provided independent validation datasets. The initial output of the model was encouraging. While a good fit was found in the observed predator/prey phenology, adjustment were needed in the amplitude of the observed responses. Corrections are currently being made by substituting mites per leaf with total plant densities per plant. Once corrected, the objectives of the modeling are to (1) valid the simulation, (2) elaborate and evaluate the ecological, production and economic dynamics of the tritrophic system with *T. aripo* and *T. manihoti* alone and together in the system, (3) estimate the areawide impact of *T. aripo*, and (4) compare the simulation model with a simpler analytical approach.

6.2.2. Virulence of the Brazilian and Beninese isolates of *Neozygites floridana* to the cassava green mite

by S.K.D., C.J.L., J.S.Y., R.H.

A bioassay was conducted to evaluate the virulence of one isolate each from Brazil (Alto Alegre) and Benin (Cotonou) of *N. floridana* against the males and females of Beninese *M. tanajoa* in laboratory bioassays. In three out of five tests, the exotic isolate was significantly more virulent than the indigenous isolate to *M. tanajoa*. In another bioassay, three exotic isolates (from Alto Alegre, Colas Almas, and Adanai Lambari) were compared with the Beninese isolate against the female mites.

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

by R..H., J.S.Y., 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).

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

by R.H. J.S.Y. – 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. Two sites with different phytoseiid species composition were established in Benin in June, 1999. Whole plant sampling is conducted at 4-hour intervals, over a 24-hour period, every three months. The data have not been fully analyzed to provide a broad picture of the spatial and temporal dynamics

of CGM and associated predators, but preliminary observations indicate that *T. aripo* inhabits the cassava plant tip during much of the day hours, and moves to the foliage during the night hours, while *T. manihoti* inhabits the young foliage throughout the day and night hours. The extent of *T. aripo's* downward movement appears to be dependent on availability of CGM. These studies are conducted in collaboration with the University of Amsterdam, Netherlands.

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

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

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 can have profound effects on the stability of cassava green mite biocontrol. The extent of these interactions, however, are not known. We initiated screenhouse and field experiments in collaboration with the University of Amsterdam, Netherlands, to determine the level of interspecific interactions between the two exotic phytoseiids. These are on-going studies and we do not have sufficient data to draw any conclusions concerning the level of interspecific interactions between the phytoseiids.

6.2.6. Infochemical use by exotic phytoseiids

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

Studies have been initiated in collaboration with Wageningen Agricultural University, Netherlands, to determine the response of *T. manihoti* and *T. aripo* to volatile chemicals related to their food. The information gained through this research will enable us to understand (1) how the two predators use infochemicals to locate prey and other food sources, (2) to what extent their use of infochemicals contributes to the level of inter- and intraspecific interactions, and (3) their use of infochemical might affect their success as biocontrol agents. These studies are on-going. Available data indicates that both phytoseiid respond to prey volatiles, but *T. manihoti* appears to respond more strongly than *T. aripo*, particularly at moderate hunger levels. Additional studies were initiated to determine the level of phytoseiid response to cassava varieties with varying growth types and leaf and apex pubescence. Early evidence indicates that *T. aripo* responds differently to cassava varieties, even in the absence of prey volatiles.

6.2.7. Regional CMD epidemiology

by J.P.L., B.D.J. – in collaboration with N. Ntonifor, A. Cudjoe, F. Ogbe

In West and Central Africa, the project 'whiteflies and whitefly transmitted viruses' of CG System-wide IPM Programme is building upon close partnership with national agricultural researchers and a budding farmer participation in IPM to develop appropriate plant protection technologies and practices in the management of the cassava mosaic disease (CMD). Part of the project activities in Ghana, Benin, Cameroon and Nigeria have been the estimation of primary CMD incidence jointly by researchers and farmers and the initiation of farmer participatory trials to understand and reduce primary incidence of cassava mosaic in principal agroecological zones. In collaboration with specifically trained extension agents, the project had also completed a season of field trials to investigate *Bemisia* whitefly population dynamics and compare the rate of CMD spread into 'healthy' plantings of cassava in contrasting agroecologies in the target countries.

6.2.8. CGM/CMD interaction studies

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

Observations of severely stunted plants within the area of the cassava mosaic epidemic in Uganda suggested the likelihood of an interaction between cassava green mite and cassava mosaic disease. 1997 results suggested that both constraints caused substantial reductions in yield, their combined effect was additive rather than a positive or negative interaction. The trial was replanted in September 1998. A screenhouse-based study was also planted in 1998 comparing the effects on cassava growth of combinations of CGM and CMD infestation/infection. The key objective was to identify the treatment/combination of treatments causing the severe 'candlestick' symptoms involving the loss of leaves immediately below the shoot tip. These symptoms are commonly associated with the CMD pandemic. Three types of CMD infection were used, including mild cutting-derived, severe cutting derived and whitefly-borne. Preliminary results suggest that 'candlestick' symptoms are particularly associated with the whitefly-borne and severe cutting-

derived treatments and appear to be independent of the CGM treatment. DNA has been extracted from a subset of the experimental plants and will be used for PCR based virus diagnostics.

6.2.9. CMD severity vs. yield loss studies

by J.P.L.

In order to quantify the relationship between severity of CMD and cassava yield, we tested in field trials differences in initial CMD infection in planted materials could affect CMD state later during the growing season. Cuttings from mildly-diseased parental stock were represented more frequently than either of the other two categories, suggesting a selection in favor of this material and confirming the hypothesis that mild disease predominates over time in situations of high incidence with mixed mild and severe disease. Diagnostic test results suggested that mildy diseased plants were most commonly infected with a form of UgV and not ACMV as initially expected. This does explain, however, the apparently greater resistance to the development of severe disease for initially mildly-diseased plants than for initially healthy plants. This is also in agreement with other recent studies of cassava mosaic geminiviruses from Uganda which have presented evidence for the occurrence of both mild and severe strains of UgV.

6.2.10. Epidemiology of cassava bacterial blight: importance of *Zonocerus variegatus*

by K.W. - in collaboration with M. Zandjanakou, A. Fanou**

In experiments on the importance of vectors for the distribution of CBB over short or long distances, the role of *Z. variegatus* was further elucidated. The insect carried bacteria on the mandibles, legs, in the intestinal channel and in the feces. It was demonstrated for the first time that feces containing the pathogen provoked symptoms on un-wounded cassava leaves, and that grasshoppers fed on CBB infected plants carried the pathogen to healthy plants where symptoms due to the marked pathogen (with resistance to two antibiotics) developed.

6.3. 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

6.3.1. Exotic phytoseiid energy conversion

by J.S.Y. – in collaboration with D. Gnanvossou

The conversion of CGM prey into predator biomass was determined by measuring the adult male and female length and width (in mm), and fresh and dry weight (in µg) of *Typhlodromalus aripo*, *T. manihoti* and their preferred prey *M. tanajoa* at 22°C, 25°C and 28°C constant temperatures. The length and width measurements of predators and prey alike were similar across males and females, regardless of treatment suggesting that temperature did not affect the size attained. However, the biomass of all mites showed the expected curvilinear relationship with temperature - the heaviest individuals coming from the 25°C treatment. Male and female predators had ca 2.8 and 1.8 times more biomass, respectively than their prey counterpart, while *T. manihoti* had ca 10% more biomass than *T. aripo* across both sexes. These data were incorporated into the parameters used to functionalized the simulation model.

6.3.2. Exotic phytoseiid life table and feeding studies

by J.S.Y. – in collaboration with D. Gnanvossou

The development and reproduction energetics of *T. aripo*, *T. manihoti* and *N. idaeus* given pure diets of *M. tanajoa* eggs, juveniles and adults females at 25°C constant temperatures were studied

in the laboratory. *N. idaeus* was 3 to 6 times more efficient at converting *M. tanajoa* eggs into offspring than *T. manihoti* and *T. aripo*, respectively. It consumed significantly fewer *M. tanajoa* eggs, but as many juveniles and adults per female per day as *T. aripo*. *T. manihoti* had high egg and juvenile consumptions rates and intermediate to high conversion efficiencies. *T. aripo* consumed intermediate to high amounts of all *M. tanajoa* stages, but was particularly inefficient at converting *M. tanajoa* eggs into offspring. This raises the question as to how the less efficient *T. aripo* manages to reduce *M. tanajoa* densities over a large spatial scale, while more efficient predators like *N. idaeus* and *T. manihoti* do not. These data were also incorporated into the parameters used to functionalized the simulation model.

6.3.3. Quarantine and culture of exotic phytoseiids

By R.H., M.T., J.S.Y.. - in collaboration with F. Bakker, G. J. de Moraes, D. Gnanvossou, G. Paraiso

Mitox, a University of Amsterdam affiliate, continued its readiness to receive and process exotic phytoseiids, although shipments were not received in 1998. The maintenance of mother cultures continued at an acceptable level of production for 4 species and a total of 17 colonies. The exotic species still in culture included *N. idaeus* (three Brazilian populations including one from a release field in Benin), *T. aripo* (five Brazilian populations), *T. limonicus* (one Brazilian populations) and *T. manihoti* (six Colombian and two Brazilian populations from release fields in Benin only). The pathogenic fungus *N. floridana* from Brazil is also being maintained in culture. New populations of cassava green mites natural enemies from Brazil or Colombia well adapted to mid-altitude and semi-arid conditions are expected in 1999.

6.3.4. Release of *N. floridana* for the control of the cassava green mite

By S.K.D., C.J.L., J.S.Y., R.H.

Four Brazilian isolates and one Beninese isolate of *N. floridana* were successfully released on live cassava green mite in two cassava fields in southern Benin. Initial observations on the release plants showed infection of cassava green mites on the release plants. Follow-up monitoring will be conducted to determine to determine and compare the level of establishments of the released isolates.

6.3.5. 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, which has resulted in failure of cassava green mite biocontrol on varieties not preferred by *T. aripo*. 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. The trials have not been harvested, but available data indicates that biological control on non-*T. aripo*-preferred varieties can be enhanced considerably by interplanting those varieties with preferred varieites at a ratio of 3:1.

6.3.6. 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 crossprotection. 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.

6.3.7. 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.

6.3.8. 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.

6.3.9. Control of CBB by pruning, intercropping, and planting date

*by K.W. - in collaboration with A. Fanou**

Data of the trials on control methods (intercropping cassava with maize or cowpea, seed treatment, pruning, characterization of varieties in different ecozones) were analysed. When infected leaves were pruned, disease severity in the following months was much less than in unpruned fields. Cassava was planted in association with maize and cowpea. The association with maize suppressed the disease more than the association with cowpea. Monocropping was favorable for disease development. Data analysis revealed that cassava yield/ha in intercropped fields with maize was not less than in monocropped fields. Shifting planting date to June suppress disease expression.

6.3.10. Development of screening methods for resistance or tolerance to root knot nematode

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

Nematodes are one of the limiting biotic factors of cassava production. Root-knot nematodes (*Meloidogyne* spp.) are the most important group of nematodes affecting cassava and are the most widely reported in many cassava growing areas of the world. Other nematode species that are associated with cassava and are of potential economic importance include *Pratylenchus brachyurus Helicotylenchus erythrinae, H. dihystera, Rotylenchulus reniformis* and *Scutellonema bradys*. Variation in host plant response of cassava to root knot nematodes has been reported. To study cassava host plant reaction to root-knot nematodes an early screening has been developed at IITA, and on-going research will establish the pest status of root knot nematodes, identify and include possibly sources of root knot nematode resistance and tolerance in currently grown cassava germplasm.

6.3.11. Screening for resistance to major pests and diseases in SARRNET countries

by J.M.T., M-K.A, J.P.L - in collaboration with M. Andrade, C. Jericho, G. Kaitisha, R. Kapinga, M. Madisa, C. Malambo, N. Mahungu, N. Mahungu, P. Muondo, M. Nzina , M. Nxumalo, M. Raya, B. Rusch, M. Simwambana, J. Teme, M. Theu, G. Thompson, J. Thresh

Screening for cassava resistance to major pests and disease continued in the SARRNET countries. At least 45 improved cassava clones (selections of local and exotic germplasm) have varying levels of resistance to the major pests and diseases. Multiplication and distribution of these improved clones combined with improved plant health (selection of healthy plant material) are a major SARRNET thrust with considerable impact in 8 SARRNET countries.

6.4. *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

6.4.1. Extension/farmer training materials

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

Four previously field tested cassava IPM extension/farmer awareness posters were produced and distributed to FFS participants in Benin, Cameroon, Ghana and Nigeria and in the SARRNET and EARRNET countries. The posters are available in English and French. Four previously field tested cassava IPM field guides for extension are in camera-ready stage for production. A source book for extension trainers in cassava IPM is being finalized.

6.4.2. Decision support systems

by R.H., J.S.Y., B.D.J. – in collaboration with F. Fuloranmi, B. Gbaguidi

Large multi-disciplinary databases like those generated during the regional diagnostic survey of the original ESCaPP project are best exploited by a system specifically designed to update, manage and interpret dynamic data. Validated inter-disciplinary systems models will provide the tools for evaluating the response of simulated agroecosystems under a range of conditions, and a basis for day-to-day decision-making in cassava plant protection.

6.4.3. Interactive information media

by J.S.Y., B.D.J., W.M.

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, the entire series of CIAT/IITA cassava newsletters, training modules, an expert system as a decision support tool, 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. Additionally, IITA staff will continue to be trained to prepare documents for conversion into an interactive format. The ultimate aim of the training would be to develop an independent capacity to create interactive cassava information resources.

6.4.4. Development of a Quality Management Protocol for cassava multiplication

by J.P.L. – in collaboration with Y. Baguma, S. Ogwal

IITA is collaborating with the national root crops programme of Uganda in implementing an extensive Project on the 'Dissemination and Utilisation of Mosaic Resistant Cassava in Uganda'. Newly released CMD resistant cassava varieties derived from IITA introductions are being multiplied at research institute and district level multiplication centres prior to distribution to farmers at secondary multiplication centres. A Quality Management Protocol (QMP) was developed in 1997 to establish guidelines for individuals or institutions who/which take on the responsibility to multiply cassava stems should aim to procure, produce and supply/sell in the manner proscribed by the QMP. The Quality Management Protocol (QMP) has been refined and

comprises three components, one for stem producers, a second for root producers and a third for stem quality assessors. Validation will be done for both the newly planted and the ratooned multiplication plots of the IITA/NARO cassava project in Uganda. Training will also be provided in the implementation of the QMP.

6.4.5. Cassava information exchange in SARRNET countries

by J.M.T., M-K.A, J.P.L - in collaboration with M. Andrade, , C. Jericho G. Kaitisha R. Kapinga, M. Madisa, C. Malambo, N. Mahungu, N. Mahungu, P. Muondo, M. Nzina , M. Nxumalo, M. Raya, B. Rusch, M. Simwambana, J. Teme, M. Theu, G. Thompson, J. Thresh

Information exchange is a major SARRNET thrust. The first SARRNET Scientific Workshop was held in Lusaka, Zambia in August 1998. It had more than 70 participants from numerous countries. More than a dozen papers were related to cassava pests and diseases. The proceedings were published in February 1999. In addition, SARRNET continued to publish ROOTS Newsletter.

6.5. 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

6.5.1. Experimental releases and follow-ups

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

A total of 25,450 actives of *T. aripo* were shipped from IITA for experimental releases in Democratic Republic of Congo (DRC), Malawi, Mozambique, and Zambia in 1998. Follow-up surveys indicated successful establishment and short distance spread in several sites in DRC, and one site in northern Malawi. In Luapula Province in Zambia and Inhambane Province in Mozambique, *T. aripo* multiplied, and persisted for 8 months after the initial release, but surveys a the beginning of the rain season, a year after the release, failed to recover the predators. It appears, however, that releases in northern Mozambique where the conditions are more favorable for the available strains of *T. aripo*, will lead to successful establishment. Foreign exploration has resumed to search for exotic phytoseiids that are adapted to the mid-altitude sub-humid regions of Southern Africa. Further releases will be made as soon as predators are processed through quarantine and multiplied in IITA-Benin. In Benin, *T. aripo* was recovered in all previous release fields and is now found up to the edge of the moist savanna. *T. aripo* was found similarly distributed with similar levels of persistence in Ghana, Guinea-Conakry, Nigeria, and Cameroon, where numerous releases were made; and in Togo and Cote d'Ivoire, where this predator was never intentionally released. *T. aripo* was has also spread extensively in Uganda and moderately in Kenya and Tanzania. 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 more than 900,000 km^2 where it reduces *M. tanajoa* populations by at least 50%. The establishment, dispersal, persistence and population dynamics of *T. aripo* will continue to be monitored this season as the predators spread in Africa. Promising phytoseiids, especially *T. aripo* and new species adapted to periodic frost, will be released in a range of ecozones from selected countries in the cassava belt of Africa.

6.5.2. Support to national programs

by R.H., M.T., J.S.Y.- 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.

6.5.3. Impact assessment of exotic predatory mites

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

The impact of the exotic phytoseiid *T. aripo* on population dynamics of *M. tanajoa*, local phytoseiids and the production of storage-root dry matter in cassava is being evaluated in two ecozones in each of Nigeria, Benin, Togo, and Uganda. Two types of trials have been established to measure the impact of *T. aripo* on cassava yield. The first type is an on-farm trial in farmers' fields managed by the respective farmers, while the other is a standard replicated field plot trial in a research plot managed by the researchers. *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. Results from trials initiated in 1998 have not been harvested, but available data indicates that *T. aripo* continues to suppress *M. tanajoa* densities by at least two thirds.

6.5.4. Economic assessment of cassava green mite biocontrol in West Africa

by O.C, J.S.Y, R.H. - in collaboration with A. Adesina, C.C. Asiabaka, D. Endamana, E. Bogonon-Ganta

In three studies, we evaluated the economic impact of classical biological control of cassava green mite in Benin, Ghana and Nigeria. The results of the three studies showed that investment in biological control of cassava green mite had attractive returns to societies in the three countries. The Net Present Values from the investment in biological control have been over $14,000,000, $170,000,000, and $116,000,000 respectively for Benin, Nigeria and Ghana at the discounted rate of 10%; or $144, $98, and $195 per hectare respectively for Benin, Nigeria, and Ghana for the year 1997. The Internal Rate of Return between 1983 and 1997 is 100% or at least ten times higher than the returns to any public investment. These results clearly show substantial returns on investment in biological control of cassava green mite. Similar studies will be conducted in other countries, as impact assessment data becomes available.

6.5.5. Participatory evaluation of multiple pest and disease resistant cassava varieties in technology transfer centres.

by J.P.L – in collaboration with Y. Baguma and G. Acola (NARO)

Within the framework of the IITA/NARO cassava project in Uganda, technology centres have been identified in each of the five target Districts in order to provide a focus for the Project's activities at the community level. A key component of these technology transfer centres will be the establishment of participatory evaluation trials to provide researchers, extension staff and farmers with the opportunity to jointly assess newly developed cassava varieties. Trials were planted in October 1998 and evaluation procedures will begin in December.

6.5.6. 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. Whyte, B. Khizzah, S. Ferris, G. W. Otim-Nape, J. Gilsenan, J. Kamau, M. Onim, R. Kapinga

Areas affected by the CMD pandemic in 1997/98 were identified primarily through activities of the Whitefly IPM Project. The Project co-ordination team was subsequently successful in attracting funding from the Office for Foreign Disaster Assistance (OFDA) of USAID for a project for which the main aim was the multiplication of CMD resistant varieties in currently affected areas, in addition to areas threatened by the pandemic in 1998/99. Cassava stakeholders meetings were held in Mwanza, Tanzania and in Rakai, Uganda to develop implementation plans for multiplication activities in the Lake Zone of Tanzania and Rakai and Masaka Districts, Uganda, respectively. Stakeholders were trained in aspects of CMD and its control in the region and an additional training workshop on the specific topic of cassava plant health management was provided for extension and NGO staff in Masaka and Rakai Districts. Project activities in Kenya will strengthen existing work being funded by the Gatsby Charitable Foundation and co-ordinated by EARRNET.

6.5.7. Organize postgraduate training

by R.H., B.D.J., J.S.Y., K.W.- in collaboration with R. Boni, C. Djedji, J.A. Tumanteh, N.G. Maroya; A.R. Cudjoe, T.N.C. Echendu

Bench and on-site training courses in cassava pest management for NARS scientists were conducted in 1998. Several Ph.D. students from various African countries began their research on CBB (3), root rot pathogens (1), and cassava green mite (3). Seven post-graduate trainees were also involved in research on cassava pests over 6-12 months. One DANIDA and IFAD-sponsored student will complete his PhD on cassava green mite biocontrol in May 1999. One SARRNET-sponsored candidate will complete postgraduate training in plant pathology in 1999.

6.5.8. Collaborative research programs

by K.W., R.H., J.S.Y.

The project on "Integrated management of bacterial diseases of cassava and cowpea", a cooperative project with the Institute for Plant Pathology and Plant Protection, University of Göttingen, continued collaboration with ORSTOM, Montpellier, in serological and genetechnological methods. Collaboration with CIAT includes the implementation of the SW-IPM project on whiteflies and whitefly transmitted viruses, test of DNA probes for the detection of *Xcm*, the exchange of *Xcm* isolates and the development of integrated control methods for CBB and the elaboration of a project. A new project on the integration and adaption of the developed methods for CBB control and the identification of the mechanisms of resistance of plants started in 1998. The project is financed by the European community and is a NARS project with the University of Benin and ITRA, Togo, with IITA as associated partner and the advanced laboratories of ORSTOM/CIAT, University of Bath and University of Göttingen. Collaboration continues with the University of Amsterdam and Wageningen Agricultural University (Netherlands), University of Sao Paolo (Brazil). New collaborative efforts were established with Ecole Nationale Superieur des Etudes Agronomiques-Montpellier (France).

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(2): 125-130.

A study on the influence of planting dates on the incidence of the cassava root scale, *Stictoccocus 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*.

D'Almeida, Y A, J.A. Lys, P. Neuenschwander, O. Ajuonu, 1998. Impact of two accidentally introduced Encarsia species (Hymenoptera: Aphelinidae) and other biotic and abiotic factors on the spiralling whitefly* Aleurodicus dispersus *(Russell) (Homoptera: Aleyrodidae), in Benin. Biocontrol Science and Technology 8(1):163-173.

In early 1993, the spiralling whitefly, *Aleurodicus dispersus* (Russell), was observed in Benin for the first time, inflicting damage to ornamental and shade trees and cassava. The parasitoids *Encarsia ?haitiensis* Dozier and *E. guadeloupae* Viggiani were observed in the second half of 1993. They were known to have the same host in the pacific region, and were thought to have been introduced accidentally. The impact of these parasitoids was quantified using four surveys from 1993 to 1995 (on 2541 trees in 537 localities) and by population studies on guava. In 1993, *A. dispersus* occurred mostly in towns in the southern part of Benin,- penetration into farmland was observed later. *E. ?haitiensis* was more abundant and widespread than *E. guadeloupae*, and by 1995 it had been recovered from most (84%) of the infested localities. On guava trees, the annual peaks of *A. dispersus* population declined by ca. 80% between 1993 and 1996 during the same period parasitism rates increased. Econometric multiple regression analyses based on 996 infested trees

demonstrated that *A. dispersus* population densities, the proportion of infested trees and damage scores all declined significantly with increasing duration of the presence of the parasitoids, indicating their impact. Other variables were also significantly related to *A. dispersus* levels.

Fessehaie, A., K. Wydra & K. Rudolph. Nutritional characterization of* Xanthomonas campestris pv. manihotis *and development of a semi-selective medium. Plant Disease (in press).

Xanthomonas campestris pv. *manihotis* is a pathogen of cassava (*Manihot esculenta*) that grows rather slowly on general media and is easily overgrown by saprophytic bacteria during isolation from diseased plants. In an effort to develop a semiselective medium, the utilizationof several carbon and nitrogen sources was studied. Results of these tests provided information used to design a basal medium allowing good growth of the target organism, while suppressing growth of several common saprophytes. Additional selectivity was achieved by incorporating three antibiotics into the basal medium. The new semi-selective agar medium, designated cefazolin-trehalose agar medium (CTA medium), consisted of a basal yeast-trehalose-glucose-agar (YTGA) supplemented with 25 ug/ml Cefazolin, 1.2 ug/ml Lincomycin, 2.5 ug/ml Fosfomycin.Cycloheximide was added at 250 ug/ml to suppress fungi. Plating efficiency using 10 pure cultures of *X. campestris* pv. *manihotis* was significantly higher on CTA than on SXM medium. Isolation and recovery of *X. campestris* pv. *manihotis* from cassava leaf tissues, homogenates and soil was much higher on CTA than on starch-based, antibiotics SXM agar. When *X. campestris* pv. *manihotis* occurs in high concentrations in diseased tissue the standard YGTA medium supplemented with 250 ppm Cycloheximide appears to be satisfactory. The newly developed CTA medium should prove useful for control strategies and to identify and remove infected planting material of cassava, as well as in basicn ecological studies of the pathogen.

James, B.D., J.S. Yaninek, M. Tchuanyo, J.A. Tumanteh & N. Ntonifor. Concerns About The Cassava Root Scale,* Stictococcus vayssierei *(Homoptera: Stictococcidae) in Africa. Journal of African Zoology (in press).

James, B.D., J.S. Yaninek & P. Neuenschwander. Arthropod Pest Constraints on Cassava Production in West and Central Africa. CORAF/IITA book chapter (in press).

Legg, J. P. & S. Ogwal, 1998. Changes in the incidence of African cassava mosaic geminivirus and the abundance of its whitefly vector along south-north transects in Uganda. Journal of Applied Entomology 122:169-178.

Surveys of the incidence of African cassava mosaic disease (ACMD) and its whitefly vector, Bemisia tabaci, were made at three-month intervals in 1992 and 1993 along two south-north transects. One was in central and the other in eastern Uganda. ACMD incidence was high within the northern localities of each transect and tow towards the south. Incidence increased over the period at localities on the ACMD epidemic 'front' which was the interface between high incidence areas to the north and low incidence areas to the south. Combining data for both transects, the relationship between 'infective potential' (the product of whitefly number and the incidence of ACMD attributed to the use of infected cuttings, 'x') and the increase in proportion of infected plants caused by whiteflies ('y', as transformed to account for multiple infection) was described by the straight line regression: $y = 47.8x + 9.2$ (F ratio = 63.0, r-2 = 0.78). This emphasises the importance for control of reducing ACMD incidence by phytosanitation and/or use of resistant varieties since reduction of whitefly numbers is not easily achieved. Possible mechanisms for the expansion of the ACMD epidemic and implications of the study findings for control of ACMD are discussed.

Legg. J.P. & M. Raya, 1998. Survey of cassava virus diseases in Tanzania. International Journal of Pest Management 44:17-23.

A survey was carded out of African cassava mosaic geminivirus and cassava brown streak virus diseases (ACMD and CBSD) in Tanzania. ACMD occurred throughout the country at low to moderate incidences in the fifteen different regions surveyed (1-64%). The incidence was generally higher along the coastal plain than in higher altitude areas in the interior. There was a significant correlation between numbers of adults of the whitefly vector, Bemisia tabaci, and incidence of recently infected plants (R = 0.77, p lt 0.01), although most infection was attributable to the use of infected cuttings. CBSD was more restricted in distribution and, where present, incidence was low to moderate (136%). Cassava plantings along the southern border with Mozambique link the highest incidence area on the south-east coast near Mtwara, with the other important area of CBSD incidence along the shore of Lake Malawi. The effects of climatic parameters on ACMD and CBSD incidence are discussed. The survey data suggest that both diseases could be controlled in Tanzania by the use of phytosanitation which involves the use of disease-free planting material and the removal (roguing) of diseased plants.

Stäubli-Dreyer B., P. Neuenschwander, B. Bouyjou, J. Baumgaertner & S. Dorn. The influence of temperature on life table of* Hyperaspis notata. *Experimental and Applied Entomology (in press).

The coccinellid *H. notata* was introduced into Africa for the biological control of the cassava mealybug, *P. manihoti*. Two cohorts of strains, one originating from Southern Brazil and Paraguay feeding on *P. manihoti*, and one from Colombia feeding on *P. herreni* were studied at different temperatures between 15 and 34 C and age-specific life tables were constructed. Although in the areas of origin the climatical conditions and the food sources are different, the survivorship and developmental times at the same temperature differed little

among the two strains, the Colombian strain being slightly more tolerant to high temperatures. Jacknife estimates of the intrinsic rates of increase (r_m) peaked very close to 30 C for the two strains.

Yaninek, J.S., B. Mégevand, B. Ojo, A.R. Cudjoe, E. Abole, A. Onzo & I. Zannou, 1998. Establishment and spread of* Typhlodromalus manihoti *(Acari: Phytoseiidae), an introduced phytoseiid predator of* Mononychellus tanajoa *(Acari: Tetranychidae) in Africa. Environmental Entomology 27:1496-1505.

The phytoseiid predator, *T. manihoti*, was introduced into the cassava belt of Africa from South America against the exotic mite pest, *M. tanajoa*, beginning in 1988. The first population to become established was released in 1989. Establishments are now found in Benin, Burundi, Ghana, and Nigeria where they cover an area estimated at 4300 km^2. *T. manihoti* dispersed at a rate of 3.3 km per year, spreading five times faster during the dry compared to the wet season in proportion to the frequency of surrounding cassava fields. Populations of *T. manihoti* fluctuated with the seasonal abundance of *M. tanajoa*. Established populations comprised a quarter of the phytoseiids found on cassava with a higher proportion present during the dry season. *T. manihoti* was recovered from 12 species of plants including five Euphorbiaceae besides cassava. Evidence of *T. manihoti* establishment in only part of the cassava belt suggests the search for other natural enemies of *M. tanajoa* in Africa should continue.

Conference papers, workshop proceedings, abstracts, newsletters

Ariyo, O.A., A.G.O. Dixon & G.I. Atiri, 1998. Relative resistance of some newly developed cassava cultivars to African cassava mosaic disease. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 47.

Twenty five IITA-improved cassava cultivars, were evaluated on the field in IITA, Ibadan for relative resistance to African cassava mosaic virus disease. These cultivars were exposed to natural infection by the viruliferous whiteflies (Bemisia tabaci). ACMD incidence (DI) and index of symptom severity (ISS) calculated on a scale of 1 (no symptom) - 5 (every severe) were the two major parameters used in evaluating the relative resistance of these cultivars. The parameters used in evaluating the relative resistance of these cultivars. The evaluation made was based on the rank sum method (i.e. adding DI and ISS ranks for each cultivar). Isu and TMS 30572 were observed to be highly susceptible to ACMV infection through this method. Clones 94/0270, 82/00058, 91/0326 and 92B/00061 were susceptible. Plants of clones 92/0325, 92/0342, 4(2) 1425, 92/0427, M94/0177 and TME-1 were moderately susceptible. Moderate resistance was observed in plants of clones M94/0192, 92B/00068, 92/0057, 94/0237, 92/0398 while plants of clones M94/0461, 91/02324, 91B/00455, 91/02327 and M94/9583 were resistant to the virus infection. Immunity as a for of resistance was observed in none of the clones screened.

Assigbétsé, K., V. Verdier, K. Wydra, K. Rudolph & J.P. Geiger. Genetic variation of the cassava bacterial blight pathogen,* Xanthomonas campestris pv. manihotis*, originating from different regions in Africa. IX International Conference on Plant Pathogenic Bacteria, Madras, India, August 26-29, 1996 (in press).

Dara, S.K., C.J. Lomer & J.S. Yaninek, 1998. Fungal pathogens of mites on cassava: Field and laboratory studies. Abstracts of the Society for Invertebrate Pathology, 31st Annual meeting, Sapporo, August 1998.

This is an update on the research activities going on at the Biological Control Centrer for Africa of the International Institute of Tropical Agriculture on microbial control of mites on cassava. A classical biocontrol program is currently carried out with the introduction of Brazilian isolates of the fungus, *Neozytites floridana* (Zygomycetes: Entomophthorales) against the cassava green mite, *Mononychellus tanajoa* (Acari: Tetranychidae). This presentation covers the seasonal incidence of the fungal pathogens in two species of mites on cassava in Benin and the results of tests that compared the virulence of the Brazilian and Beninese isolates of *N. floridana* against *M. tanajoa*. Extensive seasonal studies conducted in different parts of Benin identified two fungal pathogens viz., *N. floridana* and *Hirsutella thompsonii* (Deuteromycotina: Hyphomycetes) infecting *M. tanajoa* and *Oligonychus gossypii* (Acari: Tetranychidae). While the Brazilian isolates of *N. floridana* cause epizootics in *M. tanajoa* populations in their native country, their Beninese counterpart occurs at a low level. The virulence of Brazilian and Beninese isolates of *N. floridana* was compared against *M. tanajoa* in different bioassays. In one bioassay that compared a Brazilian isolate with a Beninese isolate against the males and females of *M. tanajoa*, the former was significantly ($P < 0.005$) more virulent in three out of five tests. In another bioassay, which compared three Brazilian isolates with a Beninese isolate against the female mites, one of the exotic isolates was found to be more virulent than the rest.

Dara, S.K. & C.J. Lomer, 1998. Influence of imidacloprid on the germination* Neozygites floridana *(Zygomycotina: Zygomycetes) and* Hirsutella thompsonii *(Deuteromycotina: Hyphomycetes). Abstracts of the Society for Invertebrate Pathology, 31st Annual meeting, Sapporo, August 1998.

In the light of the recent findings on the synergistic effect of the chloronicotinyl insecticide, imidacloprid on entomopathogenic fungi and nematodes, this study was conducted to evaluate its influence on the germination of two fungal pathogens, *Neozygites floridana* and *Hirsutella thompsonii*, of mites on cassava in Benin. Four concentrations of imidacloprid (50, 100, 200 and 500 ppm ai) were tested on the conidial germination of the two pathogens. Both the germination of primary conidia and formation of capilliconidia of *N. floridana* were significantly reduced ($P < 0.05$) at all concentrations of the insecticide (0-66% conidial

germination and 0-37% capilliconidia formation) compared to the untreated controls (81-85% conidial germination and 63-69% capilliconidia formation). However, the germination of *H. thompsonii* did not seem to be influenced by imidacloprid. Capilliconidium is the infective stage of *N. floridana* and hence the infection by the pathogen will be seriously inhibited by imidacloprid.

Fanou, A., K. Wydra, M. Zandjanakou, P. Le Gall & K. Rudolph, 1998. Studies on the survival mode of* Xanthomonas campestris *pv.* manihotis *and the dissemination of cassava bacterial blight through weeds, plant debris and an insect vector. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 116.

Cassava bacterial blight (CBB) is an epidemic disease, that can cause devastating losses in most regions where cassava is grown. To develop recommendations for an integrated control of the disease, survival modes of the causal agent and the possible propagation of the disease through weeds, plant debris and by an insect vector were studied. *Xanthomonas campestris* pv. *manihotis* (*Xcm*) survived epiphytically on most of the frequently occurring weeds until the end of their life cycle in cassava fields. Epiphytical survival of *Xcm* was observed up to 30 days on *Solanum nigrum*, *Tridax procumbens*, *Talinum triangulare*, *Maricus alternifolius*, *Pupalia lappaceae*, *Brachiaria deflexa* and *Dactyloctenium aegyptium* under field conditions. When leaves of the weeds were infiltrated with *Xcm* in the glasshouse, the survival reached 2 months on *Vernonia cinerea*, *Dactyloctenium aegyptium* and *Brachiaria deflexa*. Since weeds grow frequently in cassava and close to cassava fields, the pathogen may be disseminated from weeds within and between cassava fields during the wet season. When infected debris were kept on the soil surface, *Xcm* survived at least 2 months, but slightly covered with top soil or buried in soil, the survival did not reach 2 months. Under glasshouse conditions, the survival was less than 2 months and reached at least 2 months, when the debris mixed with soil and unmixed debris were moistened 3 times a week, respectively. When mixed and unmixed debris were not moistened, *Xcm* survived at least 5 and 4 months, respectively. Thus, infected leaves, which drop in the field at the end of the wet season can be an inoculum source and infect young cassava plants in the new cropping season. After feeding on infected plants, *Xcm* was detected on the mandibles, legs, in the alimentary canal and the feces of *Zonocerus variegatus*. Angular leaf spots developed when moistened feces were placed on scarificated leaves, in holes of leaves and on the adaxial as well as the abaxial surface of intact leaves. So the bacteria can also be transmitted by *Zonocerus variegatus*, in fact it was observed in the field that the feces could be maintained on the adaxial surface of cassava leaves for a while during the wet period.

Fanou, A., K. Wydra & K. Rudolph, 1998. Role of insect vectors and weeds in epidemiology of cassava bacterial blight. Abstracts of Deutsche Pflanzenschut-tagung, Halle, Germany, pp. 287-288.

Many insects and weeds are associated to cassava during its long growth cycle. Most of these insects are cassava leaf feeding insects. As for weeds, they occur in all cassava production areas and compete strongly with cassava during the rainy period when Cassava Bacterial Blight (CBB) occurs heavily. Under these conditons, insects and weeds are supposed to be implicated in the epiphytic survival and in the dissemination of *Xanthomonas campestris* pv. *manihotis* (*Xcm*), the causal agent of CBB. Two studies were undertaken to determine the role of *Zonocerus variegatus* (L.) and certain weeds in the spread of *Xcm* during the rainy season. After feeding for one week on cassava plants artificially infected with a marked strain (resistant to two antibiotics), *Xcm* was detected on the mandibles, legs, in the alimentary canal and in the faeces of the insects. The mandibles, legs and the alimentary canal carried few bacteria, while the feces lodged more bacteria, which kept their pathogenicity. In fact, angular leaf spots developed when moistened feces were maintained on scarified leaves, in holes on leaves, and on the adaxial as well as the abaxial surface of intact leaves. Testing the duration of the viability of *Xcm* on and in the insects, it appeared that the survival of the pathogen on legs and mandibles did not reach up to one week. In contrary, the pathogen survived more than one week, but not up to two weeks in the alimentary canal and the feces. Many angular leaf spots and some blight were observed on previously healthy plants when the infected *Z. variegatus* were transferred from infected plants to a CBB free field. But, we could not isolate the original marked strain from these symptoms. From glasshouse experiments, where leaf spots developed from moistened feces maintained on the adaxial surface of intact leaves, we conclude that *Z. variegatus* can contribute to the dissemination of the disease. In fact, in the field, the adaxial surface of cassava leaves can maintain the faeces for a while during the rainy period. In a field inoculated with the marked strain, 15 frequent weed species were collected periodically to detect the pathogen. *Xcm* survived epiphytically for at least four weeks on: *Solanum nigrum*, *Tridax procumbens*, *Talinum triangulare*, *Maricus alterfolius*, *Pupalia lappacea*, *Brachiaria deflexa* and *Dactyloctenium aegyptium*. In a glasshouse experiment, 13 weeds were infiltrated with *Xcm* inoculum. *Xcm* multiplied on most of the infiltrated weeds and survived more than one month on most of them as epiphytic population without producing symptoms. The survival of the pathogen reached two months on *Vernonia cinerea*, *Dactyloctenium aegyptium* and *Brachiaria deflexa*. This study revealed that weeds are an inoculum source of *Xcm*. Since weeds are frequent in and close to cassava fields during the rainy season, it appeared that the pathogen can be spread easily from these weeds in and between cassava fields. Thus our recommendations are to keep cassava fields and borders free from weeds during the rainy season.

Fanou, A., K. Wydra, M. Zandjanakou & K. Rudolph, 1998. 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. Abstracts of the International Congress of Plant Pathology, Edinburgh 1998.

Fessehaie, A., K. Wydra, J.D. Janse & K. Rudolph, 1998. Biochemical/ physiological characterization and detection methods of* Xanthomonas campestris pv. manihotis, *the causal organism of cassava bacterial blight. Abstracts of Deutsche Pflanzenschutztagung, Halle, Germany, p. 248.

The pathogen of cassava bacterial blight, *X. campestris pv. manihotis* (hereafter referred to as *Xcm*), was characterized by biochemical/physiological, pathogenic, and genetic features. After studying the nutritional requirements a semiselective (Cefazolin Trehalose Agar) medium was developed for selective isolation and detection of *Xcm* from cassava plants and from soils. Proteins extracted from Xcm strains and other bacterial species were analyzed by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) and immunoblotting. Strains of *Xcm* revealed homogeneous SDS-PAGE protein profiles stained by Coomassie Blue or processed by immunodetection. All the *Xcm* strains tested could be distinguished by at least one specific protein band of approximately 26-28 kDa from other pathovars of *X. campestris*. The specific protein band was used to raise a specific polyclonal antiserum and shall be very useful in conjunction with the newly developed semiselective medium for bacterial detection and epidemiological studies of cassava plantings and seeds. Fatty acid analysis using liquid-gas chromatography (LGC) discriminated 174 strains of *Xcm* below the pathovar level. Principal component analysis of fatty acids revealed that the African strains formed a rather homogeneous group. Nine of the strains from South America and Asia belonged to this group, while the other 21 non-African strains were heterogeneous among themselves, differed from the first group and did not form a homogeneous group. However, these characteristics were not correlated with virulence. Moreover, our data of fatty acid profiling demonstrate the potential and usefulness of the LGC method to characterize the diversity of the cassava bacterial blight pathogen. Carbon substrate utilization profiles were obtained using the Biolog GN MicroPlate system. Typical patterns for all *Xcm* strains were detected. The dendogram generated from cluster analysis of carbon utilization profiles showed 3 main clusters. Strains forming distinct clusters revealed no correlation to origin or virulence. This system may be useful for the identification of *Xcm* isolates. African strains metabolized starch only weakly, while Latin American and Asian strains varied widely in their ability to use starch, and their average starch metabolization was about 10 times higher than that of the African strains. Additional analysis of amylase activity revealed quantitative differences in the production of a-amylase. Strains from Latin America and Asia were heterogeneous in amylase activity. Inoculation of the susceptible cassava cultivar Agric with 47 *Xcm* strains collected from different ecozones of Nigeria and Uganda revealed six levels of virulence indicating a high diversification of the pathogen. Strains assayed for genotypic markers using a range of DNA-based techniques allowed the observance of genetic diversity within African *Xcm* population. New RFLP groups are now described in West Africa. In conclusion, although all *Xcm* strains possessed one specific protein band after SDS-PAGE, considerable variability was found in metabolic fingerprints by the Biolog system, fatty acid composition, amylase activity, genetic markers and virulence. These data allowed the distinction of different subgroups within the studied strains of *X. campestris* pv. *manihotis*. However, no correlations were found between different physiological and biochemical characteristics, genetic groups, virulence, or geographic origin.

Hanna, R., J.S. Yaninek, M. Toko, A. Onzo, D. Gnanvossou, D. Ojo, I. Zannou & G. Paraiso, 1998. Current status of cassava green mite* Mononychellus tanajoa *Bondar (Acari: Tetranychidae) biological control in Africa. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 68.

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 *Typlodromalus 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.

James, B.D., J.P. Legg, J.B. Gbaguidi, D. Annang, C.C. Asiabaka, A.R. Cudjoe, T.N.C. Echendu, N.G. Maroya, N.Ntonifor, N. Ogbe, F., Salawu, R.A., Tumanteh, J.A. Understanding Farm-level Epidemiology of Cassava Mosaic Disease. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 122.

In West and Central Africa, the project 'whiteflies and whitefly transmitted viruses' of CG System-wide IPM Programme is building upon close partnership with national agricultural researchers and a budding farmer participation in IPM to develop appropriate plant protection technologies and practices in the management of

the cassava mosaic disease (CMD). Part of the project activities in Ghana, Benin, Cameroon and Nigeria have been the estimation of primary CMD incidence jointly by researchers and farmers and the initiation of farmer participatory trials to understand and reduce primary incidence of cassava mosaic in principal agroecological zones. In collaboration with specifically trained extension agents, the project had also completed a season of field trials to investigate *Bemisia* whitefly population dynamics and compare the rate of CMD spread into 'healthy' plantings of cassava in contrasting agroecologies in the target countries. This paper presents preliminary results obtained from these activities focusing on the need for greater farmer participation in technology development and testing for CMD control.

Le Gall P. Importance du manioc dans l'alimentation de l'acridien ravageur,* Zonocerus variegatus *(Linne, 1758). IV ° Colloque International francophone d'Entomologie, St Malo, July 1998, Ann. Soc. Entomol. Fr.(in press).

Zonocerus variegatus (Linné, 1758) fait partie du cortège d'insectes ravageurs du manioc. Nous présentons ici la synthèse des observations réalisées au cours de cycles annuels dans des champs de manioc au Congo et au Bénin, ainsi que les résultats de prospections étendues au Bénin, mais concentrés sur des périodes de temps plus courtes. Que ce soit en saison des pluies ou en saison sèche, le manioc est la ressource alimentaire principale de *Z. variegatus* dès que la population est constituée d'individus des stades juvéniles 4 et au-delà. Le taux d'insectes ayant consommé du manioc peut dépasser à certaines périodes, fin de saison sèche, début de saison des pluies, les 80% de la population. Les jeunes criquets ne consomment généralement pas de manioc, d'où une décroissance de l'importance de cette plante dans le régime alimentaire des populations après les périodes d'éclosion, fin de saison des pluies et début de saison sèche. L'impact de la déprédation par *Z. variegatus* sur la production n'est pas encore clairement établi. Les observations déjà réalisée doivent être revues à la lumière des résultats indiquant une défoliation chronique, moins importante quantitativement, mais largement distribuée sur toute la vie du plant de manioc. Les études de terrain précisent ainsi le cadre dans lequel devront se dérouler des expériences sur l'impact économique de *Z. variegatus*.

Le Gall P., E. Mingouolo & G. Bani: Comportement nutritionel de* Zonocerus variegatus *(Linné, 1758) vis-a-vis de trois de ses plantes alimentaires. Insect Sci. Applic. (in press).

Une lutte efficace contre *Zonocerus variegatus* implique l'usage de sources attractives. Nous avons classé l'attrait de *Zonocerus* pour trois plantes, *Manihot esculenta*, *Chromolaena odorata*, *Vernonia amygdalina*, par des expérimentations au laboratoire, car ces quatre éléments ne se rencontrent pas en même temps sur le terrain.

Vernonia amygdalina est la plante préférée lors de présentation de la plante entière. Si la plante est coupée, alors c'est le *M. esculenta* qui est mieux consommé, mais la différence est faible et le choix varie journellement. Dans tout les cas, *C. odorata* est la moins consommée des trois plantes. Sur *V. amygdalina* le transit intestinal est beaucoup plus court qu'avec les deux autres. *C. odorata* induit le temps de transit le plus long. Le temps passé sur*V. amygdalina* avant le repas est très court, la prise de nourriture longue et unique. Tandis qu'avec le *M. esculenta* et *C. odorata* on observe un temps d'attente plus long et deux (*M. esculenta*) ou trois (*C. odorata*) repas successifs. La durée totale des repas est proche pour *V. amygdalina* et le *M. esculenta*, beaucoup plus court pour *C. odorata*.

V. amygdalina apparaît comme une excellente candidate pour fournir un appât actif envers *Z. variegatus*. Elle est déjà utilisée comme haie, ou comme aliment ce qui limite son emploi comme substrat à des agents chimiques, mais pas avec des champignons entomopathogènes (*Metharizium*). Autre avantage, cette plante ou ses extraits seront efficaces même dans des environnements saturés par *C. odorata*.

Legg, J.P. & B.D. James, 1998. Tackling whitefly and whitefly-borne virus constraints to cassava and sweetpotato in Africa: aims, approach, and progress of the CGIAR whitefly IPM project. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 64.

The 'whitefly IPM project' is the first operational project under the framework of the system-wide programme for Integrated Pest Management of the Consultative Group for International Agricultural Research. Whilst the Project is under the overall co-ordination of the International Centre for Tropical Agriculture (CIAT), it has been sud-divided in four sub-projects, two base in Latin America and the other two in sub-Saharan Africa. Sub-Project 4 focuses on whiteflies as vectors of viruses of cassava and sweetpotato in nine African countries. A two-year diagnotic phase was initiated towards the end of 1997 and by October 1998 diagnostic surveys had been completed in seven of the nine target countries. A key feature of the work has been the use of standardised protocols for the collection, field assessment and characterisation of whiteflies and whitefly-born viruses of cassava and sweetpotato across the major African production zones of the two crops. The primary aims of the diagnostic phase of the project, the methodological approach and preliminary results are discussed.

Legg, J.P., P. Sseruwagi, V. Aritua, J. Kamau, S. Ajanga, S. Jeremiah, G.W. Otim-Nape, A. Muimba-Kankolongo, R. Gibson & J.M. Thresh, 1998. The pandemic of severe cassava mosaic disease in East Africa: Current status and potential future threats. Presented at EARRNET/SARRNET Regional Workshop, Lusaka, Zambia, 71-21 August, 1998.

Lokko, Y., A.G.O. Dixon & S. Offee, 1998. Combining ability analysis of resistance to cassava mosaic disease in cassava. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 108.

Thirty-six F1 crosses were produced in a design II mating scheme, involving 4 improved clones as females and 9 African landraces as males. The parents and the progenies were evaluated for their reactions to cassava mosaic disease (CMD) under natural infection in three environments in Nigeria (Ibadan, 1996 and 1997 and Mokwa, 1997). The objectives were to determine the relative importance of general combining ability (GCA) and specific combining ability (SCA), estimate heterosis, and compare line and topcross performance for resistance to CMD. The results showed that the genetic variation among crosses was predominantly due to GCA of the male parents. The on-degree orthogonal contrasts (parents versus crosses) for mid-parent heterosis was significant. Line performance was significantly correlated with topcross performance, indicating that parental performance can be used to predict progeny performance.

Makumbi-Kidza, N.N, P.R. Speijer, & R.A. Sikora, 1998. Incidence of Root-Knot Nematode infection on cassava in Northern Uganda. ESN Conference Edinburg, Scottland, UK, 3-9 August 1998, p. 68.

Cassava, *Manihot esculenta* (Crantz), is one of the major food crops in sub-Saharan Africa., including Uganda. To establish incidence and severity of root-knot nematode (*Meloidogyne* spp.) damage on cassava, a survey was conducted in three northern districts of Uganda. Three to nine months old plants were assessed, using a galling index for feeder roots on a scale of 0 (no damage) to 5 (severely damaged). In Masindi district, in north-western Uganda, galling was present in 72.2% of fields visited and the average galling index was 2.4. Contrary to Lira- and Apac-districts, in north-eastern Uganda, where galling was present in only 41.6 % of fields visited, while the galling index never exceeded 0.7. The dominant cassava cultivars grown, being Nase 2 in Masindi and Bao and Ebwanateraka in Lira-Apac were susceptible to root-knot nematodes in pot experiments. The higher incidence of root-knot nematode damage on cassava in Masindi may therefore be explained by the type of cropping system practiced and a prevalence of sandy soils, which generally support an increased root-knot nematode development. In Masindi farmers often grow cassava in monoculture and do not always rotate the crop due to lack of land. Tobacco, which is highly susceptible to root-knot nematodes, is being intensively cultivated, which may be an additional reason for the higher incidence of root-knot nematode damage. In Lira and Apac farmers grow a wide range of intercrops, including millet and groundnuts, and soils in these districts generally have a higher clay content, when compared to Masindi soils, both factors may be less favorable for root-knot nematode development.

Msikita, W., B. James, H.T. Wilkinson & J.H. Juba, 1998. First report of* Macrophomina phaseolina *causing pre-harvest cassava root rot in Benin and Nigeria. Plant Disease 82:1402.

Msikita W., J.S. Yaninek, M. Ahounou, R. Fagbemissi, F. Hountondji & K. Green, 1998. Identification and characterization of* Fusarium *spp associated with cassava chips. In: Akoroda, M. and Ekanayake, I.J. (eds). Proceedings of the Sixth Triennial Symposium of the International Society of Tropical Root Crops-Africa Branch, 22-28 October 1995, Lilongwe, Malawi, pp. 136-139.

Cassava chips care an important form of preserved food product in West Africa. In storage, the quality of chips deteriorate within three months. A study was conducted to identify, and characterize fungi associated with the deterioration of the stored chips. chips were collected from over 100 sites in four countries of West Africa, and infected portion were cut out and cultured on potato dextrose agar (PDA). Fungi grown on the media were observed under a compound microscope, and species identification using standards. Four species of Fusarium (avencaeum, moniliforme, seemitectum, and solani) were isolated from over 75% of collected chips. There was no association of species with tsite of collection. F. moniliforme was the most prevalent species. Conidiation and growth of the species was observed under four ranges of temperature (20, 25, 30, 35c), light and dark incubation. Growth and conidiation varied by species, and was significantly affected by temperature, but not light. For all species, the est frowth was attained at 25C and least at 25C. In pathogenicity studies of two weeks old tranplanted cassava stems (Cultivar "Agriculture"), F. solani and F. moniloforme induced variable degrees of wilting. This is the first report of F. moniloforme causing disease in cassava.

Muimba-Kangolongo, A., J.M. Teri, N.M. Mahungu, M.C.M. Porto, C. Jerico, J. Mukumbira, A. Zacaria & E. Kanju, 1998. Rate of re-infection and prospects for control of african cassava mosaic disease in Southern Africa. In: Akoroda, M. and Ekanayake, I.J. (eds). Proceedings of the Sixth Triennial Symposium of the International Society of Tropical Root Crops-Africa Branch, 22-28 October 1995, Lilongwe, Malawi, pp. 157-163.

The re-infection rate and spread of the African Cassava Mosaic Disease (ACMD) within plots of cassava (Manihot esculenta Crantz) plants grown from either symptom-less or diseased cuttings of various clones were evaluated in different agroecological zones of Southern Africa. The study assessed the feasibility of crop sanitation as a method of control of ACMD across the region and to identify sites of high and low disease pressure that can be used for screening for resistance to the disease and multiplication of healthy propagation materials. Cassava genotypes, source of cuttings, location, seasonal weather changes and vector (whitefly) population each had an effect on ACMD development. Higher incidence and severity of ACMD were observed at mid and low altitudes during the warm periods when the whitefly population and activity were highest, and in plots with cuttings obtained from diseased plants of susceptible clones. ACMD control

could be achieved in locations with high disease pressure by introducing resistant or tolerant clones whereas in those areas with low disease pressure, crop sanitation by selection of 'clean' planting materials and rouging of diseased plants can be used as an effective control approach.

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, 1998. Importance of cassava mosaic disease and intervention strategies to overcome its spread in the southern Africa Development Community (SADC) region. Presented at EARRNET/SARRNET Regional Workshop, Lusaka, Zambia, 17-21 August 1998.

Nukenine, E.N., Hassan, A.T. & A.G.O. Dixon, 1998. The role of amino acids in field resistance of cassava to green spider mite (Mononychellus tanajoa Bondar). In: Akoroda, M. and Ekanayake, I.J. (eds). Proceedings of the Sixth Triennial Symposium of the International Society of Tropical Root Crops-Africa Branch, 22-28 October 1995, Lilongwe, Malawi, pp. 176-183.

Studies on cassava, Manihot esculenta Crantz were carried out at the IITA, Ibadan, Nigeria in the dry season of 1992 to investigate the relationship between 15 foliar amino acids (aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, methionine, isoluecine, leucine, tyrosine, phenylalanine, lysine, and arginine) and field resistance to green spider mite, Mononychellus tanajoa Bonda. The 11 cassava cultivars with varied resistance to M. tanajoa were used. Mite population, damage and 15 amino acids in these cultivars were estimated. Glutamic acid was the most concentrated while methionine was the least concentrated amino acid in the cultivars. The cultivars varied in their concentrations of threonine, glutamic acid, alanine and lysine for data pooled over the 3rd, 9th, and 15th fully expanded leaves. Principal component analysis revealed that phenylalanine, tyrosine, leucine, isoleucine, glutamic acid and aspartic acid were important in grouping the cultivars. But mite damage reduced with higher levels of phenylalanine, tyrosine, and isoleucine. It is proposed that breeding for cultivars with high foliar concentrations of phenylalanine, tryosine, isoleucine, glutamic acid and aspartic acid will reduce leaf damage by M. tanajoa and improve the level of cassava resistance to it.

Oduor, G.I., J.S. Yaninek & G.J. de Moraes, 1998. The pathogenicity of* Neozygites cf. floridana *(Zygomycetes: Entomphthorales) to the cassava green mite,* Mononychellus tanajoa *(Acari: Tetranychidae). In: Akoroda, M. and Ekanayake, I.J. (eds). Proceedings of the Sixth Triennial Symposium of the International Society for Tropical Root Crops-Africa Branch, 22-28 October 1995, Lilongwe, Malawi, pp. 146-149.

The cassava green mite, Mononychellus tanajoa (Bondar) causes cassava yield losses of up to 80% in Africa. Emphasis on its biological control is laid on the use of predatory mites. Reports of Neozygites cf. floridana (Wiser & Muma) causing epizootics among populations of M. tanajoa aroused interest in the use of this fungal pathogen as a biological control agent. The pathogenicity of this fungus to the active development stages of M. tanajoa was tested at 28C, 12L:12D photoperiod and 90-100% RH. Both the percent mortality and time to death after infection were significantly affect by the mites-development stage. Mortality among larvae (77.8%) and protonymphs (74%) was significantly lower than among adult females (96.9%) and males (98.2%). The period of time from infection to death were significantly longer among larvae and protonymphs (76.3 and 77.2 hr, respectively), compared to adult females and males (66.9 and 58.7 hr, respectively). Between 75.7 and 93.2% of the infected mite died during the scotophase.

Ogbe, F.O., G.I. Atiri, G. Thottappilly, A.G.O. Dixon, H.D. Mignouna & F.M. Quin, 1998. Evidence of double infection and random occurrence of cassava begomoviruses in sub-Saharan Africa. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin.

Good knowledge of the occurrences of cassava geminiviruses namely African cassava mosaic (ACMV) and East African Cassava Mosaic (EACMV) begomoviruses would enhance effective control of Cassava Mosaic Disease (CMD) in Africa. Diagnostic survey conducted in Nigeria in 1997 indicated that ACMV and EACMV occurred both in single and double infections. These findings together with recent detection of EACMV in Cameroon, Togo, Western Kenya, Western Tanzania and north-eastern Zambia where only ACMV was known to occur provides evidence for probable random occurrences of both viruses in sub-Saharan Africa. The implication of double infection of the two viruses on the development of new strains/variants that could cause outbreak of severe CMD is noted. The need for responsive breeding and genetic engineering programmes for the development of durable resistant cassava clones is emphasized.

Onyeka, T.J., A.G.O. Dixon, T. Ikotun & K. Wydra, 1998. Reactions of elite cassava genotypes to root rot disease and the role of different micro-organisms. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin.

Otim-Nape, G.W., J.P. Legg, J.M. Thresh & T. Alicai, 1998. Advances in research on severe cassava mosaic epidemic in Uganda. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 61.

A severe cassava mosaic disease (CMD) was first reported in November 1988 in Buruli county, Luwero district where it had destroyed over two thousand hectares of cassava. It subsequently spread and covered the rest of the country causing serious devastation. Each year since 1988, the epidemic moved southwards, towards Kampala, at a rate approximately 20-30 km per annum. It is concluded that the epidemic originated

from more than one place from northern parts of Uganda and spread southwards along a broad from several km wide. The cause of the epidemic has been investigated. Because the C isoltes differed consistently, and in a characteristic way, from both EACMV and ACMV, they have been subsequently referred to as the Uganda variant (UgV), which has arisen through recombination between the two similar viruses which have been in East Africa since 1894. The role of the whitely in the epidemic development and substainability of the epidemic and methods of the epidemic control are discussed.

Raji, A.A., A.G.O. Dixon & T.A.O. Ladeinde. 1998. Genetic diversity among Nigerian cassava landraces resistant to cassava mosaic disease. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 111.

Eleven landraces resistant to the cassava mosaic disease, selected from the collection of Nigerian landraces maintained at the International Institute of Tropical Agriculture (IITA), were assessed together with an improved CMD resistant cultivar (TMS 30572) and a susceptible check (IŞU) for the levels of genetic diversity among them for possible utilization in the breeding program. Large genotypic variation was observed among landraces for their reactions to CMD and CGM. In addition, there significant genetic variation among these landraces for various agronomic and food quality characteristics. Additional sources for resistance far better than the popular improved cultivar, TMS 30572, especially to the cassava mosaic disease and cassava green mite were identified. Principal component analysis using the correlation matrix of 53 agrobotanical characteristics identifed five distinct groups of clusters among these cultivars. TMS 30572 and an offspring of the *Manihot glaziovii* derivative (58308) which has been the sole and extensively used source for resistance to CMD, was found to be genetically unrelated to the sources of resistance to CMD identified among the landraces.

Seruwagi, P., J.P. Legg, V. Aritua, B. Odong & G.W. Otim-Nape, 1998. Farmer awareness and assessment of whiteflies and whitefly-borne virus diseases of cassava and sweetpotato in Uganda. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 65.

A survey was conducted to assess farmer knowledge and management of whiteflies and whitefly-borne virus diseases of cassava and sweetpotato in Uganda. A relatively small proportion of farmers (22%), were able to recognize whiteflies on both crops. In contrast, the diseases CMD and SPVD where both more highly recognized (100 and 48%, respectively) and were commonly described by the mottling or deformation of leaves. Virtually all cassava farmers recognized CMD as the most important production constraint, whereas for SPVD, only 35% considered it to be a problem. The majority of cassava farmers (74%) and 38% of sweetpotato farmers considered that CMD and SPVD, respectively, were becoming more severe. Whilst cassava farmers assessed losses to CMD as more than 75% of production, sweet potato farmers indicated losses less than 25% of production. Over 30% of farmers considered selection of disease-free planting material and rouging as the most important practices for controlling both diseases. Less than 20% of cassava farmers and none of the sweetpotato farmers had resistant varieties.

Wydra, K., A. Fanou, & K. Rudolph, 1998. Effect of cassava bacterial blight on cassava growth parameters and root yield in different ecozones and influence of the environment on symptom development. Abstracts of the Seventh Symposium of the International Society for Tropical Root Crops-Africa Branch, 11-17 October 1998, Cotonou, Benin, p. 115.

In Africa, diseases are among the most important constraints to cassava production with losses estimated at 25 Mio tons per year. Recently, severe epidemics of cassava bacterial blight are reported from different areas in West Africa [1]. The present studies aimed at elucidating the effect of ecozone on disease development and yield loss due to CBB. Field experiments were conducted in 4 ecozones, using the susceptible variety Ben 86025 and the 'resistant' variety TMS 30572, planted in a nested arrangement of inoculated and non-inoculated plots. In each ecozone cassava plants were spray-inoculated with a virulent strain of *Xanthomonas campestris* pv. *manihotis*, incitant of cassava bacterial blight, originating from the same area. Both, inoculated and non-inoculated fields were also naturally infected with CBB. Symptoms were evaluated every 3-4 weeks during the rainy season and plant growth data were collected after 6 and 12 months. CBB reduced root yield by 21-69% and 0-50% of the susceptible variety and by 8-50% and 0-41% of the 'resistant' variety after 6 and 12 months, respectively. The resistant variety generally developed fewer symptoms, but the susceptible variety generally yielded higher root weights. Yield loss due to CBB varied with ecozone. In the dry savanna zone only the relative root yield loss was higher in the susceptible variety than in the 'resistant' variety, and disease severity of the susceptible variety was 30% higher. In general, the 'resistant' variety developed a lower percentage of spots and much lower percentage of blight than the susceptible variety. In the canonical correlation of disease and growth variables, die-back was the most important factor affecting leaves, stems and roots, while blight was the most important variable for root yield in the stepwise regression of symptoms against root weight.

Wydra, K. & W. Msikita, 1998. An overview of the present situation of cassava diseases in West Africa. In: Akoroda, M. and Ekanayake, I.J. (eds). Proceedings of the Sixth Triennial Symposium of the International Society of Tropical Root Crops-Africa Branch, 22-28 October 1995, Lilongwe, Malawi, pp. 198-206.

Surveys on the importance of cassava pests and diseases were conducted in Ghana, Benin, Nigeria and Cameroon in collaboration with the national programs. Two hundred-thirty four sites evenly distributed across all ecozones where cassava is grown were inspected in the dry and wet seasons. An overview is given on the situation of the most important diseases in the four countries in the wet season in 1994. Cassava mosaic disease (CMD) was identified as the most prevalent disease with an incidence near 100 % in all ecozones. Nevertheless, low average plant incidence was regionally observed in different ecozones (Cameroon, moist savanna: 29%, Cameroon, mountain forest: 38%, Benin, transition forest: 46%), whereas in most other regions and ecozones plant incidence was between 64% and 97%. The average severity of infected plants varied between score 2.3 and score 3.4 on a 1 to 5 scale. Cassava bacterial blight (CBB) was present in all ecozones across countries with a high regional importance in the transition forest (61% site incidence) and the savanna zones (moist savanna: 62% site incidence, dry savanna: 42% site incidence) and a low incidence in the rainforest. Plant incidence was highest in the wet savanna zone (32%). Average severities of infected plants between score 2.4 (dry savanna) and score 3.1 (transition forest) were observed. Site and plant incidence of cassava anthracnose disease (CAD) were high across countries in the rainforest (90% and 64%, resp.) and considerable in the transition forest zones (56% and 26%, resp.), while in the savanna zones this disease was less important. A high variation in average severity of infected plants between score 2 (dry savanna) and score 3.8 (mountain forest) was recorded. Cercospora leaf blight and brown leaf spots were frequent in all ecozones, mostly with high plant incidence between 50% and 98%, while white leaf spots were more expressed in the rainforest zone (plant incidence: 84%). The average severity of infected plants was low for the three Cercospora diseases. Recommendations are given for the development of control strategies adapted to the local conditions, and research needs are prioritized.

Wydra, K., A. Fanou, J.S. Yaninek & K. Rudolph, 1998. Distribution of bacterial blight in different ecozones in West Africa and the interaction of environment, symptom development and growth parameters of cassava. Abstracts of the International Congress of Plant Pathology, Edinburgh 1998.

Cassava is a major staple food for more than 400 million people in Africa, Latin America and Asia and the main carbohydrate supply for the people in many African countries, with Sub-Saharan Africa being the biggest cassava producer in the world. In Africa, diseases are the most important biological constraint, and losses contributed to diseases were estimated at 25 Mio to. Cassava bacterial blight (CBB) epidemics, which caused devastating losses in the 1970's in Africa, are recently reported from different areas in West Africa [1]. Leaf spots, leaf blight, leaf fall and systemic symptoms resulting in the formation of cankers and die-back on the stem are the typical symptoms. For diagnostic surveys, 234 sites were visited in the wet season in 1994: rain forest zone (85 sites), transition forest zone (60 sites), wet savanna (Southern Guinea savanna) (44 sites), dry savanna (Northern Guinea savanna) (19 sites), mountain zone (mid altitude and highland) (26 sites). Incidence and severity of CBB was recorded, data on 5 other cassava diseases were published elsewhere. Field experiments were set up in 4 ecozones, using the susceptible variety Ben 86025 and the "resistant" variety TMS 30572, planted in a nested arrangement. Field plants were spray-inoculated with a virulent strain of *Xanthomons campestris* pv. *manihotis*, incitant of cassava bacterial blight, from the same area. Symptoms were evaluated each 3-4 weeks during the rainy season, plant growth data collected after 6 and 12 months. Surveys in Ghana, Benin, Nigeria and Cameroon revealed that cassava bacterial blight was present in all ecozones. However, incidence and severity differed in ecozones, indicated by a higher incidence and severity in the transition forest (present in 61% of sites) and the savanna zones (moist savanna and dry savanna, present in 62% and 42% of sites, respectively) and a low incidence in the rainforest. Disease incidence of plants was highest in the wet savanna zone (32%). In Benin, fields with an average severity class of > 4 (beginning die-back) were frequently observed in the transition forest and the wet and dry savanna. Disease incidence and severity was variable comparing data of two subsequent years. Epidemiological studies on disease development on a "resistant" and a susceptible variety after artificial inoculation in different ecozones revealed a strong effect of environmental factors. In the humid forest zone of South Nigeria, the formerly resistant variety developed severe symptoms, while the same variety expressed 'field resistance' in the transition forest zone. Symptom development was variable between locations and years. Although in some locations (transition forest, dry savanna zone), tuberous root yield loss due to CBB infection was significant after 6 months, no significant loss was observed after 12 months in both varieties. Yield loss due to CBB varied with ecozones. Our recommendations for screening for resistance are multi-location trials and inoculation with a set of highly virulent strains of different geographic origin.

Project 7

IMPROVING PLANTAIN- AND BANANA-BASED SYSTEMS

by G. Blomme, J. Crouch, G. Dahal, T. Dubois, S. Ferris, C. Gold, K. Green, J. Hartman, S. Hauser, J. d'A. Hughes, C. Nolte, S. Okech, M. Pillay, P. Schill, P.R. Speijer, A. Tenkouano, M. Tshiunza, R. Vermeulen D. Vuylsteke (project coordinator)
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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. 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 to banana and plantain production 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*) and Fusarium wilt.

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

7.1. 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

7.1.1. Diagnostic surveys of pest and disease constraints to highland banana production in Uganda.

by C.S.G., S.H.O. - In collaboration with J. Ngoya, J. Ssenyonga, R. Ssendege, F. Bagamba, W.K. Tushemereirwe*

Country-wide surveys of banana production constraints have been completed. Analysis of survey data sets to explain factors underlying pest and disease distribution patterns is being conducted by an M.Sc. fellow. This work is scheduled to be completed by mid-1999.

Survey activities for banana pests and diseases are now restricted to collection of georeferenced baseline data at benchmark sites (section 7.1.3). This includes an initial survey at the onset of activities in each site and baseline data for on-farm activities. For example, an initial survey of 60 farms at the Ntungamo site, conducted in 1996, found 100-fold differences in weevil densities among farms. Crop sanitation appeared to be the only factor influencing weevil levels. Further

baseline data, taken for individual experiments (e.g. sanitation studies), will be integrated into the same data base.

Baseline pest surveys were also undertaken on 60 farms at the Masaka. Extensive socio-economic questionnaires were also administered on these 60 farms (Section 3.2). Cross section damage ranged from 1 to 12% with a mean value of 5%. Mean damage scores for the four parishes ranged from 3 to 6%.

7.1.2. 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. Ssenyonga, W. Tushemereirwe, W. Tinzaara

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 commence in mid-1999. Site protocols include a participatory rural appraisal, baseline socio-economic and pest surveys, and on-farm and farmer participatory research.

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 the use of clean planting material; selection of cropping systems and improved agronomic practices to promote plant vigor; placement of mulches; trapping; and management of crop residues. However, these methods are labor intensive and of unclear benefit. Research has included both socio-economic assessment of cultural controls through farmer interviews and studies on efficacy of these methods (Section 7.2).

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.

To understand the farm-level feasibility of cultural controls of banana weevil, a collaborative study was undertaken with NBRP and ICIPE's socio-economic unit to determine extent of knowledge of cultural controls at the site, including (1) levels of awareness, adoption, modification, rejection, abandonment and (2) how farmers monitor the costs (including labor investment) and benefits of these controls (Section 7.2).

7.1.3. Nematodes – Ethiopia

by P.R.S., C.S.G. – in collaboration with M. Bogale

In Ethiopia twenty-five *Ensete* growing sites, representative for seven agro-ecological zones, were visited in September 1997. The elevation of these sites ranged between 1523 - 2797 meters above sea level. In each site, five 1-2 year old, enset plants were sampled for nematodes present in roots. The dominant nematode species found in Enset roots was *Pratylenchus goodeyi;* followed by an *Ektaphelenchoides* sp. and *Meloidogyne* spp. Split pseudostem traps were placed in the farms to determine presence of banana weevils. However, no banana weevils, *Cosmopolites sordidus*, were encountered during the survey. Leaves of young enset plants often showed severe streak-like symptoms. The *Ektaphelenchoides* sp. was the single species isolated from these leaves and may be associated with the streak-like symptoms. A total of 71 different enset cultivar names were recorded during the survey and different levels of susceptibility to *P. goodeyi* are expected.

7.1.4. Nematodes – Zanzibar

by P.R.S., C.S.G. – in collaboration with K. Rajab, S. Salim

A survey was conducted at the end of the rainy season May - July, 1997, to understand the relative importance of pests and diseases affecting *Musa* production in the two islands of Zanzibar, Unguja and Pemba. A total of 12 representative sites with *Musa* cultivars of the genome groups ABB, AAA, and AAB were selected. Pest incidence and severity were assessed and pest impact measured by relating damage levels to plant growth parameters. In Unguja, bunch weights were

low, almost half of those in Pemba. It is most likely that in Unguja poor soil fertility (sandy, coral rag soils) is the major production constraint. This situation is aggravated by root damage, caused by *Helicotylenchus multicinctus*, *Radopholus similis* and leaf decay caused by *Mycosphaerella fijiensis*. Banana weevil damage was observed in Unguja, though it was not related to bunch weight reduction but appeared highly associated with *R. similis* and *Pratylenchus coffeae*. In Pemba, *Musa* production was mainly affected by root damage and *H. multicinctus* densities followed by *R. similis* densities. No weevil damage was observed inside banana rhizomes in Pemba. Neither rhizome surface damage due to weevils nor leaf decay were related to bunch weight reduction in Pemba.

7.2. 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

7.2.1. Identification and characterization of viruses

by J.d'A.H., P.R.S., D.V. - in collaboration with K. Rajab, G. Pietersen, J. Thomas, E. Dongo, G.I. Atiri*

Banana die-back virus (BDBV) was first isolated from banana plants of cv. Valery grown at IITA, Ibadan, Nigeria. Since then, the virus has been isolated from bananas in fields at the IITA High Rainfall Station, Onne, Southeastern Nigeria, and also from banana plants growing in farmers' fields around Ibadan, Nigeria. Serological relationships between this virus and members of the genus Nepovirus (tobacco ringspot, tomato ringspot and cacao necrosis viruses) were confirmed. However, no vector nematodes have been found. As a report on the identification of BDBV has now been published, the virus is considered a quarantinable pathogen of *Musa* spp. Diagnosis of BDBV remains by serological tests. A murine polyclonal antiserum with a titer of 1/4096 has been produced and is used in protein A-enzyme-linked immunosorbent assays as well as immunosorbent electron microscopy. Further studies on the characterization and diagnosis of BDBV with the South African Plant Protection Institute and the Queensland Department of Primary Industries, Australia have been initiated.

The incidence of cucumber mosaic virus (CMV), genus Cucumovirus, the causal agent of banana mosaic, was determined in southern Nigeria. Possible alternative hosts for the virus investigated. In a survey of banana and plantain farms in southern Nigeria, 500 *Musa* spp. symptomatic leaf samples were collected as well as samples of *Dioscorea* spp., solanaceous weeds and crop species. CMV was found in about 25% of the *Musa* spp. leaf samples, 65% of the solanaceous leaf samples and 10% of the *Dioscorea* spp. leaf samples. The physical and serological characteristics of the different CMV isolates are being studied to understand the epidemiological significance of CMV in weeds as well as the likelihood of the virus being transmitted from one crop species, or genus, to another.

For further characterisation, one isolate each from the Solanaceae, Dioscoreaceae and Musaceae were mechanically sap transmitted with ease to 10 herbaceous indicator species in three families. *Chenopodium quinoa* and *Vigna unguiculata* were useful as diagnostic hosts, developing distinct necrotic local lesions within four days of inoculation. Some *Nicotiana* spp. and *Capsicum* spp. were infected systemically and exhibited mosaic, chlorotic mosaic, puckering and vein-clearing symptoms. Purified virus particles of the isolates trapped in ISEM revealed spherical particles typical of CMV with particle diameters of 28 nm for all three isolates. The molecular weight of the coat protein sub units of the purified virus was determined by discontinuous polyacrylamide gel electrophoresis. The coat protein had a molecular weight of 29,000. This value is in the range of molecular weights reported for CMV. The virus isolates are being maintained in *N. tabacum* in the screenhouse and will be further differentiated into serogroups using RT-PCR.

7.2.2. Mode of BSV transmission and BSV-vectors-cultivars interactions

*by J.d'A.H., A.T. - in collaboration with G. Harper, J.S. Heslop-Harrison, R. Hull, R. Swennen, J. Osuji**

Results from 1997 reporting seed transmission of banana streak virus (BSV), genus Badnavirus in 150/1750 *in vitro* germinated seeds of plantain and banana hybrids should not be taken as confirming seed transmission of the virus. BSV sequences are incorporated into the host genome and it is hypothesized that tissue culture may be the stress that triggers transcription of the integrated virus and subsequent symptom expression. However, 10% of the 600 *in vivo* germinated seeds also expressed symptoms and the presence of BSV was confirmed by triple antibody-sandwich enzyme-linked immunosorbent assay. The screenhouse in which the seeds were grown were not completely insect-proofed. However, there is little published evidence of the field spread of BSV, and natural spread of the disease in the field in Nigeria has not been observed. Therefore it is likely that this study did in fact confirm the seed transmission of BSV in banana and plantain.

In a collaborative study, the possibility of using embryonic cell suspension culture to obtain BSV-free *Musa* spp. plantlets was investigated. Two plantain landraces were used for this study: Three Hand Planty and Bise Egome. Both were obtained from the International Network for the Improvement of Banana and Plantain (INIBAP) International Transit Centre, Belgium. Plants from embryonic cell suspension cultures from symptomless plants sent *in vitro* from the Katholeike Universiteit, Leuven, Belgium to IITA. The plantlets were rooted and nursed in soil and 'hardened' in an insect-proofed screenhouse for three weeks before transfer to a constant environment room (22-24°C, 12 hour photoperiod). The use of the 'cool' controlled environment room was to induce symptom expression and a concurrent increase in virus titer, thus permitting more reliable virus diagnosis. The plants were observed for symptom expression, and tested for BSV by immunosorbent electron microscopy (ISEM), enzyme-linked immunosorbent assay (ELISA) and immuno-capture polymerase chain reaction (IC-PCR) during the experimental period. All the plants of both landraces eventually tested positive for BSV by one or more of the testing methods.

Studies on the transmission of BSV have been started using BSV-'free' Cavendish cv. Williams. *In vitro* plantlets were obtained from the International Network for the Improvement of Banana and Plantain (INIBAP) International Transit Centre, Belgium and multiplied *in vitro* at IITA, Ibadan, Nigeria. Over 50 plants are being prepared for interplanting in a plot comprised entirely of BSV-infected plants of different banana and plantain hybrids. The Cavendish cv. Williams plants are scored weekly for virus-like symptoms, occurrence of potential insect vectors on the plants. Each of the plants will be tested on two-weekly by ISEM for BSV. Where symptoms are seen but no BSV is seen, the plants will also be tested for cucumber mosaic virus, genus Cucumovirus and banana die-back virus which are also endemic in Nigeria. In addition, vector transmission of BSV to BSV-free Cavendish cv. Williams with *Dysmicoccus brevipes*, *Planococcus musae*, *Ferrisia virgata* and *D. grassii* will be attempted.

7.2.3. Banana weevil life table studies - Density dependent oviposition

by C.S.G. - in collaboration with P. Nemeye

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 are being studied in laboratory experiments which are continuing into 1999. Newly trapped weevils were offered banana maiden sucker corms (highland clone Kisansa) in ventilated plastic containers (capacity 20 l) containing a 10 cm layer of moistened sand at the bottom. The test weevil densities were 5, 10, 20 and 40 females, with equal numbers of males. Corms were replaced and the number of eggs oviposited was assessed at 5 day intervals for 30 days. A fifth treatment consisted of offering 20 females corms which were changed daily.

Higher weevil densities produced greater number of eggs. Forty females produced an average 697 eggs/month, while 5 females produced 197 eggs/month. The other groups produced intermediate numbers of eggs. However, oviposition rates per female appeared to be density dependent with females producing 1.4 eggs/week in the lowest density treatment and 0.6

eggs/week in the highest density. Dissections of females at the end of 30 days showed no treatment differences in the number of mature eggs and developing oocytes.

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.

7.2.4. Banana weevil life table studies- *Population censuses*

by C.S.G, K.G. - in collaboration with P. Nemeye, H. Sintim, K. Afreh-Nuamah*

Instar number and stage duration have been determined in laboratory studies. Most weevil larvae pass through 5-7 instars. The first 4 instars can be differentiated on the basis of head capsule size, while separation of later instars is difficult. It was also possible to separate the first 4 instars of field populations on the basis of head capsule widths.

Studies to assess egg and larval mortality are being undertaken in banana plots at Kawanda A.R.I. and Sendusu Farm. In Kawanda, a trial was planted in November 1996, while in Sendusu, an existing clean planting material trial was modified by planting in existing alleys and treating blocks as plots. Treatments will include plots with and without myrmicine ants (e.g. *Pheidole* and *Tetramorium*) believed to be predacious on banana weevil. Regular censuses will be taken of the different life stages through destructive sampling of maiden suckers and flowered plants. During 1998, the selective pesticide Amdro was tested for efficacy against these ants. At the same time, workers were trained in extracting weevil larvae of all stages to prevent bias against small early instars. Actual sampling

Results from a diagnostic survey (1994-1996) showed that the severity of weevil damage in Ghana is generally low compared with damage levels reported on Highland banana in East Africa. It is hypothesized that weevil damage remains low because the plantain cropping cycle in Ghana 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 will subsequently increase. Field experiments to test these hypotheses are being conducted.

7.2.5. 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, B. McIntyre, G. Night.

The effects of soil nutrient management and amendments on plant vigor and ability to weevil pressure is being tested in an on-farm trial planted in 1996. Treatments, applied to existing plantations, included control; contour bands; contour bands plus mulch; farm yard manure; and mulch. Weevil damage was low (mean corm damage per farm ranging from 0.8 to 3.2%) and not significantly different among treatments, although weevil adult density was higher in mulched plots. Plant vigor and yield was higher on plots with improved soil management practices (contour bands, mulch and/or farmyard manure). The experiment will be concluded in 1999.

7.2.6. Responses of banana weevil to K-Mg balances

by S.H.O., C.S.G. - in collaboration with H. Ssali, B. McIntyre, G. Night.

This study, established in February 1997 in an existing banana stand, tests the hypothesis that K*Mg balances influence banana defence against weevil attack. Plant vigor was higher in plots which received N, P, K and Mg than those in plots which received N and P only. Weevil damage was generally very low in the whole farm (range 0.3 to 1.2%) and was not significantly different among treatments. However, when weevil larvae were reared on corms harvested from test plots, larval to adult development was longer (38 to 42 days) in corms from plots which received Mg compared to (35 to 38) in corms from plots which did not receive Mg. Adult weight ranged from 50 to 80 mg and was not significantly different among treatments.

7.2.7. Influence of mulch placement on soil fertility, plant growth and banana weevil population dynamics and associated damage

by S.H.O., C.S.G. - in collaboration with H. Ssali, B. McIntyre, G. Night.

The study tests the hypothesis that placement of mulch up to the base of the mat encourages weevil population and damage. The crop was planted in October 1996 and first mulch applied in February 1997. Treatments were (a) a control without mulch, (b) grass mulch placed in contact with the

pseudostem (c) grass mulch placed 50 cm away from the base of the mat and (d) grass mulch placed 100 cm away from the mat. The trial will continue through 1999.

The adult weevil population was lower in control plots, but was not significantly different among the plots which received mulch placed at varying distances from the mat. Weevil damage was not significantly different among all the treatments (range 3 to 4.2%). Mulched plots had higher yields than control.

7.2.8. Weevil distribution and movement studies

by C.S.G. - in collaboration with G. Kagezi, G. Night

Knowledge on the distribution and behavior of banana weevil may elucidate the poor relationship found between weevil adult density and damage and provide insight into management practices. For example, green manures are more likely to affect weevil populations

Banana weevil adults are seldom observed in banana fields except when they are attracted to traps. Therefore, 1500 marked weevils were released in field plots which were later dissected. Sixty-two percent of the marked weevils were recovered along with a similar number of unmarked weevils. Most weevils (65%) were found either in the base of old leaf sheaths or in the soil around the base of the mat. A third of the weevils were associated with cut crop residues, while a small number were found in leaf trash.

Trivial movement of banana weevils is being studied by marking each of 2000 weevils with a unique combination of marks. Half of the weevils were released in a mulched plot with the remainder being placed in an adjacent bare soil plot. Mat location was recorded for each weevil release site. Pseudostem traps are being placed on all mats in alternate weeks and captured weevils are identified by number and mat and then released at the base of mat. This study will continue into 1999 and should provide information on weevil trivial movement, weevil disappearance (i.e. trap catches over time) and the influence of rainfall on weevil activity.

A preliminary interpretation of results suggests that > 75% of trapped weevils which had been observed less than 1 week before were recorded on the same mats. However only 36% of weevils in the mulch and 49% of the weevils in the bare plot were recorded at the same mat when 2-3 weeks elapsed between observations. Ten weeks after release, 16% and 33% of the weevils were found at the original mats in mulches and bare plots, respectively. Similarly, 60% of the weevils in the mulch compared to 27% in the bare plot moved > 10 m in 10 weeks. Thus, a higher percentage of weevils were active and moved ove. longer distances in the mulch.

7.2.9. Biotyping of banana weevil

by C.S.G. - in collaboration with E. Osir, V. Ochieng

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 entomapathogenic nematode strains in killing weevils in Tonga and Australia.

A collaborative project on banana weevil biotypes is being initiated with ICIPE with work to begin in 1997. The primary objective of this project is to study genetic variability in banana weevil populations from different parts of the world. Such studies are crucial for a clear understanding of the insect's behavior across its geographic range, host plant resistance studies and the interaction of local populations of the pest with its natural enemies.

The genetic diversity in 13 banana weevil populations from 11 countries were analyzed by random amplified polymorphic DNA polymerase chain reaction (RAPD-PCR) using five universal primers.

From the genetic matrix data, a dendrogram, representing the genetic relationships of the weevil populations was constructed. Five well separated clusters were observed. The first cluster (Ghana, Uganda and France) had a distance of 0.105, followed by the second cluster (South Africa, Honduras and Costa Rica) with a distance of 0.136. Only Cameroon was in the third cluster with a distance of 0.183, whereas Kenya (Mbita), USA (Florida), Australia and Tanzania were in the fourth cluster and Kenya (Embu) in the last cluster. The highest cumulative mutation was observed in the fourth cluster.

It is concluded that considerable variation exists within and between banana weevil populations from different parts of the world and that the data obtained so far provides a good foundation for a more detailed study of weevil population structures.

7.2.10. Nematode-root system interactions - Ghana

by K.G., P.R.S. - in collaboration with C. Brentu, B. Hemeng*

A micro-plot experiment was conducted using single-species nematode populations, to assess the effects of different densities of individual nematode species and species combinations on the growth and yield of plantain (Apantu-pa) in Ghana. *Pratylenchus coffeae* was found to be the most devastating of the three species tested, resulting in 61% plant toppling in plots receiving a high level of infestation (10,000 nematodes per plant) (see Table 1 and completed studies).

Table 1. Micro-plot evaluation of effect of *Pratylenchus coffeae, Helicotylenchus multicinctus* and *Meloidogyne* spp. on Apantu-pa (*Musa* AAB) production in Ghana

Treatments	Bunch weight (kg)	Production (t/ha)	Fruits lost due to toppling (%)
Non-infested	12.8	14,165	0
Meloidogyne 1,000$^{\Phi}$	9.8*	10,894	0
Meloidogyne 10,000	8.9*	9,968	0
H. multicinctus 1,000	9.8*	10,834	0
H. multicinctus 10,000	9.5*	10,517	0
P. coffeae 1,000	9.4*	8,369	20
P. coffeae 10,000	8.6*	4,242*	61*
Mixture 3,000/3,000/3,000	10.1*	7,470	55

$^{\Phi}$Number of nematodes used to infest individual plants

*different (P<0.05) from the control (pair-wise comparison)

An associated series of experiments is ongoing to determine the effect of nematodes on plantain root health. Split corms from hot-water treated suckers are placed in beds of sterile sawdust and emerging roots are individually inoculated with a range of nematode densities either as single species or species combinations. The objective is to determine the relationship between nematode species / densities and resulting plantain root health (damage type, position and severity), in order to provide insight into damage mechanisms and niche displacement.

7.2.11. Nematode-root system interactions - Uganda

*by P.R.S. – in collaboration with D. De Waele, H. Talwana**

The spatial distribution of nematode populations and damage in roots of three banana cultivars widely grown in Uganda: Pisang Awak, Sukali Ndizi and Nabusa was investigated in three areas in Uganda, each with a distinctive nematode species profile. Roots were excavated from an existing experimental trial at Namulonge (Central Uganda) where *R. similis* was the dominant nematode species and an existing farmer's plantation at Ntungamo (South Western Uganda) where *P. goodeyi* was the dominant species. Three experiments were set up using hot water treated suckers of cultivars in the existing fields at Namulonge, Ntungamo and Mbarara (South Western Uganda, where *R. similis* and *P. goodeyi* coexisted). Nematode population densities were randomly distributed along the primary roots while root necrosis was significantly ($P \leq 0.05$) higher close to the corm than farther along the primary roots, independent of cultivar. The observations made by this study show that nematode damage is among the major causes of drastic yield loss in East African Highland bananas and that *R. similis* is more pathogenic than *P. goodeyi* where they coexist.

7.2.12. Nematode species profiles - Nigeria

*by P.R.S. – in collaboration with D. De Waele, O. Rotimi**

A pot trial was carried out at Onne, South Eastern Nigeria, to assess the susceptibility of two plantain (*Musa* AAB) cultivars to plant parasitic nematodes. after three months of infestation.

Four weeks old suckers of Agbagba, a False horn and Obino l'ewai, a French, plantain were infested with natural nematode population mixture of *R. similis, H. multicinctus, H. dihystera, Hoplolaimus pararobustus and Meloidogyne* spp. Infestation was at four levels: 0, 100, 1000 and 10000 *R. similis*; the reference species in the mixture. For the two genotypes, spp composition in the primary and secondary roots differed. Except for *H. dihystera*, Obino l' Ewai supported significantly more nematodes than Agbagba. *R. similis H. multicinctus*, and *Meloidigyne* spp. were positively correlated with root necrosis on Obino l'Ewai. *Meloidogyne* spp. density was positively correlated with root knot incidence for Obino l' Ewai. Not such a correlation was observed for Agbagba, however, *Meloidogyne* density was positively correlated with root necrosis. This suggests that among plantain cultivars there is a variation in nematode susceptibility and preferred location of nematode attack. *H. multicinctus* and *Meloidogyne* spp. prefer secondary roots to primary roots on the cultivar Obino l' Ewai, while no such preference was observed for Agbagba.

7.3. 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 *R. 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

7.3.1. Yield loss due to weevils under low and high soil fertility conditions.

by C.S.G., S.H.O. - in collaboration with H. Ssali, W. Tushemereirwe

This trial tests the hypothesis that bananas growing under fertile soil conditions are more tolerant to weevil attack than those under low fertility and also aims at quantifying actual losses in banana yield from 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 fertilizer stimulated faster growth, and crop maturity. 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 second 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.

7.3.2. Yield loss from nematodes

by P.R.S. – in collaboration with F. Ssango, C. Kajumba

The nematodes, *R. similis, H. multicinctus* and *P. goodeyi* are associated with both highland banana in East Africa. The species occur in mixed populations in central Uganda, which ranges from 1000 masl to 1350 masl, while at the higher elevations *P. goodeyi* is the dominant and often single species. In central Uganda *R. similis* and *H. multicinctus* combined cause production losses to highland banana ranging from 30% to 50% per cycle. The first cycle results of an on-station trail in Mbarara (1350 masl) suggest that *P. goodeyi* is far less aggressive to highland banana than *R. similis*. Independent of the crop management, no reduction in bunch weight was observed in infested plots, when compared to non-infested plots (Table 2). When *R. similis* is introduced into a *P. goodeyi* dominated system, the root system of small suckers was reduced by 50% (Table 3) and consequently great losses can be expected.

Table 2. Bunch weight and nematode densities in suckers detached from harvested plants for the highland banana cultivar Mbwazirume (*Musa* AAA), grown in nematode or non-infested plots, under the management regimes of heavy mulching or bare, Mbarara, Uganda.

Treatment	n	Bunch weight (kg)	Nematode density per 100 g. *P. goodeyi*	*R. similis*	*H. multicinctus*
Mulched					
Non-infested		20.7	4,289	148	55
Infested		19.8	50,513	1,667	6
		ns	**	*	ns
Bare					
Non-infested		16.3	1,345	1,063	6
Infested		16.2	10,612	2,004	11
		ns	**	ns	ns

Ns; not significant, *: significant at $P<0.05$, **: significant at $P<0.01$

Table 3. Plant height, plant girth and root system of suckers detached from highland banana mats (cv Mbwazirume, *Musa* AAA), infested with *P. goodeyi* alone or with a mixture of *P. goodeyi* and *R. similis*, Mbarara, Uganda.

Infestation	n	Height (cm)	Girth (cm)	Root bases (nr)	Total functional root length (cm)	Total dead root length (cm)
P. goodeyi	20	76.3	40.7	146.4	2124.9	834.8
P. goodeyi and *R. similis*	20	77.8	33.9	147.6	1212.8	1420.2
		ns	*	ns	*	**

Ns; not significant, *: significant at $P<0.05$, **: significant at $P<0.01$

7.4. 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

7.4.1. IPM of weevil, incl. clean planting material, trapping, harvest residue management, and biocontrol agents

by K.G. - in collaboration with C. Lomer, I. Godonou, K. Afreh-Nuamah, J.N Ayertey, K. Oduro*

Studies to determine the potential for biological control of the banana weevil on plantain in Ghana, using the entomopathogenic fungus, *Beauveria bassiana* were continued.

Experiments were undertaken to determine whether *B. bassiana* could be established as an 'endophyte' within the roots of plantain in order to sustain the protection provided by the fungus against the banana weevil. Both split-corms and tissue-culture plantlets were inoculated with the fungus by a variety of methods but the fungus could not be re-isolated from the plant tissue at a later date.

More promising resuts were obtained using oil palm kernel cake (a by-product of oil palm processing) as a cheap media for production of the fungus and subsequent application to the suckers. In pot experiments, the formulation enhanced the persistance of the fungus after application to the sucker, such that a weevil mortality of 61.0% was obtained when suckers were attacked 28 days after sucker treatment, compared with 12.3% using conidial powder alone and 3.8% in the untreated control.

Two different formulations of *B. bassiana* were subsequently tested for their efficacy in controlling *C. sordidus* under conditions of natural weevil infestation in a farmers plantain field (Akanteng, Eastern Region, Ghana). The treatments were:

- Rhizomes dusted with 3 g of dry conidial powder (2 x 10^{10} conidia g $powder^{-1}$)
- Plantain suckers planted in holes containing 60 g oil palm kernel cake (OPKC) carrying conidia (10^9 conidia g $OPKC^{-1}$)
- Untreated plantain suckers

Sixty days after planting, only 5.6% of suckers treated with OKPC showed signs of weevil damage, compared with 25.0% of suckers treated with conidial powder and 33.3% of suckers in the control. There were no dead plants in the OPKC treatment compared with 16.7% dead in the conidial powder treatment and 19.4% dead in the control. Live weevils trapped from the experimental field were observed in the laboratory. Forty two percent of weevils from the OKPC treatment died, compared with only 5.7% and 3.3% from the conidial powder and control treatments, respectively.

7.4.2. 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*

Based on training and experience provided by IITA West African Plantain Project from 1996-1997, Ghanaian farmers in three villages established their own community plantain nurseries. The farmers produced and multiplied their own clean planting material with technical backstopping provided by project staff together with the Ministry of Food and Agriculture (MoFA), Ghana. Farmers field days were held at each site in June/July so that MoFA staff and plantain farmers from neighbouring districts could see the progress that had been made.

Several experiments were conducted to determine the effect of growing media (top soil, sawdust, rotten oil palm fibre and rice husk) on sprout emergence from plantain split corms. All the media tested except rice husk were found to be suitable for sprout emergence. The low emergence in rice husk was attributed to its inability to maintain moisture. Farmers who established community nurseries conducted their own experiments and selected media for split corm germination on the basis of sprouting performance and local availability of the materials. For example, farmers in Brong Ahafo Region tested cocoa pod husk (widely available) as a sprouting media but found that emerging roots became 'singed'.

Data collection is ongoing for an on-farm experiment (six farms in each of three regions in Ghana) designed to compare the performance (growth, yield, pest and disease levels) of clean planting materials produced in nurseries, hot water-treated materials and farmers' untreated materials, under two management options. From data collected, it is clear that hot-water treated materials consistently perform better than untreated materials (approximately double the number of bunches harvested). The performance of nursery-derived materials has been more variable and is thought to be highly dependent on environmental conditions at the time of transplanting from nursery to field, since excessive rainfall or drought resulted in poor establishment. The number of bunches harvested from plots under improved management (regular weeding, optimum plant spacing) was approximately 25% higher than for farmer-managed plots.

Table 4. Effect of planting material treatment on production of Apantu-pa (*Musa* AAB) in Ghana

Treatment	Bunch weight (kg)	Yield (t/ha)	Fruits lost to toppling (%)	Nematode density per 100 g at flowering		
				P. coffeae	*H. multicinctus*	*Meloidogyne*
Hot water	12.6	9,379	32	73	1,910	1,154
Nematicide	11.9	10,064	23	778	937	1,786
Paring	12.3	8,165	40	3,529	1,680	1,421
Tissue culture	11.5	4,995	61	71	2,215	2,334
Untreated	10.5	5,113	56	18,588	2,009	1,495

A field trial conducted at ARS Kade (Ghana) to compare different methods of planting material disinfestation with respect to build-up of the residual nematode population in treated suckers, and plantain growth and yield, was completed. Planting material treatments tested were i) nematicide,

ii) paring and hot-water treatment, iii) paring only, iv) use of tissue culture materials and v) untreated suckers (control). Plantain production was highest for the hot-water and nematicide treatments, and was approximately double that recorded for tissue culture plants and the control. Tissue culture-derived plants performed poorly with a high incidence of viral symptoms and toppling. The density of *P. coffeae* (the most damaging nematode species on plantain in Ghana) was highest in the control and lowest for the hot water and tissue culture treatments (see Table 4). The density of *P.coffeae* was also relatively high for the paring treatment, indicating that the residual nematode population remaining after this planting material treatment can rapidly accumulate in plantain roots.

7.4.3. Farmers perceptions and economic analysis of IPM interventions

by K.G. - in collaboration with W. Danso, A. Mensah-Bonsu, K. Afreh-Nuamah, E.K. Andah

Analysis showed that the use of clean suckers and improved management practices for plantain production in Ghana was economically feasible over a 3-year period and that farmers' perceptions of the techniques were favourable (see completed studies).

Financial analysis is also ongoing to evaluate the profitability of plantain sucker production in a nursery scheme. Data for the analysis was collected from farmers and MoFA staff who established community nurseries at three villages in Ghana. Costs included land rent, suckers, boxes for germination of split corms, labour (land preparation, planting material treatment, planting and weeding) and transport. Clean planting material produced from the nursery had a higher value than untreated planting material obtained from farmers plantations. Results indicate that the gross returns at each location were over and above the respective total production costs and that nursery production was profitable.

7.4.4. 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.

Clean planting material provides a first line of defense against banana weevils and nematodes in newly planted fields. No further research was conducted in 1998 on the use of paring and/or hot water treatments on banana weevil numbers and damage.

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.

7.4.5. 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 traps to control banana weevils is controversial. A trapping study was conducted through farmer participatory research at the Ntungamo benchmark site from 1996-1997. Analysis of results suggested that researcher managed trapping (one trap/mat/month) could substantially reduce weevil numbers, while farmer managed trapping (variable trap intensity) resulted in moderate reductions. However, results were highly variable such that the benefits of trapping can not be guaranteed. Trapping resulted in limited reductions in damage. However, weevil population decline was gradual so it was expected that the full impact on reducing weevil numbers on plant damage could not be felt within a single year.

Farmers concluded that trapping can reduce weevil populations but cannot be adopted as a single control measure because (a) it is laborious; (b) trapping materials are limited at certain times of year; and (c) weevil migration from neighboring farms can offset positive benefits. Adoption of trapping in Ntungamo during the year following the study was limited.

Enhanced trapping, using semiochemicals may provide a means of efficiently collecting weevils while reducing labor and material demands. Preliminary trials with the pheromone Cosmolure Plus (produced by Chemtica, Costa Rica) have shown that baited pitfall traps can

collect 16-25 times as many weevils as pseudostem traps. On-station research is being conducted to determine trap densities that might be used in on-farm testing at benchmark sites.

7.4.6. 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.

7.4.7. Habitat management of banana weevils: Mulching

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*

Mulches are highly beneficial for banana production by adding nutrients and by increasing moisture conservation. However, banana weevils are subject to rapid desiccation and, therefore, are highly sensitive to soil moisture levels. Results from on station research trials in Uganda and elsewhere have demonstrated that mulched systems support higher densities of banana weevil adults than systems without mulches. Many farmers are cognizant of this and will not place mulch at the base of banana mats.

An on-going study in Ntungamo district is comparing weevil dynamics in controls and grass mulched plots (to the base of the mat and up to 1 m of the base). A similar study is being undertaken at the Kawanda Agricultural Research Institute to study mulch effects on both water balances and weevil population dynamics and damage. Both trials will follow plant growth, weevil adult densities and weevil damage for 2 crop cycles.

7.4.8. Habitat management of banana weevils: Green Manure

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*

Nutrient availability and uptake has been demonstrated to be a primary constraint throughout most of the banana growing regions of Uganda and has been a driving force behind the decline and disappearance of cooking banana in central Uganda. Lack of organic matter and low levels of nitrogen appear to be ubiquitous problems while K and Mg have been found deficient in foliar samples in central Uganda. Green manures may be the most effective strategy for restoring soil nutrients in sites such as Masaka where mulches and fertilizers are not available. Therefore, research has been implemented on the efficacy of green manures in making nitrogen available for banana. At the same time, the effects of green manures on banana weevil populations is currently under study.

A trial was planted in November 1996 comparing weevil numbers and damage in banana monoculture (i.e. controls) and intercrops with *Mucunua*, *Carnavalia* and *Tephrosia* spp. Banana weevil populations and damage levels were similar among all treatments. It is possible that the relatively sedentary nature of the weevil limits the interface with the green manures, thereby reducing their impact. Therefore, further work is being done on the effects of extracts from the green manures on weevil behavior.

In the Masaka benchmark site, farmers initially were not receptive to growing green manures in banana fields. Therefore, a on-farm trial is looking at the use of a *Crotolaria* mulch. First results suggest that weevil populations might be lower in the *Crotolaria* mulch than in a grass mulch or control.

7.4.9. Botanical insecticides for the control of banana weevils

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*

Studies on the potential of neem for control of banana weevil began in 1998. In pot and field experiments, neem cake and neem seed powder at 20% concentration were evaluated for their potential for oviposition deterrence, adult repellency and systemic effects on larval survival. In both no choice and choice experiments, oviposition was significantly lower on corms treated with neem formulations than on controls. Weevil catches in neem treated pseudostem traps were significantly lower than those in untreated traps. Larval mortality was significantly higher in treated corms suggesting systemic effects.

7.4.10. Biological control of banana weevils

by C.S.G. - in collaboration with A. Abera, M. Griesbach*, P. Nemeye, A. Hasyim*

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 (section 7.2.) and will be studied as part of a Ph.D. program.

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.

7.4.11. 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 NBRP and ICIPE, 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.

Seventy-five percent of surveyed farmers in the benchmark site identified pests (especially banana weevil) as the leading or second most important constraint. Farmers have a clear recollection of the widespread plantation failures attributed to banana weevil attack. As a result, some farmers with low levels of weevils implement control measures as a prophylaxis to prevent

population outbreaks, while other farmers are attempting to bring down existing levels of weevil damage. Additionally, farmers often modified practices to suit their needs or resources. For example, some farmers only trapped at the base of mats where they felt they had most severe weevil attack.

Most (i.e. > 70%) farmers were aware of using uninfected planting material, removing leaf sheaths (hiding place of adult weevils), disk on stump trapping, removal of corms, application of urine, and pesticides as means of controlling weevils. Lesser numbers (i.e. 35-70%) of farmers knew of rogueing heavily infected plants, applying ash, splitting pseudostems, cleaning suckers with hot water treatment and placing mulches away from the base of mats. Few farmers knew about covering of corms (26%), tolerant cultivars (19%), pseudostem trapping (12%) paring suckers (3%) for weevil control.

A majority of farmers believed sheath removal and corm removal as moderately to very effective. For all other methods, a majority of farmers were unsure how effective the methods were. High adoption rates were found for selection of healthy planting material, removing sheaths and removing corms. At least a third of the farmers also excised the damaged sections of suckers, used disk on stump trapping, applied ash, chopped pseudostems and rogued infested plants. Intensity of use was related to socio-economic stratum.

7.4.12. Micro-organisms to enhance root health.

*by P.R.S., C.S.G. – in collaboration with R. Sikora, B. Niere**

Over 200 fungi have been isolated form healthy highland banana (*Musa* AAA) and Pisang Awak (*Musa* ABB) rhizomes. A number of them are expected to be endophytes and have developed mutualistic relationships with banana plants. Some may act as antagonists to pests and diseases. The prevalent mode of action appears to be through the production of metabolites, which act as oviposition repellents, toxins or feeding deterrents. Plant physiological and ecological factors may influence endophyte efficacy. Four *Fusarium* isolates, selected on the bases of *R. similis* reducing qualities, were inoculated to Mbwazirume and Gros Michel tissue cultured plants. Fourty biological protected plants of each cultivar were planted in August '98. Bunch weights of the biological protected plants are expected by December '99. A number of trials have been initiated, using the most promising *Fusarium* isolate V5w2 for biological protection of the highland cultivars Mbwazirume and Enyeru. Another isolate V4w5, was observed to increase plant growth of the cultivar Gros Michel, by 25% over a period of four months.

7.5. Utilization of germplasm enhanced

On-going and future activities

7.5.1. Host plant resistance to banana weevil

by C.S.G. D.V. - in collaboration with A. Kiggundu

Plantains (AAB) and highland bananas (AAA-EA) were most susceptible to banana weevil attack. The data suggest different levels of susceptibility to weevil attack among highland cultivars. Bogoya (= Gros Michel) (AAA) demonstrated peripheral damage similar to highland cultivars but penetration into the central cylinder was limited. Introduced beer types (AB, ABB) appeared resistant although, in some cases, heavy weevil attack was found in crop residues. These results provided the foundation for a trial to screen the highland banana group for possible sources of resistance.

A trial to screen highland banana germplasm for resistance or susceptibility to banana weevil was planted at the IITA Sendusu Farm in November 1996. The trial encompasses 45 cultivars of which half are highland banana types, while the remainder include a mixture of dessert and brewing bananas, plantains and IITA hybrids.

Harvest of the plant crop began in January 1998 and extended into 1999. Weevil damage was assessed as percentage of damage to the periphery of the upper 10 cm of corm; and in two cross sections as percentage tissue consumed in the outer cortex and in the central cylinder. For highland clones, damage levels ranged from 11 to 23% for peripheral damage; 1 to 16% for cortex damage and 4 to 12% for central cylinder damage, suggesting differences in susceptiblity within the group. Highland brewing bananas displayed approximately the same range in damage scores. Plantains and several hybrids were highly susceptible, Bogoya and bluggoe were moderately susceptible and most other exotic bananas and hybrids were relatively resistant.

7.5.2. Resistance mechanisms against banana weevil

by C.S.G. D.V. - in collaboration with A. Kiggundu

Host plant resistance may reflect host plant location (attraction), host plant acceptance and host plant suitability. Trapping studies suggest that weevils are not preferentially attracted to any clones. Field and laboratory oviposition studies also indicate that weevils show little or no clonal preference in determining where they deposit their eggs. Further trials on clonal preferences are on-going. Thus, egg density appears to be similar among different clones although the same plants may later show marked differences in damage. This suggests that antibiosis is an important component of host plant resistance.

Host plant suitability is being studied in the laboratory for selected clones. Larvae are placed individually in rearing chambers consisting of 2 corm slices (4x4 cm and 0.2 cm thick) with a notch (simulating a gallery) in the lower slice to avoid possible damage of the larva by pressure of the upper piece. The rearing chambers were then placed singly in petri dishes. The larvae are being monitored regularly for mortality, developmental rates and, ultimately, for pupal weights.

7.5.3. Identification of durable nematode resistance/tolerance sources

by P.R.S., T.D., R.V., A.T., J.H. – in collaboration with D. de Waele

In Nigeria the bunch weight of the genotypes FHIA-3, Km 5, FHIA-1, Pisang Ceylan, SH 3640 and Cardaba were not affected by *R. similis* and *H. multicinctus* (Table 5) and are anticipated a good level of field tolerance. None of the genotypes was observed to be absolutely resistant (no nematode reproduction and no damage).

In Uganda the host plant response to *R. similis* and *H. multicinctus* attack of 60 genotypes was evaluated using root chambers. On the genotypes 1156s-4, 1156s-6, 1156s-7, 1353k-20, 1353s-1, 1369s-15, 1718-2, 632s-66, 780k-1 and Pisang Awak no *R. similis* reproduction was observed, while *R. similis* reproduced poorly on Gross Michel, 1411s-6, 761k-4, 1156s-24, 1353k-4, 1369s-14 and 1156s-32, suggesting that sources of *R. similis* resistance are present in the germplasm pool present in Uganda.

Table 5. Bunch weight for Musa genomes grown in plots infested with *R. similis and H. multicinctus* and for plants grown in fenamiphos protected plots, Onne station, Nigera.

Cultivar	Group	N	Bunchweight-loss(%)			t-value	Sign.
			Infested *versus* non-infested				
Mimi Abue	AAB	8	88.4	a	0.0	0.0001	***
Obino l'Ewai	AAB	20	81.8	ab	0.0	0.0001	***
Valery	AAA	12	64.9	abc	0.0	0.0008	***
TMPx 2796-5	AAB*AA	20	62.0	abcd	0.0	0.0001	***
FHIA-22	AAB*AA	8	59.8	bcd	0.0	0.0021	**
TMPx 548-9	AAB*AA	20	57.0	bcd	0.0	0.0001	***
SH 3436-9	AAAA	20	54.6	bcd	0.0	0.0001	***
Bluggoe	ABB	20	47.5	cde	0.0	0.0004	***
FHIA-23	AAAA	20	35.1	def	0.0	0.009	**
FHIA-3	AABB	20	23.8	ef	0.0	0.0757	
Km 5	AAA	20	23.2	ef	0.0	0.0843	
FHIA-1	AAB*AA	20	21.0	ef	0.0	0.1166	
Pisang Ceylan	AAB	8	12.2	fg	0.0	0.566	
SH 3640	AAB*AA	20	10.8	fg	0.0	0.4185	
Cardaba	ABB	20	-8.0	g	0.0	0.5504	

7.5.4. Ideotype of a nematode-resistant or tolerant banana

by J.H., D.V., P.R.S. – in collaboration with D. Makumbi, F. Ssango

Path analysis was used to establish the relative influence of *R. similis* and *H. multicinctus* densities, nematode damage (percentages dead roots, root necrosis and root bases with necrotic lesions) and

banana weevil related damage (percentages outer and inner corm damage) on bunch weight of highland banana (cv Mbwazirume, *Musa* AAA). The highland banana was grown under two management regimes. Either the plots were kept weed free and heavily mulched or plots were inter-cropped with finger millet. Nematode densities ($r>-0.59$, $P<0.05$) and damage parameters ($r>-0.76$, $P<0.01$), independent of crop management, were negatively correlated to bunch weight Under good management banana weevil damage was negatively correlated with nematode densities and damage ($r>0.70$, $P<0.05$). However no such association was observed under poor management. Path analysis revealed, that root necrosis, followed by dead roots are the major factors negatively affecting bunch weight in well-managed plots. While in the finger millet inter-cropped plots *R. similis* densities, followed by *H. multicinctus* densities directly affected the bunch weight.

7.6. Improved genotypes and populations available

On-going and future activities

7.6.1. Virus indexing, diagnostics and elimination for germplasm distribution
by J.d'A.H., S.Y.C.N., G.T.

During 1989, four of IITA's plantain hybrids that had been sent to the INIBAP International Transit Centre (ITC) in Leuven, Belgium were retrieved for further virus testing at IITA, Ibadan. TMPx 4479-1, TMPx1621-1, TMPx7152-2 and TMPx 4479 were sent to IITA from the ITC Stock Collection and the ITC Medium Term Storage (MTS) facility. They were subjected to the standard indexing protocols for banana streak virus (BSV), genus Badnavirus. This comprised of growing at 22-24°C in a controlled environment room for six months with regular observations and indexing by enzyme-linked immunosorbent assay ELISA) and immunosorbent electron microscopy (ISEM). Only three plants out of five each of TMPx 44879-1 from ITC Stock and MTS remained free of BSV, one and three out of five respectively of TMPx1621-1 and five out of five TMPx7152-2 from ITC Stock but none of the five from MTS were free of BSV.

Sixteen lines were received from IITA Onne for virus indexing. Of all the TMPx lines, at the second test after four months, some plants tested negative for BSV (TMPx2829-62: 2/3; TMPx15108-6: 3/12; TMPx1297-3: 2/3; TMPx1378: 2/9; TMPx 4479-1: 7/7 and TMPx5295-1: 1/8). Three out of nine TMPx 7152-2 also test negative at the first test. TMPx4479-1 is remarkable in that it is the only clone in which all the plants have tested negative for BSV at the second test. Eight further lines are being prepared for indexing: Ney Poovan, Highgate, Bobby Tannap, Obino l'Ewai, Mun, Gros Michel, Guyod and Big Ebanpa.

All *Musa* clones originating from IITA are checked, in addition, for cucumber mosaic virus, genus Badnavirus and banana die-back virus by ELISA and ISEM. There is also a final check by electron microscopy for the putative potyvirus that may be present in Nigeria, 'Ducasse' virus, and any other virus-like particles.

Plantlets of Cavendish cv. Williams obtained from ITC, Leuven have been confirmed to be free of BSV and have been multiplied for use in field epidemiological and transmission studies for BSV.

7.7. Improved cropping systems available

On-going and future activities

7.7.1. Management practices for plantain production in Ghana
by K.G. - in collaboration with K. Afreh-Nuamah

On-farm trials have shown the importance of timely weeding in conjunction with the use of clean planting material for improved plantain production (see Section 7.4.). Weeding is, however, a costly practice and farmers may abandon fields if they are unable to manage the weeds. Another serious production constraint faced by plantain farmers is that of declining soil fertility. To address these problems, field trials are being planned at ARS Kade to determine the effect of leguminous cover crops and organic soil amendments (mulches) on both weed growth, soil fertility and plant nutrient status.

Completed studies

Journal articles and book chapters

Dahal, G., J.d'A. Hughes & B.E.L. Lockhart, 1998. Status of banana streak disease in Africa: problems and future research needs. Integrated Pest Management Reviews 3: 1-13

Streak disease of banana and plantain caused by banana streak virus (BSV) was first reported in the Ivory Coast in 1974 and occurs in at least 16 countries in Africa. Based on genomic characteristics, BSV has been shown to be a member of genus Badnavirus. Efficient and reliable diagnostic methods for BSV have recently become widely available. This paper summarizes the current knowledge on its causal agent, geographical distribution, symptomatology, transmission, host range, available diagnostic techniques and management options for the disease in Africa. Further research needs are identified in light of the widespread occurrence of BSV in most plantain/banana germplasm and the difficulties in obtaining BSV-free plantlets through tissue culture.

Dahal, G., J.d'A. Hughes, G. Thottappilly & B.E.L. Lockhart, 1998. Effect of temperature on symptom expression and reliability of banana streak badnavirus detection in naturally-infected plantain and banana (*Musa *spp.). Plant Disease 82:16-21.

The effect of temperature on symptom expression and detection of banana streak badnavirus (BSV) by immunosorbent electronmicroscopy (ISEM) and enzyme-linked immunosorbent assay of 12 in vitro-propagated plantain hybrids (genome AAB x AA), 3 ABB cooking banana, and 3 AAB plantain landraces was studied. Experiments were done for 2 years under two temperature regimes, 28 to 35°C in a screenhouse and 22°C in a temperature-controlled room. Most BSV-infected plants of plantain hybrids expressed symptoms under both conditions. Symptom expression was enhanced when plants were continuously grown at 22°C, but later became indiscernible when plants were continuously grown at 28 to 35°C. Plants grown at 22°C and showing severe symptoms contained significantly higher virus titer than plants grown at 28 to 35°C. When asymptomatic plants with very low virus titer at 28 to 35°C were transferred back to 22°C, there was a significant increase in both symptom severity and concentration of virus (greater than 3 to 5 times) in leaf tissues after 9 months. In contrast, the concentration of virus and symptom severity decreased in plants after transfer from 22°C to 28 to 35°C. Micropropagated plants of AAB plantain landrace cv. Mimi Abue and ABB cooking bananas (cvs. Bluggoe, Cardaba, and Pelipita) did not express visible symptoms under either temperature regime, but BSV was detected by ISEM in 23% of the plants. After 2 years at 22°C, virus was detected in 64% of the plants, but the concentration of virus remained low. Implications of these results on quarantine screening of in vitro plants and virus diagnosis are discussed.

Dahal, G., C. Pasberg-Gauhl, F. Gauhl, G. Thottappilly & J.d'A. Hughes, 1998. Studies on a Nigerian isolate of banana streak badnavirus: II. Effect of intraplant variation on virus accumulation and reliability of diagnosis by ELISA. Annals of Applied Biology 132:263-275.

Gold, C.S., E.B. Karamura, A. Kiggundu, F. Bagamba and A.M.K. Abera. Geographic shifts in highland cooking banana (*Musa *spp., group AAA-EA) production in Uganda. Int. J. Sustainable Agriculture and World Ecology (in press).

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.

Gold, C.S., G. Night, A. Abera and P.R. Speijer, 1998. Hot-water treatment for control of banana weevil,* Cosmopolites sordidus *Germar (Coleoptera: Curculionidae) in Uganda. African Entomology 6: 215-221.

Paring and hot-water treatment of banana suckers have been recommended to prevent the spread of banana weevil, *Cosmopolites sordidus* Germar, into new banana plantations. Mortality of banana weevil eggs and larvae were recorded after immersion of infested banana suckers in 4 hot water regimes: 43 °C for 2 h, 43 °C for 3 h, 54 °C for 20 min and 60 °C for 15 min. Paring removed 90 % of banana weevil eggs, while all hot-water treatments resulted in 100 % mortality of eggs. However, only hot-water baths of 43 °C for 3 h provided a high percentage (i.e. 94 %) kill of weevil larvae. Larval mortality in other treatments ranged from 26-32 %.

It is unlikely that Ugandan farmers will implement three h hot-water baths for banana weevil control. Also, the hot-water treatment most effective for nematode control (54 °C for 20 min) provided limited control of banana weevil. The data suggest that paring alone may be the most appropriate recommendation for resource-farmers to clean planting material of banana weevil.

Gold, C.S., G. Night, P.R. Speijer, A.M.K. Abera and N.D.T.M. Rukazambuga, 1998. Infestation levels of banana weevil, Cosmopolites sordidus ***Germar, in banana plants established from treated propagules in Uganda. African Entomology 6:253-263.***

Two trials were undertaken to quantify the effects of cleaned planting material on the levels of banana weevils and nematodes and on plant growth and yields. Treatments included: (1) untreated suckers (controls); (2) pared corms; (3) pared and hot-water treated corms.

Initial weevil populations were lower in plots established with cleaned planting material than in controls. In Trial 1, weevil numbers in pared and pared/hot-water treated material were lower than in control plots for up to 11 months, while in Trial 2, plots grown from pared and pared/hot-water treated planting material had lower numbers of the pest for 27 months and 20 months, respectively. Weevil damage levels in controls were 70-200 % higher than in plots grown from treated planting material for the entire plant crop cycle. All treatments displayed similar levels of weevil damage in the first ratoon. Hot- water treatment afforded excellent nematode control for the duration of both trials.

In both trials, treated plants had faster plant maturation rates and lower levels of plant loss due to pests. In Trial 1, 21 % of plants in the plant crop were lost to weevils and nematodes compared to 2 % in treated plots. In Trial 2, plant loss to weevil and nematodes were 34 % in controls, 6 % in pared and 2 % in hot-water treatments. Eventual bunch size was similar among treatments in both trials. However, plots with treated plants provided higher yields in that a greater number of bunches was harvested during the course of the study.

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 Protetion 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.

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., Ch Kajumba & F Ssango. East African highland banana production as influeneced by nematodes and crop management in Uganda. International Journal of Pest Management (in press).

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 occured 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.

Conference papers, workshop proceedings, abstracts, newsletters

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 (submitted)

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.

Green, K.R. & K. Afreh-Nuamah. Plantain IPM in Ghana: A case study. Proceedings of an International Workshop on Banana IPM. Nelspruit, South Africa. November 1998 (in press).

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 favourable. 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. Farmers' perceptions of integrated crop management strategies for plantain production in Ghana. 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.

Hughes, J.d'A., P.R. Speijer & O. Olatunde, 1998. Banana die-back virus - a new virus infecting banana in Nigeria. Plant Disease 82:129

Two viruses naturally infect Musa in Nigeria: banana streak badnavirus (BSV) and cucumber mosaic cucumovirus (CMV). During a recent field survey at Ibadan (Nigeria), some severely stunted banana plants (cv. Valery) were found that tested negative for CMV, banana bunchy-top virus, and BSV. The plants had symptoms of leaf crinkling, leaf necrosis, and cigar-leaf die-back. Subsequent suckers from the same mats were progressively more stunted. A 28- to 30-nm isometric virus was purified, and used for the production of antibodies, from the affected plants with $(NH_4)_2SO_4$ to precipitate the virus. The antiserum (titer of 1: 10,000) was used in enzyme-linked immunosorbent assay and in immunosorbent electron microscopy to detect the virus. Mechanical inoculation with partially purified virus preparations resulted in stunting and development of pin-point chlorotic lesions on *Vigna unguiculata* TVu-76 and symptomless systemic infection of *Nicotiana occidentalis*. The virus was not mechanically transmissible from *N. occidentalis* to banana. A serological relation-ship between this virus, banana die-back virus (BDBV), and tobacco ringspot, tomato ringspot, and cacao necrosis nepoviruses was found. The nematode species around the affected banana plants were isolated: *Helicotylenchus multicinctus* (Cobb) Golden was the dominant species, low numbers of *H. dihystera* (Cobb) Sher were present but no virus-transmitting nematodes were found in soil or banana roots. Further studies are needed to determine the mode of spread of BDBV and the implications for banana/plantain production in sub-Saharan Africa, and the safe international movement of germplasm.

Hughes, J.d'A. & G. Dahal, 1998.* Musa *viruses in Nigeria. 7th International Congress of Plant Pathology, 9-16 August 1998, Edinburgh, Scotland. Abstract 1.13.13

Banana and plantain leaf samples from the humid forest region of Nigeria with virus-like symptoms were collected in addition to some symptomless samples. Diagnosis of the causal agent(s) of the symptoms was initially done using enzyme-linked immunosorbent assay (ELISA) for BSV and CMV. When required, confirmatory tests of mechanical inoculation to *Nicotiana tabacum* (for CMV) and immunosorbent electron microscopy (ISEM) for BSV were done. Diagnosis of BDBV was initially based on symptom expression, and confirmed by ELISA and mechanical inoculation to *Vigna unguiculata* TVu 76.

BSV was consistently found associated with symptomatic leaf samples showing distinctive white streaking and was also found, at low frequency, in some asymptomatic samples. The disease was identified in most plantain-growing areas. It commonly occurred in some plantain hybrids, but the incidence was low in most landraces. An isolate of the virus from southern Nigeria was found to be serologically distinct from *Dioscorea alata* badnavirus in yams and cocoa swollen shoot badnavirus in cocoa.

While the symptoms of CMV are usually distinct, they can be confused with those exhibited by plants infected with BSV. The presence of CMV was confirmed in both banana and plantain, but was less common than BSV. CMV was also found in mixed infection with BSV in plantain. CMV in banana and plantain was found to be distinct from that found to be infecting adjacent cowpeas, causing less severe symptom expression after mechanical inoculation and vector transmission to *N. tabacum*.

The presence of BDBV was confirmed in banana by ELISA but was not found to be widely distributed. It was found in mixed infection with BSV in some cases. The vector of the virus is unknown but it is putatively a member of the nepovirus group, exhibiting a serological relationship with tobacco ringspot, tomato ringspot and cacao necrosis nepoviruses.

The presence of these viruses in banana and plantain, and the failure to eliminate BSV by meristem culture, emphasises the need for care in selecting planting material as these viruses can all be transmitted vegetatively through suckers used as planting material. With regard to their spread, no natural vector has been identified for BSV although mealybugs are implicated; aphids are known to be vectors of CMV and no vector has been found for BDBV.

The epidemiology of these viruses in Nigeria is not known. Despite the presence of large numbers of mealybugs, there appears to be no natural spread of BSV. Spread of CMV through vector transmission appears to be very localised, as does the occurrence of BDBV. However, care must be taken as these three

viruses are transmitted vegetatively through suckers and can often be widely distributed by farmers and national / international germplasm movement.

Hughes, J.d'A., 1998. Banana streak badnavirus research at the International Institute of Tropical Agriculture. p.28-33 In: Frison, E. A. and Sharrock, S. L. (1998)* Banana streak virus: a unique virus-Musa interaction? *Proceedings of a workshop of the PROMUSA Virology working group held in Montpellier, France, January 19-21 1998. IPGRI, Rome, Italy; INIBAP, Montpellier, France.

Kashaija, I., R Fogain & P.R. Speijer. Habitat management and cultural controls. Proceedings of an International Workshop on Banana IPM. Nelspruit, South Africa. November 1998 (in press).

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.

Mensah-Bonsu, A., K.R. Green, S. Adjei-Nsiah, E.K. Andah & K. Afreh-Nuamah. Economic analysis of integrated crop management strategies for plantain production in Ghana. 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. 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 immobilising 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-colonisation 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. Fungal endophytes for the biocontrol of nematodes. Proceedings of an International Workshop on Banana IPM. Nelspruit, South Africa. November 1998 (in press).

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*.

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, Cameroun, 10-14 November 1998 (in press).

In 1993 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 desinfested 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 orginally short (<15 cm in pseudostem length). The benifits farmers observe of the technology is the increase of bunchweight, increase in sucker production and reduction of bunch loss due to plant toppling. The disadvantage if the technology is the level of organisation 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. Proceedings of an International Workshop on Banana IPM. Nelspruit, South Africa. November 1998 (in press).

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.

Vuylsteke, D., K. Rajab & J.d'A. Hughes, 1998. Banana streak badnavirus and cucumber mosaic cucumovirus in farmers' fields on Zanzibar. Plant Disease 82: 1403.

Symptoms resembling those of viral leaf streak, caused by banana streak badnavirus (BSV), were observed in May 1998 on two banana (*Musa* spp.) landraces grown from farmer-collected propagules in a farmer's field at Kiboje Uchukuni, Zanzibar. The cultivars showing symptoms were French plantain (*Musa* AAB group) cv. Mzuzu and 'Giant Cavendish' banana (AAA) cv. Mtwike. Leaf symptoms were chlorotic streaks and blotches. Leaf samples were indexed by immunosorbent electron microscopy with BSV and cucumber mosaic cucumovirus (CMV) antibodies using partially purified preparations. The two landraces tested positive for BSV, corroborating the occurrence of BSV in Zanzibar. Also, cv. Mtwike was infected with CMV. This is the first report of CMV infecting banana in Zanzibar. No other virus-like particles were seen by electron microscopy. BSV has been reported in Zanzibar (1), but only from symptoms in the *Musa* field genebank at the Kizimbani Research Station. BSV has been found in many *Musa* collections worldwide, particularly in the widespread cv. Mysore. This report confirms the presence of BSV in farmers' fields using advanced diagnostics.

Project 8

INTEGRATED MANAGEMENT OF *STRIGA* AND OTHER PARASITIC PLANTS

by B. Badu-Apraku, D.K. Berner (project coordinator), K.E. Dashiell, J.M. Fajemisin, J.G. Kling, A. Melake-Berhan, S. Schulz

Project rationale

Striga (Scrophulariaceae) is a genus of obligate root-parasitic flowering plants composed of 30-35 species, over 80% of which are found in Africa. In sub-Saharan Africa the damage caused by these parasites can be devastating to resource-poor farmers whose lives can be threatened through complete yield loss. All of the cultivated food-crop cereals in Africa are parasitized by one or more *Striga* spp. In West Africa alone it is estimated that about 40 million hectares in cereal production are severely infested with *Striga* spp., while nearly 70 million hectares have moderate levels of infestation. As a result, FAO estimates that annual yield losses due to *Striga* spp. in the savannah regions alone account for $ 7 billion and are detrimental to the lives of over 100 million African people. In addition to these *Striga* spp. on cereals, *Striga gesnerioides* (Willd.) Vatke and *Alectra vogelii* (Benth.) parasitize cowpea and other legumes and are serious constraints to legume production.

The *Striga* problem in Africa is intimately associated with change in intensity of land use. Traditional African cropping systems have included prolonged fallow, rotations, and intercropping which were common practices that kept *Striga* spp. infestations at tolerable levels. As population pressure has increased, subsequent demand for food production has increased, and land use has intensified. This intensification is reflected in greater use of cereal monocropping with little or no fallow to nonhost crops. As a result, the extent and intensity of *Striga* spp. infestations have rapidly increased and become threats to food production. To reverse this trend and put *Striga* spp. infestations back to tolerable levels, cropping systems that increase food production while repressing *Striga* spp. need to be implemented over increasingly large areas in Africa. This implies a rational system of land management that employs the most basic of crop husbandry practices, crop rotation, in conjunction with other *Striga* management practices that will be acceptable and implementable by African farmers. To be sustainable, these *Striga* control practices must independently improve crop yield per unit area, improve soil fertility, and be farmer-preferred even in the absence of *Striga* spp. infestation.

The goal of the IITA parasitic plant project is to reduce infestation of parasitic plants and associated crop yield loss in the savannas of sub-Saharan Africa, while improving soil conditions in African farm lands. The immediate purpose of the project is to develop, with NARES, sustainable integrated parasitic plant management measures and components, with emphasis on rotation with selected non-host legume cultivars, which will be disseminated by NARES to farmers. The group has identified various research activities aimed at producing 10 outputs which aim at achieving the project purpose. The activities to date, work in progress, and future activities are presented.

Outputs

8.1. Crop rotations with non-hosts to deplete the S. hermonthica *seedbank*

Background

Traditional African cropping systems have included prolonged fallow, rotations, and intercropping which were common practices that kept *Striga hermonthica* infestations at tolerable levels. As population pressure and demand for food production has increased, land use has intensified with more cereal monocropping and little or no fallow to nonhost crops. As a result, the extent and intensity of *S. hermonthica* infestations have rapidly increased and has become a threat to food production. To reverse this trend, a rational system of land management that employs the most basic of crop husbandry practices, crop rotation, in conjunction with other *S. hermonthica* management practices needs to be implemented.

On-going and future activities

8.1.1. Continue, with ILRI, screening of *Aeschynomene histrix* cultivars for ability to germinate *S. hermonthica* seeds

by D.K.B. - in collaboration with M. Alabi, S. Tarawali

During the last several years we have developed a rapid *in vitro* screening technique that can quantitatively distinguish between cultivars, breeding lines, and other germplasm for potent parasite seed germinating ability. This methodology is rapid and has good differentiating ability. Using this screening methodology, cultivars and accessions of several *Aeschynomene histrix* cultivars have been identified as efficacious in stimulating *S. hermonthica* seed germination. Promising materials were tested in the field in 1998. Initial impressions are that difficulties with stand establishment of this small-seeded legume preclude on-farm usefulness. Direct effects of *A. histrix* on reduction of *S. hermonthica* in the field will be determined in 1999.

8.2. Soybean and cowpea cultivars for S. hermonthica *seedbank depletion*

Background

An important part of our integrated program for *S. hermonthica* control focusing on efficacious non-host rotation is improved soil fertility. Neither soybean nor cowpea are hosts of *S. hermonthica*, but certain cultivars/accessions of each species are very effective in stimulating parasite seed germination and reducing densities of parasite seeds in the soil. In addition, both species are capable of nitrogen fixation and can be used to improve African soils. In soybean, promiscuous nodulation that allows symbiotic N-fixation with native *Rhizobium* spp., is a character that has been bred for by IITA and is present in IITA's advanced materials. To offer *S. hermonthica* control, these N-fixing legumes need to be screened and selected for their ability to suicidally germinate *S. hermonthica* seeds. Past work on selected soybean cultivars in rotation with *S. hermonthica* susceptible sorghum has shown dramatic benefit of the selected soybean cultivars in both reducing *S. hermonthica* parasitism and increasing sorghum yield.

On-going and future activities

8.2.1. Screening soybean breeding lines for ability to cause *S. hermonthica* seeds to germinate

*by K.E.D., D.K.B. - in collaboration with U. di-Umba**

Using a simple and inexpensive *in vitro* technique, about 200 breeding lines were screened for their ability to reduce germination of *S. hermonthica* seeds. The assay was conducted at IITA, Ibadan using roots cut from single soybean plants in a non-destructive fashion. The results showed that many of the soybean breeding lines were able to stimulate high levels of *S. hermonthica* seed germination. Some of the best breeding lines (for agronomic traits) that were also able to stimulate high levels of *S. hermonthica* seed germination include, TGx1789-7F, TGx 1019-2EB, TGx 1802-1F and TGx 1843-26E. Six genotypes with high stimulant production capacity were used as parents in the soybean breeding program for this project, and the F1, F2, and backcross plants have been harvested and tested for ability to stimulate *S. hermonthica* seed germination. Results indicate that, for the isolate of *S. hermonthica* used, the ability of soybean lines to stimulate germination of parasite seeds is highly heritable.

8.2.2. Soybean density effect on Striga seedbank reduction

by S.S., R.C., D.K.B., K.E.D.

Soybean root exudates have been shown to stimulate suicidal germination of S. hermonthica under controlled conditions in laboratory tests. Soybean plant density (root-lengths density) should be an important factor for optimizing the beneficial effect of a soybean rotation on *S. hermonthica* seedbank reduction. On-farm trials conducted in 1996 and 1997 in northern Nigeria showed that *S. hermonthica* parasitism was significantly lower after soybean than after the sorghum control treatment. However, soybean plant density did not influence subsequent *S. hermonthica* density despite the increase of more than 100% in soybean root length density with increasing plant density.

After having completed the first cropping cycle in 1997, the experiment was continued in 1998 with identical treatments to evaluate possible long-term effects of a soybean rotation on *S. hermonthica* seedbank reduction. Soybean variety TGx1740-7F (maturity in approx. 97 days) was sown at several densities with and without phosphorus fertilizer (SSP) at the higher densities and

with a sole sorghum (60 kg N/ha applied) control treatment. A maize test crop (with 30 kg N/ha applied) followed to assess effects of the rotation on emerged *Striga hermonthica* plant density and maize yield.

Yield of maize grain and stover were generally higher following soybean than following sorghum at all sites. Also maize yield was higher when previous soybean received P fertilizer. The effect of increasing soybean density on subsequent maize yield was low.

8.2.3. Selection for *S. gesnerioides* resistant cowpea cultivars with greater ability to stimulate germination of *S. hermonthica* seeds

by B.B.S., D.K.B.

In an activity similar to 8.2.1 above, cowpea lines will also be screened for production of *S. hermonthica* seed germination stimulant. Those lines showing high stimulant production and low variability will be used in field trials and in a breeding program to incorporate the character into adapted cowpea cultivars.

8.2.4. Selection of adapted cowpea cultivars with greater ability to stimulate germination of *S. hermonthica* seeds.

by D.K.B. - in collaboration with SG2000

To facilitate demonstrations of integrated *S. hermonthica* management by SG2000, cowpea cultivars that were farmer preferred were tested for ability to stimulate germination of *S. hermonthica* seeds. Those cultivars that were found to be effective were planted by farmers in SG2000 demonstration plots in 1998.

8.3. Adapted maize cultivars with S. hermonthica *resistance and improved sources of resistance in maize*

Background

Striga resistant maize cultivars provide an economic means of *Striga* control and are important components of integrated *Striga* management strategies. Selection for reduced host plant damage symptoms under artificial infestation with *Striga hermonthica* has been quite effective in developing a diversity of hybrid and open-pollinated cultivars which can withstand *Striga* parasitism under field conditions. In recent years, increased emphasis has been placed on selecting maize genotypes which support fewer emerged *Striga* plants, thereby limiting reproduction of the parasite. Some progress has been achieved, despite the low heritability of *Striga* emergence. Problems encountered include 1) different mechanisms of resistance exist and are not well understood, 2) sources of resistance in maize have been limited and levels of resistance are incomplete, 3) in-field variability of *Striga* infection and development makes accurate selection of resistant materials difficult. An important focus of the project is to elucidate mechanisms and sources of resistance and to develop technologies which will aid breeders in selection of resistant materials.

On-going and future activities

8.3.1. Development of elite *Striga* resistant maize populations

by J.G.K. - in collaboration with S.T.O. Lagoke, V. Adetimirin

In 1998, 464 S_1 families from TZE Comp. 5 C6, and 326 S_1 families from TZL Comp. 5 C1 were screened in replicated trials under artificial infestation with *Striga hermonthica* in Mokwa and Abuja, Nigeria. Selected families will be recombined to form new cycles of selection. Additional population improvement for *Striga* resistance is carried out at the IITA station in Côte d'Ivoire, as part of our ongoing efforts to develop intermediate, early, and extra-early maize varieties adapted to the savannas.

The best available late- and intermediate- maturing, *Striga* tolerant and resistant cultivars were evaluated in multilocational trials under *S. hermonthica* infested and noninfested conditions in 1998 (Table 1). Levels of stress due to *Striga* were quite high in these trials. The trial in Mokwa, Nigeria was affected by severe drought stress during the month of July, which reduced grain yield under noninfested conditions to an average of 1.9 Mg/ha at that site. Average grain yields under noninfested conditions were 2.5 Mg/ha at Abuja, Nigeria and 4.3 Mg/ha at Ferkéssedougou, Côte d'Ivoire. Some of the open-pollinated cultivars were comparable to the resistant hybrid for yield under infestation, maize damage rating, and *Striga* emergence, but none of these synthetics or

composites were better than the resistant hybrid check based on an index of traits. Composites Z. diplo. BC_4 C1 F_2 and TZL Comp. 1 C4 ranked second and third for the index of traits, respectively, because they supported relatively few emerged *Striga* plants and also had good levels of tolerance to *Striga*. Among the open-pollinated varieties, STR EV IWF had the highest average grain yield under *Striga* infestation. The best entries from this trial will be included in the 1999 International Trials, for wider distribution to collaborators.

Table 1. Average performance of late- and intermediate-maturing maize cultivars under *S. hermonthica* infested and noninfested conditions across three sites† in 1998.

Cultivar	Days to midsilk (noninf.)	Yield inf. rating‡	Yield non. 10 WAP	*Striga* count 8 WAP (5 m row)	Ears at harvest (inf.) (5 m row)	Ear aspect rating (inf.)	Grain yield (inf.) Mg/ha	Grain yield (noninf.) Mg/ha
9022-13 (Resistant hybrid)	56.8	4.8		32	18.8	3.7	2.5	3.4
STR EV IWF	*57.9*	*5.3*		*27*	*15.8*	*4.5*	*2.3*	*2.9*
Z. diplo. BC_4 C1 F_2	58.5	5.0		24	17.5	4.5	2.2	3.2
STR EV IWD	58.8	5.8		43	14.4	5.0	2.0	3.0
ACR 95 TZB-STR BC_2-W	59.3	5.2		34	14.5	5.1	2.0	2.4
TZ 96 STR Syn-W	59.9	5.3		23	17.3	4.6	1.9	2.5
TZL Comp. 1 C4	59.1	5.7		24	16.0	4.7	1.9	3.6
IWD STR C0	58.3	5.7		36	14.3	5.0	1.8	3.1
Low Emergence Pool C1 F_1	58.8	5.7		32	15.8	5.2	1.8	3.0
TZ 96 STR Syn-Y	59.0	5.6		29	16.8	4.3	1.7	2.8
TZL Comp. 5 C1 F_1	60.3	6.1		33	12.7	4.8	1.7	2.8
Acr 93 TZL Comp.1-W	60.2	5.4		44	14.5	4.7	1.6	2.8
IWF STR C0	57.8	6.3		47	15.4	5.5	1.6	2.8
ACR 95 TZB-STR BC_2-W/Y	59.4	5.9		33	14.8	5.3	1.5	2.3
TZB-SR (Susc. RE)	61.3	6.1		47	15.2	5.3	1.4	2.9
8338-1 (Susc. hybrid)	58.5	7.3		54	8.9	6.9	0.7	2.5
Mean	59.0	5.7		35	15.2	4.9	1.8	2.9
SE	0.70	0.30		12.7	1.07	0.30	0.23	0.24
Prob.>$F_{cultivar}$	0.0176	0.0015		0.0242	0.0003	0.0000	0.0020	0.0378
Prob.>$F_{location\ x\ cultivar}$	0.033	0.0003		0.383	0.013	0.037	0.0001	0.0236

† Sites were Mokwa and Abuja, Nigeria, and Ferkéssedougou, Côte d'Ivoire.
‡ Rating of host plant damage where 1=little or no damage and 9=severe damage due to *S. hermonthica*.
¶ Rating of the general appearance of the ears, where 1=excellent ear aspect and 9=poor ear aspect.

Although location x cultivar interactions were significant for most of the traits measured in this trial, cultivar means were positively correlated across sites for a number of *Striga* resistance traits. Correlations for ears at harvest, ear aspect, and grain yield measured under infested conditions were greater than for the same traits measured under noninfested conditions. These results suggest that *Striga* resistant cultivars developed at one site can be used as source germplasm for breeding programs throughout the sub-region, but that further improvements in resistance can be achieved through selection at the local, or country level.

The best available early-maturing open-pollinated varieties were also evaluated at the same three sites in Nigeria and Côte d'Ivoire in 1998. Data analysis has been completed for Mokwa and Abuja, Nigeria. The level of stress due to *Striga* infestation was not adequate in Abuja, so only the results from Mokwa are presented (Table 2). The trial in Mokwa was severely affected by both *Striga* and drought stress, but *Striga* emergence was low. Averages for days to midsilk under noninfested conditions ranged from 52.8 to 54.3 days after planting, and differences among cultivars were not significant (data not shown). The most resistant entries in the trial were 98 Syn. WEC and TZE Comp. 5 C6, which were both new or improved entries in the trial in 1998. The best entries from this trial will be included in the 1999 International Trials, for wider distribution to collaborators.

Table 2. Average performance of early-maturing maize cultivars under *S. hermonthica* infested and noninfested conditions in Mokwa, Nigeria in 1998.

Cultivar		Ears at harvest (inf.) (noninf.) (5 m row) Mg/ha	Grain yield	Ear aspect rating† (inf.)	Anthesis-silking interval (inf.)	Grain yield (inf.) Mg/ha
98 Syn. WEC	11.8	4.0		0.5	1.3	1.4
TZE Comp. 5 C6	13.8	4.0		2.3	1.3	1.7
TZE Comp. 5 C5	12.0	4.8		2.3	1.0	1.9
Acr 94 TZE Comp. 5-Y	11.8	4.8		3.5	0.9	1.5
TZE Comp. 4 C2 (Susc.)	10.3	5.0		2.0	0.8	1.3
EV DT 97 STR C1	8.0	5.0		1.3	0.7	1.5
Acr 94 Pool 16 DT STR	7.5	5.8		5.3	0.5	1.5
TZE Comp. 3 C2 (Susc.)	7.5	6.3		2.5	0.5	1.9
Mean	10.3	4.9		2.4	0.9	1.6
SE	1.65	0.39		0.79	0.14	0.16
Prob.>F	0.0897	0.0062		0.0148	0.0035	0.1070

† Rating of the general appearance of the ears, where 1=excellent ear aspect and 9=poor ear aspect.

Table 3. Performance of S_3 lines derived from Acr. 94 TZE Comp. 5-Y under *S. hermonthica* infestation in Abuja and Mokwa, Nigeria in 1998.

Inbred	Days to midsilk (Abuja) (Mokwa) Mg/ha	*Striga* damage rating† (Abuja)		*Striga* damage rating† (Mokwa)	Ears at harvest (Abuja) (3 m row)	Ear aspect rating‡ (Abuja)	Grain yield (Abuja) Mg/ha
(S_2 21)-2-#	53.4	5.4	4.4	15.1	3.5	5.9	4.3
(S_2 23-1)-1-#	55.4	6.1	4.5	11.6	4.0	3.9	4.0
(S_2 22)-5-#	54.5	5.7	4.5	12.3	4.5	4.5	2.9
(S_2 20)-3-#	55.1	5.6	5.7	12.7	4.5	4.4	1.8
(S_2 25)-3-#	55.6	5.1	5.4	13.6	5.0	4.3	2.1
Checks							
5057 (susc.)	59.4	6.9	6.6	2.3	7.5	0.4	0.4
9030 (tolerant)	63.3	5.6	5.2	13.1	5.5	3.5	1.7
9450 (resistant)	64.2	5.8	5.5	6.1	6.0	1.7	0.6
Mean (30 lines)	56.6	6.3	5.9	11.2	5.6	2.8	1.7
SED	2.0	0.5	0.6	1.7	0.6	0.62	0.57
Prob.>F	0.0000	0.0025	0.0160	0.0003	0.0002	0.0000	0.0000

† Rating of host plant damage where 1=little or no damage and 9=severe damage due to *S. hermonthica*.
‡ Rating of the general appearance of the ears, where 1=excellent ear aspect and 9=poor ear aspect.

8.3.2. Maize inbred line development

by J.G.K, A.M.

A total of 912 partially inbred lines (S_2-S_5) were screened in replicated trials in Mokwa and Abuja under *S. hermonthica* infestation in 1998. These lines represent a new generation of inbred lines derived from more than ten diverse breeding pools. A total of 238 testcrosses were evaluated to determine combining ability of some of the new lines. A large number of experimental hybrids outperformed for both yield and reduced *S. hermonthica* emergence – the standard tolerant hybrid 9022-13. The most promising inbred lines and hybrids will be reevaluated in 1999. The best among these will be made available to National Programs in international trials in 2000. Similarly,

new intermediate- and early-maturing inbred lines with *Striga* resistance are being developed by IITA maize breeders in Côte d'Ivoire.

New early-maturing, yellow S_3 lines derived from TZE Comp. 5 were evaluated in replicated trials under *S. hermonthica* infestation at Mokwa and Abuja, Nigeria. *Striga* emergence was relatively low in these trials, but damage symptoms were severe (Table 3). Selected lines were 6-10 days earlier in maturity than the standard inbred check, 9030, yet yields were superior to the check under infestation at both sites. Selected lines have been crossed to inbred testers for evaluation of combining ability in 1999.

8.3.3. Development of a maize pool witb reduced *S. hermonthica* emergence

by J.G.K.

In the early 1990's, African landraces were identified which supported fewer emerged *S. hermonthica* plants, and these were crossed to improved, resistant cultivars to form a low emergence pool. Because the landraces were obtained from diverse ecologies throughout Africa, the pool is not very well-adapted to the lowland environments of West and Central Africa, and is susceptible to foliar diseases and ear rots. However, it has a high level of genetic variation for *S. hermonthica* resistance, and yield performance has been improved through selection (see Table 1). In 1998, we screened 154 S_2 families derived from the C0 and 177 S_1 families derived from the C1 in replicated trials under *S. hermonthica* infestation in Mokwa and Abuja, Nigeria. The S_1 trial was also sent for screening under *S. hermonthica* infestation at the AMS project screening sites in Cameroon and in Benin, and under *S. aspera* infestation through collaboration with the PASCON network at the ICRISAT farm in Bagauda, Nigeria. Results from those trials have recently been received and are being analyzed.

Among the S_2 lines evaluated from this pool, about 50% exceeded the performance of the standard resistant inbred, 9450, based on an index of desirable characteristics. The best lines showed fewer damage symptoms, supported reduced numbers of emerged *Striga*, and had high grain yield and good ear aspect under *S. hermonthica* infestation. Selected lines will be further inbred under *Striga* infestation and testcrossed for evaluation of combining ability in 2000.

Similarly, over 50% of the S_1 lines evaluated from this pool were superior to 9450 based on an index of desirable traits. Collaborators in Benin and Kenya have requested additional seed of a number of promising lines. Four replicates of this trial were evaluated in both Abuja and Mokwa, providing a very precise assessment of performance. When data are fully analyzed from sites in Benin, Nigeria, and Cameroon, it should be possible to identify superior lines with stable resistance across diverse environments, *Striga* species and biotypes. These will be further inbred and recombined to form a new cycle of selection.

8.3.4. Dissemination of resistant maize germplasm

by J.G.K.

Regional Trials of *Striga* resistant germplasm distributed to NARS collaborators in 1998 included late and intermediate open-pollinated cultivars (18 sets to 9 countries), and early-maturing open-pollinated cultivars (21 sets to 9 countries). In addition, bulk breeder's seed of *Striga* resistant open-pollinated cultivars (260 kg) and inbred lines (11 kg) were distributed on request. The consignments ranged in size from less than one kg up to 25 kg of each cultivar, and were used for both seed multiplication and on-farm testing of varieties by collaborators. Hybrid seed (74 kg) was also distributed on request.

Seeds of two improved *Striga* resistant cultivars were given to ten farmers in the vicinity of the *Striga* screening site in Mokwa, Nigeria. A farmers' field day was held at harvest, which attracted over 100 local farmers. The farmer who hosted the field day had severe *Striga* infestation in his field. The late-maturing, improved variety produced approximately double the yield of the farmers' local under those conditions, and had acceptable grain type. Bulk seed of this variety will be given to the Mokwa Agricultural Development Project in 1999 for multiplication and distribution to farmers.

8.3.5. Mapping of *Striga hermonthica* resistance gene(s) in *Z.mays* x *Z. diploperennis* crosses

by A.M.-B., J.G.K., D.K.B. in collaboration with J.K.Ransom, H. Mignouna, D. Hoisington, H.G.Welz, H.H. Geiger, J.DeVries

Progress in breeding for reduced *Striga* parasitism in maize has been constrained by limited genetic variation for resistance in adapted germplasm. Several years ago, IITA scientists identified

resistance to *S. hermonthica* in the wild relative of maize, *Zea diploperennis*. Through backcrossing, the resistant gene(s) have been incorporated into adapted maize genotypes. Selected full-sib families from the *Z. diploperennis* BC_4 C_0 generation from 1996 field trials were selfed for two generations under *S. hermonthica* infestation in the screenhouse in Ibadan. In late 1997, 75 selected S_2 families were evaluated in replicated trails under artificial infestation in the screenhouse in Ibadan and in the field in Kibos, Kenya. At the same time, crosses were made to susceptible inbred lines from East and West Africa to initiate formation of mapping populations. In 1997, a project to map genes for *Striga* resistance and to develop markers for Marker Assisted Selection was initiated through collaboration between IITA, CIMMYT, KARI (Kenya Agricultural Research Institute), and the Univerisity of Hohenheim, with funding from the Rockfeller Foundation.

In 1998 we finished setting up the maize molecular genetic laboratory in order to start mapping the Striga hermonthica resistance gene(s) in Z. mays x Z. diploperennis crosses. In a collaborators meeting held in Nairobi, Kenya, in June 1998 it was decided, based on field and greenhouse results both in West and East Africa, that the F_2 populations from the following crosses would be used to map the striga resistance gene(s) for West Africa:

i) 44-6-1 X 1393 (362 progenies)
ii) 607-2-1 X 1393 (302 progenies)
iii) 91-5-1 X 1393 (290 progenies

DNA was isolated from selected resistant BC_4 S_2 lines and two susceptible lines (1393 and 5057), and screening of molecular markers (RFLP, SSR, AFLPs) was initiated to identify the most polymorphic markers that could be used to genotype the mapping populations. In addition, leaf samples from the F_2 mapping populations were collected and we have started isolating DNA. Two of these mapping populations will be evaluated under artification infestation with *S. hermonthica* in Mokwa and Abuja, Nigeria in 1999.

In addition, conventional backcrossing programs to transfer the resistance genes to the adapted, susceptible parents are being carried out for each population. In 1998, the BC_1 generations were screened under artificial *S. hermonthica* infestation in Mokwa.

8.3.6. Improved resistance to S. hermonthica in a maize population derived from Zea diploperennis

by J.G.K. and A.M.-B.

Population improvement for *Striga* resistance and other agronomic characteristics has continued in the *Z. mays* x *Z. diploperennis* BC_4 C_0 population described in the previous section. In 1998, selected full-sib families from 1997 field trials were recombined to form the BC_4 C_2, and new S_1 families were generated for field screening in 1999.

A large number of promising inbred lines which show reduced *Striga* emergence and high yield under *Striga* infestation have also been extracted from this population. The lines per se (S_3 to S_4 stage) and their testcrosses were evaluated in replicated trials in Mokwa and Abuja in 1998. The best lines and hybrids will be available in International Trials in the year 2000. New S_2 lines derived from Cycle 1 will be evaluated in Mokwa and Cameroon in 1999.

8.3.7. Development of Striga resistant early and extra-early varieties from elite populations

by B.B.-A.

S_2 inbreds extracted from the early drought tolerant, *Striga* and streak resistant populations, TZEW-Pop STR (white) and TZEY-Pop STR (yellow) and the extra-early *Striga* resistant populations, TZEE-W Pop STR (white) and TZEE-Y Pop STR (yellow) in 1997 were advanced to the S3 stage in a program to extract *Striga* resistant synthetics from each population.

8.3.8. Improvement of the *Striga* resistance level of some widely cultivated extra-early varieties

by B.B.-A.

A program was initiated in 1994 to introgress *Striga* resistance into the widely cultivated extra-early varieties, TZEE-W SR BC_5 and TZEF-Y. The *Striga* tolerant inbred, 1368 STR (donor for STR) was crossed to TZEE-W SR BC_5 while 9450 STR (donor for STR) was crossed to TZEF-Y followed by a cycle of backcrossing to recover earliness. Inbred extraction from the backcrosses was then initiated with six generations of selfing and screening under artificial infestation of *Striga*. One hundred and forty-four S_6 inbreds developed in 1998 from the backcross (TZEE-W SR

BC_5 x 1368 STR) x TZEE-W SR BC_5 would be screened for *Striga* resistance in 1999 and 7-10 most resistant S_6 lines would be selected to form a synthetic. Also, nine S_4 inbreds extracted from (TZEF-Y x 9450 STR) x TZEF-Y SR were recombined in 1998 to form a synthetic.

8.3.9. Development of *Striga hermonthica* resistant early varieties from elite germplasm
by B.B.-A.

Three main activities were carried out: a)The development of a *Striga hermonthica* tolerant variety, 98 Syn WEC STR from seven S_6 inbred lines extracted from 86 Pool 16 DT was completed and the variety evaluated in preliminary yield trials in Nigeria and Cote d'Ivoire. b)EV DT-W 97 STR C_1, a *Striga* tolerant variety developed from 86 Pool 16 DT in 1997 was promoted to the Regional Uniform Variety Trials and evaluated at several locations in West and Central Africa. c)Ten *Striga* tolerant early S_4 lines developed from the backcross (TZEW-Pop x 1368 STR) x TZEW-Pop were recombined under artificial *Striga* infestation to form a synthetic.

Striga hermonthica tolerant varieties, EV DT-W 97 STR C_{02} EV DT-W STR Ci and 98 Syn WEC STR showed superior performance in Regional Uniform Variety Trials and/or preliminary trials. Two *Striga* tolerant synthetics, TZEW-Pop x 1368 STR and TZEF-Y x 9450 STR developed for preliminary evaluation in 1999.

8.3.10. Development of intermediate maturing *Striga* Tolerant/Resistant (STR) maize populations
by J.M.F.

In each of the three intermediate duration STR maize populations (IWD-STR, IWF-STR, IYFD-STR), 6-10 families (S4) selected for least host plant damage and low *Striga* emergence under artificial infestation with *Striga hermonthica* at Ferkessédougou (Ferké), Côte d'Ivoire were recombined to form Cycle 1 experimental varieties in 1997 B. They were advanced to F_2 in 1998A. Seed of these new varieties were increased in 1998 B.

8.3.11. Development of intermediate maturing STR inbreds and hybrids
by J.M.F.

Lines from the STR populations were advanced to S6. Apart from selecting these lines for low *Striga* counts and least host plant damage, they were at various stages subjected to other important stresses especially foliar diseases, low soil nutrients and drought. The S6 inbreds were crossed among themselves and to elite IITA and CIMMYT lines for subsequent evaluation as hybrids.

8.3.12. Evaluation of STR open-pollinated varieties
by J.M.F.

Sixteen STR experimental varieties and synthetics, including 9 from Cycle 1 were compared with 4 checks under standard artificial infestation of *Striga* at Ferké. Each was planted in 2-row plots of 5 meters per row and in 4 replications. Both rows in each plot were rated for host plant damage and number of emerged *Striga* plants at 8 and 10 weeks after planting. All the STR open-pollinated varieties gave 85-185% more grain yield than the *Striga* susceptible hybrid check 8338-1 with average host plant damage scores of 5 and 7 (1-9 scale)respectively. Although EV-IWDSTR (FkB) C1F2 and EV-IWDSTR CoF4 gave 0.5t/ha higher yield than the commercial hybrid Oba Super 1, this difference was not statistically significant.

8.3.13. Evaluation of new hybrids for *Striga* reaction
by J.M.F.

Thirty white-grained new hybrids (24 single cross, six 3-way crosses) which had been evaluated in preliminary yield trials in 1996 and 1997 were subjected to Striga infestation. They were tested in two sets of 18 entries per set including three common checks namely: (i) Oba Super 1 (commercial hybrid), (ii) TZB-SR (a widely grown open-pollinated variety), and (iii) TZL Comp.4 (a most recent top-performing improved open-pollinated maize). They were planted in 4 replications of two 5m-rows per plot and infested with Striga at planting. The entries were rated on plot basis for host plant damage and number of emerged Striga at 8 and 10 weeks after planting.

Nine hybrids including one 3-way cross were significantly higher yielding than all the checks, with yields of 6.2-7.5 t/ha compared to 4.0-4.8t/ha under *Striga* infestation. They exhibited an average *Striga* damage rating of 3.4 compared to 5.0 for the checks on a scale of 1-9 (1=highly resistant and 9=highly susceptible). There was great variability among the entries in the reaction of

the plants regarding the relationship between plant damage due to *Striga* and the number of emerged *Striga*. There were, for example, entries that induced a large number of *Striga* plants while the plants continued to exhibit lush green leaves and/or little reduction in plant vigour (height and stem diameter). Hybrid 1102 x 9030 is an exceptionally consistent *Striga* tolerant/resistent high yielding entry.

One set of yellow-grained hybrids consisting of 12 single-cross hybrids, three 3-way crosses and three checks (Oba Super 2, EV8728SR, IYFD) was planted also at Ferké. It was infested with *Striga* and subjected to the same treatment and observation as the white hybrids. Only one test entry (2401A x 2110) was significantly higher yielding than the best check (Oba Super 2, yellow commercial hybrid). It produced 5.6t/ha compared to 4.0t/ha for Oba Super 2.
One hundred and five white and 48 yellow experimental hybrids were evaluated in preliminary yield trials (1 row per plot) in 20-entry sets. Each set contained 5 common checks for white and 4 for yellow entries. They were all artificially infested with *Striga*. Only 11 entries gave grain yields superior to the best check. None of the yellow experimental hybrids was superior to the hybrid check, Oba Super 2.

8.4. Adapted cowpea cultivars with S. gesnerioides *and* A. vogelii *resistance and improved sources of resistance in cowpea*

Background

A systematic breeding program to develop cowpea cultivars resistant to *S. gesnerioides* and *Alectra vogelii* was undertaken in 1987. The source of resistance was B301 which was crossed to a high yielding cultivar with resistance to aphid, bruchid, thrips, and several diseases. Progenies were selected under disease, insect and both *S. gesnerioides and A. vogelii* pressures, leading to development of a number of a *S. gesnerioides* and *A. vogelii* resistant breeding lines with combined pest resistance and a mean yield imnprovement of 56 percent over the parasite-susceptible parents. These lines have been distributed to various national programs in Africa and further breeding continues using these lines as parents. Subsequently, five different strains of *Striga gesnerioides* were identified. B301 was resistant to 4 strains and IT81D-994, IT89KD-288, Suvila-2 and 58-57 were resistant to 3 strains including the one for which B301 was susceptible. Therefore, to develop a range of cultivars with combined resistance to different strains of *S. gesnerioides*, the B301 derived lines are being crossed with IT81D-994, IT89KD-288, Suvita-2 and 58-57. Efforts are also being made to incorporate *Striga* and *Alectra* resistance in local varieties.

On-going and future activities

8.4.1. Incorporation of *Striga/Alectra* resistance in local varieties
by B.B.S.

Eight local varieties, viz: Bausse local Danwuri, Aloka, Bauchi early, Vya local, Kamboinse local, IAR1696, Zinder local and Gorom local were crossed with *Striga* resistant lines IT90K-76 and IT93K-693-2 for systematic backcrossing program to incorporate *Striga/Alectra* resistance in these varieties. The F_1 plants and parents will be grown in the coming season for backcrossing.

8.4.2. Screening of breeding lines
by B.B.S.

A total of 601 breeding lines were screened for resistance to *S. gesnerioides* using a combination of screenhouse and field screeening at Kano, Babura and Zinder. Based on their complete resistance to *S. gesnerioides* and other desirable agronomic traits, 81 lines were selected for further testing. Some of these lines were also screened for resistance to *Alectra* in collaboration with Professor S.T.O. Lagoke of Institute for Agricultural Research, Ahmadu Bello University, Zaria, and several lines with combined resistance to *Striga* and *Alectra* were identified.

8.4.3. New crosses made
by B.B.S.

A number of new crosses involving most promising *S. gesnerioides* and *Alectra* resistant lines and other desirable parents were made and F_2, F_3, F_4 populations evaluated at Babura in Striga infested field. A large number of resistant plants/progenies have been selected for further evaluation.

8.4.4. Breeding for resistance to multiple strains of *S. gesnerioides*
by B.B.S.

By using a combination of screenhouse test at Kano and field tests at Babura and Zakpota (Benin Republic), a large number of breeding lines were evaluated for combined resistance to the Nigerian and Zakpota strains of *S. gesnerioides*. The most promising among these were IT93K-513-2, IT93K-693-2, IT93K-440-3, IT95K-1090-1, IT95K-1091-3, IT95K-1090-12, IT96K-757 and IT96KD-759.

8.4.5. Map based cloning of cowpea RSG genes encoding resistance to Striga gesnerioides
by D.K.B., B.B.S. - in collaboration with M. Timko, C. Fatokun

A few sources of near-complete resistance to *S. gesnerioides* infestation are known to exist in cowpea. Included among those cultivars reported to be resistant are Tvu 14676, Suvita-2, B301, IT81D-994, and IT82D-849. Resistance to *S. gesnerioides* parasitism is conferred through one of two main processes: necrosis of the host root localized to the site of infection or failure of the parasite to develop after attachment. Inheritance studies suggest that a single dominant gene or tightly linked group of genes are responsible for resistance. Resistance also appears to involve some level of physiological specialization, since different races of *S. gesnerioides* elicit different types of defense response on a particular cultivar, or in some cases elicit no resistance response. The only exception appears to be IT82D-849 which shows inheritance of resistance to the Niger strain of *S. gesnerioides* consistent with the action of a single recessive gene.

A limitation to the rapid genetic improvement of cowpea for resistance to *S. gesnerioides* and other parasitic plants is the lack of markers that specifically identify the resistance or susceptibility phenotype. Such markers could be useful in marker-assisted breeding strategies as well as in the identification and cloning of the genes conferring resistance to parasite attack. The goal of our studies has been to identify molecular genetic markers that reproducibly segregate with resistance or susceptibility of cowpea to infection to *S. gesnerioides* and possibly other parasitic plant species. These molecular markers and the resistance/susceptibility genes they identify could then be used in breeding for improvement of this crop or in the isolation of genes for engineering of *Striga* spp. resistance in other crops.

We are currently using the cloned 81-S-4 fragment and one other low copy sequence to screen a lambda genomic library constructed from Tvu 14676 (*S. gesnerioides*-resistant cowpea parent from Nigeria) to isolate phage containing the polymorphic DNA fragments. The flanking DNA may contain additional markers. Over the next several months, we would like to place our markers on the existing cowpea genetic map(s). We have obtained parental material and 94 RILs (Recombinant Inbred Lines) from a cross involving IT84S-2049 and 524B, provided to us by A.E. Hall (U.C, Riverside). We are testing to see whether the markers or associated flanking regions detect polymorphisms between the parents of the mapping population. If we can place these markers on an existing genetic map of cowpea, along with the cloning of the markers and flanking regions, we will be well on our way toward map-based cloning of the *S. gesnerioides* resistance/susceptibility conferring gene(s) in cowpea. Once this occurs, we should be able to transfer this gene(s) into other cowpea varieties (lines), and, potentially, into maize for *S. hermonthica* resistance. We anticipate that an initial publication reporting the isolation of AFLP markers for *Striga gesnerioides* resistance/susceptibility will be forthcoming in the next several months.

8.5. Chemical seed treatments for reduction of Striga *spp. damage on host crops and depletion of* Striga *spp. seedbank*

Background

Pre-emergence herbicides aimed at stopping germination or killing the newly germinated *Striga* spp. seedlings are generally not effective because the parasite seeds germinate over a longer period of time than the effective activity of the herbicide and the parasite does not emerge through the herbicide layer until 6 to 8 weeks after planting, by which time the herbicide is no longer active. Postemergence herbicides can kill the parasites prior to flowering and prevent seed production; however, as most damage to the host has been done by this time and not all *Striga hermonthica* seeds germinate in a single growing season, benefits from postemergence herbicide applications may not be demonstrable for several seasons. An alternative chemical control approach is to apply translocated herbicides that have little or no effect on the host, but are detrimental to the parasite. This approach, using the acetohydroxyacid synthase (AHAS) inhibitor, imazaquin, has been used

successfully to control *Orobanche crenata* (Forsk.) and *Cuscuta* spp. in broadbean and soybean. Another approach is to treat seeds of the host plant with imazaquin. This approach has been successfully used for *S. gesnerioides* and *A. vogelii* control in cowpea. Because seed treatments are inexpensive and do not require spray application equipment, they are particularly suitable for African farmers.

On-going and future activities

8.5.1. Field testing of seed treatments on tropical imazaquin (IR) resistant maize
by D.K.B. - in collaboration with J. Green

Seed treatments with two ALS-inhibiting herbicides, the sulfonylurea herbicide nicosulfuron and the imidazolinone herbicide imazaquin, controlled the parasitic weed *S. hermonthica* in maize. The XA-17 gene in ALS-modified P3180IR maize strongly reduced maize injury from herbicide seed treatments while another ALS-modification was not effective. Combining seed treatment of ALS-herbicides and ALS-modified maize with the XA-17 gene may offer a practical means for African growers to control *S. hermonthica*. In addition, maize lines with the XA-17 gene are suitable for over-the-top application of ALS-inhibitors and can be efficiently used with inexpensive and effective (metsulfuron methyl) herbicide application programs for general weed control.

8.5.2. Incorporation of IR gene for ALS-inhibitor resistance into adapted maize
by D.K.B. - in collaboration with J. Green

In order for ALS-inhibitors to be successfully used in controlling *S. hermonthica*, the gene for ALS-inhibitor resistance must be incorporated into tropically adapted maize. Using a rapid screening technique that we developed for ALS-inhibitor resistance numerous homozygous resistant tropical inbred and open pollinated maize lines were produced. These were tested in the field in 1998 and will be further multiplied for use and release in 1999.

8.6. Increased awareness of Striga *spp. contamination of crop seed lots*

Background

In *S. hermonthica*-infested areas of Africa, crop seed lots are frequently contaminated with *S. hermonthica* seeds as a result of harvesting, threshing, and drying processes. Harvesting is frequently done by cutting the plant at the ground level and laying the whole cut plant in the field to dry. When collecting the plants from the field, any *S. hermonthica* plants and seeds which are interspersed with the drying crop are also inadvertently collected and taken to the threshing area where *S. hermonthica* seed contamination among different crop seeds can easily occur. After winnowing out the heavier crop trash, the seed lots are either stored in the village house or taken to market for sale. Seeds purchased from the markets are used both for food and planting material in the next season as are household-stored seeds. In the latter case, within village exchanges of seed also take place. Thus, newly infested sites can quickly result through contamination, sale, and redistribution of crop seeds. As *S. hermonthica* seeds are not moved to any great extent by wind, the use of *S. hermonthica*-free planting material is the important first step in preventing new infestations or reinfestations and in making sustainable control feasible. This can be ensured by purchasing seeds from reputable seed companies, planting seeds harvested only from *S. hermonthica*-free areas.

On-going and future activities

8.6.1. Alternative solutions to ensuring *Striga*-free planting material.
by D.K.B.

A simple method of ensuring *Striga*-free planting material is to reserve the uppermost portion of seeds from newly harvested materials for planting. As *Striga* seeds are dense (specific gravity 1.4) they settle to the bottom of seed containers and become mixed with crop seeds at the bottom of the containers. As this portion of seeds is most commonly left for planting in subsequent seasons, farmers frequently, but inadvertently, plant *Striga* seeds with their crop seeds. By changing this practice and reserving the relatively uncontaminated crop seeds at the top of the container for planting, farmers can help to ensure that they are planting clean materials. The balance of the seeds, with the *Striga* seed contamination, can be safely consumed

8.7. *Microbial agents and delivery systems for controlling Striga spp.*

Background

Because *S. hermonthica* is endemic to Africa there is little opportunity for classical biological control through introduction of pests and pathogens of *S. hermonthica* from areas outside Africa. What might work is the manipulation (through multiplication and periodic release) of indigenous insect pests and microbial agents for *S. hermonthica* control. Because these biocontrol agents are indigenous to Africa, they also have indigenous pests, diseases, and competitors that keep their own populations in check. Also, as in classic predator-prey relationships, once the population of the target species drops below a certain threshold, the biocontrol agent population is also likely to decrease thereby allowing the target species population to rise again. Thus, it is unlikely that a single release of such indigenous biocontrol agent will provide sustained control. Periodic release will be needed for sustained control. However, use of indigenous biocontrol agents is not free since there is considerable expense involved, after the initial isolation and testing phases, in multiplying and releasing these control agents. So, for the use of these biocontrol agents to be sustainable (not merely defrayed to external funding agencies), the cost associated with their multiplication and release must eventually be willingly taken up by the farmer. In the case of *S. hermonthica*, this requirement virtually excludes the use of pests and diseases of emerged and/or flowering parasites. For a resource-poor African farmer to be willing to pay for the cost of a *S. hermonthica* control treatment (biological or otherwise), there must be a demonstrable host crop yield benefit within the season of use. Because *S. hermonthica* causes most crop damage before the parasites emerge, pests and diseases of emerged *S. hermonthica* cannot demonstrate this immediate benefit. A workable alternative is the use of pests and diseases of *S. hermonthica* seeds to reduce the amount of parasite seeds in the soil (and the resulting amount of parasitism) prior to planting the host crop.

On-going and future activities

8.7.1. Continue isolation and evaluation of bacteria influencing S. hermonthica seed germination and survival - laboratory and screenhouse

by D.K.B. - in collaboration with N. Schaad, M. Ahonsi, J. Alao

A plethora of microbes could probably be isolated from suppressive soils, tested, multiplied, and re-released. However, isolating and characterizing the tremendous number of soil microbes is a daunting task. The approach that we have taken is to isolate bacteria and fungi from *Striga* spp. seed coats, from where there is a more likely association in hyperparasitism. Only the isolated microbes that can be soilborne are tested further. Future studies will focus on trapping bacteria from suppressive soils by baiting with *Striga* spp. seeds.

8.7.2. Testing of promising *Pseudomonas* spp. isolates in controlled field studies and give technology to NARES

by D.K.B.- in collaboration with N. Schaad

Some of the more promising bacterial candidates are isolates of *Pseudomonas* spp. After testing for efficacy in the laboratory, these isolates have been tested in screenhouse pots studies, and then large screenhouse studies, and finally in the field from where they were isolated. Results of a series of pot studies with two different *Pseudomonas* spp. isolates indicate that as length of incubation of the bacteria with the *S. hermonthica* seeds increased, there was a significant decrease in number of attached *S. hermonthica*. Data from large-scale tests with different application methods and incubation times show that one of the isolates is extremely effective in reducing *S. hermonthica* parasitism and improving yields of local sorghum. This work will continue and technology will be transferred to NARES.

8.7.3. Test several delivery systems for promising bacteria in field

by D.K.B.

Bacteria suspensions were used as seed treatments and seedling dips and were tested for efficacy in the field in 1997. Improved seed treatment techniques and bacteria inoculant will be further tested in the future to determine efficacy in relation to bacteria concentration of seed treatment and planting time. In addition seed treatments will be tested on rotation crops for efficacy on the subsequent cereal crop.

8.7.4 Testing of ethylene-producing bacteria in laboratory and screenhouse studies
by D.K.B.

A proven method of eliminating *Striga* seed reserves in the soil is soil injection of ethylene gas, but ethylene gas injection is dangerous, costly, and generally unsuitable in Africa. In this study known ethylene-producing strains of *Pseudomonas* spp. were tested in the laboratory for efficacy in stimulating *Striga* spp. seed germination. Two strains stimulated germination of *S. aspera* and *S. hermonthica* seeds as well as both a synthetic germination stimulant and ethylene and significantly better than root pieces of a *Vigna unguiculata* cultivar known to stimulate *Striga* spp. seed germination. Seeds of *S. gesnerioides* are notoriously difficult to germinate, however, one strain stimulated significantly more *S. gesnerioides* seed germination than the *V. unguiculata* cultivar. These and other ethylene-producing strains will be further tested for efficacy in laboratory and screenhouse studies

8.7.5. Determine relationship between soil suppressiveness and edaphic factors
by D.K.B. - in collaboration with M. Ahonsi, J. Alao

Natural biotic soil suppressiveness is widespread in Nigeria, including soils from *S. hermonthica* infested areas. Soils collected from farmers' fields in 11 locations in Nigeria ranging from 11.80 ° N. latitude to 7.17 ° N. latititude showed a highly significant overall reduction in number of attached parasites of 43% attributable to soil suppressiveness. Preliminary work has shown that C:N ratio in the soil is one of the primary factors influencing suppressiveness. Future studies will focus on the involvement of other edaphic factors in soil suppressiveness and how to best manage soils and cropping systems to maximize suppressiveness.

8.8. Improved understanding of Striga *spp. biology and epidemiology*

Background

All *Striga* species do not occupy the same ecological zones in Africa. *S. hermonthica* is not found south of the Guinea savanna while *S. asiatica* is not usually found north of the southern Guinea savanna. Morphotypes of *S. gesnerioides* are specific for different hosts, the distributions of which vary depending on ecological zone. The niches for less well known species like *S. aspera* and *S. forbesii* seem to be even more restrictive, based on the limited data available. However, the parameters that govern these distributions have not been understood even though these parameters offer insight into control strategies. Information on the physical mechanisms of *Striga* distribution is also lacking and it is these data which are necessary to construct efficient control schemes. Thus, a substantive portion of the project is directed at understanding these components of *Striga* biology and epidemiology and the interactions of various *Striga* spp. with host and non-host plants and other organisms in the respective ecosystems.

On-going and future activities

8.8.1. Characterize potential germination inhibitors among pure compounds obtained from root and shoot extracts
by D.K.B. - in collaboration with J. Rugutt

Striga spp. seeds have a complex germination biology which includes the need for an exogenous stimulant which, in nature, is provided by root exudates of various plants. However, in the absence of adequate environmental conditioning, these stimulants are ineffective. A feasible explanation for this is that germination inhibitors are leached out of the *Striga* seeds during conditioning. We have been able to consistently identify zones of inhibition in parasite seed germination assays. To isolate and identify these potential *Striga* seed germination inhibitors, pure compounds were isolated from conditioned and non-conditioned *Striga* seed lots. These compounds appear to be tetradeconoic acid, cis,cis-9,12-octadecadienoic acid, cis-9-octadecenoic acid, sitosterol, 2,6-dimethoxy-p-benzoquinone (2,6-DMBQ) and several long chain aldehydes and n--hydrocarbons. The role of these compounds in germination stimulation and inhibition will be further studied.

8.8.2. Continue characterization of active germination stimulants of *Striga* spp. among pure compounds obtained from root and shoot extracts
by D.K.B. - in collaboration with J. Rugutt

Pure compounds isolated from host and non-host roots were tested for efficacy in stimulating *Striga* spp. seed germination. Those compounds that were highly effective are currently being chemically characterized to determine underlying communality of structure and function.

8.8.3. Continue *S. hermonthica* - host physiology studies on transpiration flow, stomatal regulation, and the role(s) of plant hormones in disease development

by D.K.B. in collaboration with O. Babalola

Work on the epidemiological and physiological bases of *Striga*-host interactions needs to be conducted with specific reference to environmental parameters. To do this, experiments will be conducted which measure physiology of the parasite-host interaction, e.g. photosynthesis, carbon fixation, transpiration, sap flow, hormone changes, root growth, etc., of both hosts and *Striga* spp. under closely measured environmental conditions. These responses will then be related to successful *Striga* parasitism and reproduction and to host resistance. These basic experiments will result in appropriate control options which mechanistically and economically reduce *Striga* parasitism and reproduction while promoting host yield.

8.8.4. Determine how environmental parameters, host crops and cultivars, and planting date can best be manipulated for *S. hermonthica* control

by D.K.B. in collaboration with S. Nokoe

Studies are continuing on the effects of environmental and host variables on *S. hermonthica* parasitism and reproduction. These are long term studies which attempt to link *S. hermonthica* parasitism and reproductive parameters to environmental and host parameters. Through these studies, optimum combinations of host cultivar, planting density and planting date for *S. hermonthica* control and host yield will be constructed in relation to environmental events. These data are currently being analyzed with a view to developing a practical predictive model.

8.8.7. Specificity of host-parasite interactions at parasite seed germination

by D.K.B.

When seeds of single-plant isolates of *S. gesnerioides* were tested against roots of seedlings from sorghum and millet landraces, and from a susceptible cowpea cultivar, only specific *S. gesnerioides* isolate and plant combinations produced parasite seed germination. This specificity strongly resembled gene-for-gene complementarity. Proposed gene-for-gene models for *S. gesnerioides* seed germination were developed, and it was found that predicted germination closely fitted the study data. The models suggest different germination stimulants and the stimulant receptors, the interactions of which may either stimulate or inhibit parasite seed germination depending upon the plant-parasite combination. Geographically diverse isolates of *S. gesnerioides* and local cowpea cultivars were collected in 1997 and isolate by cultivar interactions were tested in the laboratory in 1998. These data are being analyzed, and a proposed gene-for-gene model will be tested based on interactions between the isolates and the cultivar collections.

8.9. Demonstration of effective and adoptable integrated Striga spp. *management*

Background

The IITA *Striga* IPM project has developed an integrated program of control that replaces traditional bush fallow rotation with nonhost legume rotations using cultivars selected for efficacy in germinating *Striga* spp. seeds. These legume rotations produce food and improve soil conditions while controlling *Striga* spp. on subsequent cereal crops. The complete IPM program starts with *Striga*-free planting material and focuses on selected legume cultivar rotations which are supplemented by biological control, cultural control to enhance biological suppressiveness, host-plant resistance, and host-seed treatments. The project members feel that this program offers sustainable control to African farmers, but, because of the cropping systems approach, the effectiveness of the program requires demonstration over several seasons. This output is designed to create NARES and farmer awareness of this effective program through on-farm and on-station demonstrations.

On-going and future activities

8.9.1. Establish demonstration plots for *S. hermonthica* control

by D.K.B., S.S., K.E.D., J.G.K.

About 5 hectares of IPM demonstration plots at Mokwa, Nigeria were infested with *S. hermonthica* in 1996. In 1997, these plots were used to demonstrate the effectiveness of selected N-fixing legume cultivar rotations, resistant maize cultivars, ALS seed treatments, enhanced soil suppressiveness and supplemental inundative-type biological control. A field day was conducted

and the same farmers and extensions workers who participated in 1997 returned for a follow-up field day in 1998. As a result of this field day over 50 farmers from Mokwa, Kaduna, and Zaria areas are eager to participate in implementation of integrated *Striga* management on their own farms. This implementation at the farm level will begin in 1999.

8.9.2. Establish demonstration area for *S. hermonthica* IPM in benchmark areas
by D.K.B., S.S., K.E.D., J.G.K.

On-farm *Striga* IPM demonstrations sites will be established in farmers' fields in RCMD benchmark areas. The demonstrations will be set up in fields heavily infested with *S. hermonthica* and will employ a complete set of IPM options developed by IITA. Control areas with no IPM will be included. The demonstrations will start with selected legume cultivar rotations for one and two years. These rotations will be managed to enhance soil suppressiveness to *S. hermonthica* while directly reducing the parasite seedbank through parasite seed germination. Following the rotations, resistant maize treated with ALS inhibitors will be planted. The maize crop will also be planted and managed to enhance natural soil suppressiveness. Comparisons, both visual and statistical, will be made with the control areas as proof of effectiveness. This is a continuation of the outcome of 8.9.1.

8.10. Development of improved mechanisms for technology flow to NARES and for implementation of parasitic plant IPM by NARES

Background

In addressing the purpose of the project, i.e. to develop, with NARES, sustainable integrated parasitic plant management measures and components which will be disseminated by NARES to farmers, an output for improving technology flow was developed. This output includes activities to promote collaboration between CG centers and to assist NARES in technology dissemination. Collaboration between CG centers is being fostered by the formation of a system-wide task force on parasitic flowering plants. To further assist NARES in implementation of integrated parasitic plant management, technology dissemination proposals with multiple country focus are being developed with PASCON.

On-going and future activities

8.10.1. Develop PFPI framework and funding proposal with CG centers, ecoregional initiative coordinators, related network coordinators, and FAO
by D.K.B. - in collaboration with J.K. Ransom, D.E. Hess, M. Saxena, O.A. Al-Menoufi, Moist Savanna Consortium (part of EPHTA), African Highlands Initiative, Desert Margins Initiative, Cool Season Legumes Initiative, NARES networks

Based on an initial meeting of the parasitic flowering plants intiative (PFPI-a component of the CG system-wide IPM initative) in October, 1995, a meeting of the CG and NARES network partners was held at IITA, Cotonou, Benin in August of 1996. As a result of this meeting a logframe of project outputs and activities as well as a tentative project budget was developed. The full PFPI proposal has been developed and submitted to BMZ for funding.

8.10.2. Develop audio-visual support for integrated *Striga* management
by D.K.B in collaboration with P. Philpot

An audio and visual CD-ROM detailing the biology, life cycle, and integrated management of Striga spp. has been initiated. Copies of the first press will be made available to NARES researchers and other Striga researchers for further input in their areas of specialisation, so that the final product could be a good reference and a representation of the current knowledge on Striga management.

Completed studies

Journal articles and book chapters

Aigbokhan, E.I., D.K. Berner, & L.J. Musselman, 1998. Reproductive ability of hybrids of* Striga aspera *and* Striga hermonthica. *Phytopathology 88: 563-567.

Striga aspera and *Striga hermonthica* are sympatric in Africa. Each may serve as virulent gene reservoirs for the other if they hybridize and their hybrids are virulent and fertile. Intraspecific and interspecific crosses were made within and between the species and reproductive success was determined. Freshly harvested seeds

from the parental and F_1 crosses were tested over time for germination. Chromosome counts from shoot tip squashes of seedlings of *Striga aspera* were determined as n=18 and n=19 for *Striga hermonthica*. Hybridization results indicated that *S. aspera* and *S. hermonthica* could be intercrossed and their hybrids successfully backcrossed to either parent. Reproductive success in all crosses, ranged from 68 to 95% and seeds of all the crosses were viable, germinated on exposure to a synthetic germination stimulant, and were pathogenic on maize. Seeds from the hybrids and backcrosses were less viable and germinable than either parent suggesting that the two species were not 100% compatible. Results suggest that the two species are closely related but are separate taxa perhaps at the subspecies level. Seed dormancy for both species and the F_1 hybrids was less than 84 days after pollination. Germination of *Striga hermonthica* seeds reached 31% at 28 days after pollination. Frequently occurring seed germination peaks were observed for all the seeds tested.

Aigbokhan, E.I., D.K. Berner, L.J. Musselman & H.D. Mignouna, 1999. Evaluation of variability in* Striga aspera, Striga hermonthica, *and their hybrids using morphological characters and random ampllified polymorphic DNA markers. Weed Research (submitted).

Striga aspera and *Striga hermonthica* are recognized as separate species but their close morphological similarity causes difficulty in distinguishing between them in areas where they coexist in West Africa. In this study, crosses between the species were made using randomly selected morphologically typical parental plants collected from different locations in Nigeria. Genetic analysis of both species and their reciprocal F_1 hybrids were determined using cluster analysis of DNA profiles derived from polymerase chain reaction (RAPD-PCR) random amplified polymorphic DNA markers. Principal component analyses and hierarchical cluster analyses were used to separate the parental and hybrid populations based on 13 morphological characteristics. Morphological data from wild samples of both species from 9 locations in Nigeria were compared with the parental, F_1 and F_2 hybrids, and backcrosses derived from hand-pollination. Results showed that *S. aspera* and *S. hermonthica* were genetically and morphologically distinct. Genetic similarity was 55% and morphologic similarity was 50%. The morphological and genetic analyses revealed two major clusters: a *S. aspera* cluster and a *S. hermonthica* cluster. F_1 hybrids showed closer genetic affinity to their maternal parents. Morphologically, the F_1 hybrids formed distinct clusters intermediate to the parents. Most of the F_2 plants and backcrosses were morphologically similar to *S. hermonthica*. Comparative morphological analysis of wild and hand-pollinated populations showed that a few samples from the wild populations clustered with the hybrids, suggesting that F_1 hybrids may exist in nature.

Berner, D.K. & O.A. Williams, 1998. Germination stimulation of* Striga gesnerioides *seeds by hosts and nonhosts. Plant Disease 82:1242-1247.

Cowpea is an important source of protein in Africa, but production is hindered by the parasitic plant *Striga gesnerioides*. Crop rotation with nonhost cultivars, selected to stimulate parasite seed germination, is being used successfully to control other *Striga* spp. However, little information has been available on nonhosts of *S. gesnerioides* that are capable of stimulating parasite seed germination. A selection procedure developed for another *Striga* sp. was used to evaluate both host and nonhost species and cultivars for their ability to stimulate *S. gesnerioides* seed germination. Genotypes of all *Vigna* spp. tested stimulated parasite seed germination. Some genotypes of the nonhost species *Lablab purpureus* and *Sorghum bicolor* also stimulated parasite seed germination. One cultivar of *S. bicolor* stimulated significantly more germination than any other cultivar or species while other *S. bicolor* cultivars had no effect. When seeds of single-plant isolates of *S. gesnerioides* were tested against roots of seedlings from *S. bicolor* landraces, and from a susceptible cowpea cultivar, only specific *S. gesnerioides* isolate and plant combinations resulted in parasite seed germination. Control of *S. gesnerioides* through rotation with selected nonhost cultivars has potential if selection is done with the parasite isolate(s) from the locality of intended use.

Berner, D.K., N.W. Schaad & B. Voelksch, 1999. Use of ethylene-producing bacteria for stimulation of* Striga *spp. seed germination. Biological Control (in press).

Striga spp. are obligate root-parasitic flowering plants that threaten cereal and legume production, and consequently human well-being, in Africa. Successful control depends on eliminating the seed reserves of *Striga* spp. in soil and preventing parasitism. A proven method of eliminating these seed reserves is soil-injection of ethylene gas. This method was used successfully in the United States to control *Striga asiatica*, but injection of ethylene gas is potentially dangerous, very costly, and generally unsuitable in Africa. The bacterium *Pseudomonas syringae* pathovar glycinea synthesizes relatively large amounts of ethylene. In this study a laboratory procedure was developed for testing strains of *P. syringae* pv. glycinea for efficacy in stimulating germination of seeds of *Striga* spp. The procedure allows comparisons among bacteria, volatile compounds, root exudates, and synthetic stimulants for germination of *Striga* spp. seeds. Seeds of three *Striga* spp. were tested over a 10-month period. No seed germination was ever observed with sterile water. When compared across *Striga* spp. the bacterial strains were consistently better stimulators of germination of seeds of the parasites than ethylene gas or root pieces of a *Vigna unguiculata* cultivar known to stimulate germination of parasite seeds. The strains were as effective in germinating *S. aspera* and *S. gesnerioides* seeds as a synthetic germination stimulant. Our results showing that ethylene-producing bacteria are highly effective in promoting seed germination in *Striga* spp. suggest that these bacteria may provide a practical means of biological control of *Striga* spp. in Africa and other locations.

Rugutt, J.K. & D.K. Berner, 1998. Activity of extracts from nonhost legumes on the germination of* Striga hermonthica *seeds. Phytomedicine 5:293-299

Dichloromethane and water extracts from leaves, stems and roots of ten different legume cultivars were assayed for germination stimulation of moisture and temperature conditioned *Striga hermonthica* (Del.) Benth. seeds. Optimum concentrations for most active extracts was in the undiluted or dilution x10 range. Unlike water extracts, all dichloromethane extracts induced some stimulatory activities at the various concentrations. A potential high stimulant producing cultivar, V. unguiculata cv. it-84d-975 was identified. The nondestructive thin-layer chromatography (TLC) technique was employed in investigating the dichloromethane-soluble substance(s) in legume cultivars. TLC data indicated that most legume species and cultivars produce four chromatographically different germination stimulants with retention factors 0.10, 0.60, 0.70 and 0.77.

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. Pages 65-78. in: Containment Facilities and Ssafeguards for Exotic Plant Pathogens and Pests. Kahn, R.P. and Mathur, S.B., eds. APS Press.

This book describes quarantine and containment facilities of CG centers. Of relevance for this report are descriptions of *Striga* spp. containment procedures and facilities.

Conference papers, workshop proceedings, abstracts, newsletters

Berner, D.K., N.W. Schaad & B. Völksch, 1998. Ethylene-producing bacteria for Striga spp. control. Phytopathology 88: S7. Publication no. P-1998-0048-AMA.

Striga spp. are obligate root-parasitic flowering plants that threaten cereal and legume production in Africa. Successful control depends on eliminating Striga spp. seed reserves in soil and preventing parasitism. A proven method of eliminating these seed reserves is soil injection of ethylene gas, but ethylene gas injection is generally unsuitable in Africa. The pathovar glycinea of Pseudomonas syringae synthesizes relatively large amounts of ethylene. A laboratory procedure for testing strains of P. syringae pv. glycinea (Psg) for stimulation of Striga spp. seed germination was developed. The procedure allows comparison of volatiles, root exudates, and synthetic stimulants of Striga spp. seed germination. Three Striga spp. were tested. In general, Psg strains were more effective in stimulating seed germination than ethylene gas (4 kg ha-1) or root exudates of a Vigna unguiculata cultivar. In one test, two strains were more effective in stimulating germination than the definitive synthetic stimulant. Ethylene-producing bacteria may offer potential to control Striga spp. in Africa.

Ng, S.Y.C., J d'A. Hughes, D.K. Berner, N.Q. Ng, & K. Cardwell, 1998. Germplasm health at the International Institute of Tropical Agriculture. 7th International Congress of Plant Pathology 4.6.5.

The goal of IITA is to improve the nutritional status and well-being of low-income people in the humid tropics and subtropics of sub-Saharan Africa. In collaboration with the national agricultural research systems (NARS), IITA conducts researches on the improvement of food crops and cropping practices.

The exchange of germplasm to and from NARS is one of the major activities but great care must be taken to ensure that no pests or pathogens are inadvertently transferred particularly the seedborne pathogens, viruses and Striga. To consolidate and organize germplasm health activity, a Seed Health Committee was constituted in 1990 to advise on issues of germplasm health and movement. A Seed Health Unit was established in 1992 to monitor the health status of true seed imported and exported. The movement of the germplasm of vegetative materials is handled by the tissue culture laboratory in close collaboration with the virology laboratory. IITA works closely with the Nigeria Plant Quarantine Services (NPQS).

Project 13

IMPROVING YAM-BASED SYSTEMS

by R. Asiedu (project coordinator), O. Girardin, 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 labour 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

13.1. Characterization of biological and socio-economic constraints in yam-based systems and farmers management strategies

On-going and future activities

13.1.1. Distribution and severity of yam pests and diseases in West Africa

by J.d'A.H. - in collaboration with L.N. Dongo, G.I. Atiri, O. Olatunde*, L. Kenyon, S.K. Offei*

The yam virus survey was conducted in 1998 throughout the major yam growing areas in five Regions of Ghana (Volta, Eastern, Western, Brong Ahafo and Ashanti Regions). Leaf samples were collected from different *Dioscorea* spp. varieties that showed virus-like symptoms in farmers' fields. Samples were also collected from symptomless plants. The samples were tested by protein A-sandwich enzyme-linked immunosorbent assay (ELISA) and/or triple antibody-sandwich ELISA for the following viruses: yam mosaic virus (YMV), genus Potyvirus; Dioscorea alata virus, genus Badnavirus; Dioscorea alata virus (DAV), genus Potyvirus; Dioscorea bulbifera virus, genus Badnavirus; cucumber mosaic virus, genus Cucumovirus; Dioscorea latent virus, genus Potexvirus; and Dioscorea dumetorum virus, genus Potyvirus. YMV was found to have the highest incidence, followed by DAV. YMV was found in 63% of the samples from Brong Ahafo and Ashanti Regions, in 53% of the samples from Eastern Region and more than 23% of the samples from Volta and Western Regions.

YMV was detected in most *D. rotundata* leaf samples with a lower incidence in *D. alata*. The most common symptoms associated with YMV were leaf chlorosis, mosaic, mottle, green vein banding and veinal chlorosis. Mosaic and mottle were the most common symptoms. Mosaic and mottle were observed on about 70% and 57% of the leaf samples respectively. It was clear that YMV was found at the greatest incidence in the major yam-growing areas of Ghana, particularly Brong Ahafo, Ashanti and Eastern Regions. The incidence of DAV was very low compared with YMV. DAV was found mainly in *D. alata* plants and mosaic was the most common symptom associated with the virus.

Other unidentified viruses are also likely to be present as virus-like symptoms such as leaf crinkling and shoe-stringing were found and could not be associated with any previously characterised yam virus.

13.1.2. Establishment of the geographic distribution of yam nematodes

by J.C.M., P.R.S., O.G., P.V., R.A. - in collaboration with C. Kwoseh, J. Mudiope*, R. Plowright, T.E. Sangoyomi*.*

The geographical distribution of nematode species associated with yam in Nigeria was established using collections from multi-location trails and specific surveys on post-harvest constraints in Nigeria. Sites in Oyo, Kwara, Niger, Federal Capital Territory, Plateau, Benue, Ebonyi, Rivers, Delta and Edo States were sampled. The yam nematode *Scutellonema bradys*, is widely distributed in the major yam growing areas in Nigeria, whereas *Meloidogyne* spp. seem to be more predominant in areas with shortened fallow. *Pratylenchus* spp. are occasionally isolated and an *Aphelenchoides* sp. was found to be associated with yams in Ebonyi State. Farmers in that region frequently incorporate rice in their yam-based cropping system.

In Benin two Sous-Préfectures around Parakou were surveyed (see 13.3.2.) The yam nematode *Scutellonema bradys*, is not common in Benin. In contrast to Ghana and Nigeria *Meloidogyne* spp. appear to be dominant species.

In central Ghana, a survey revealed the presence of *S. bradys* only. *Pratylenchus coffeae* was not found associated with yam, despite it is major nematode species in the Caribian, Asia and the Pacific.

A survey was undertaken to establish the nematode species profile of yam in the major yam growing regions of Uganda. Mature tubers of various cultivars were uprooted and the incidence of root-knot nematode galls and tuber skin cracks were observed. Incidence of gall symptoms and tuber cracks were low, not exceeding 1 on a scale of 0 (no symptoms) to 3 (severe symptoms). Nematodes were extracted from tissue blocks of 1 cm^3 taken out of the tuber surface. *Pratylenchus sudanensis* was the dominant species, while *Meloidogyne* spp. were observed in low densities. In contrary to Ghana, Benin and Nigeria, no *S. bradys* was observed. *P. sudanensis* was reported for the first time associated with yam.

13.2. *Development and evaluation of strategies for integrated control of pests and diseases in yam-based systems*

On-going and future activities

13.2.1. Screen yam germplasm for resistance to field and storage pests/diseases

by J.d'A.H., R.A., N.Q.N. - in collaboration with B. Odu, S.A. Shoyinka, A.O. Oladiran*

On the basis of past performance in various field trials, 48 apparently virus-resistant landraces of *Dioscorea rotundata* and 16 of *D. alata* were selected for further evaluation. Up to twenty-two accessions of *D. rotundata* were planted in four agro-ecological locations in Nigeria. These locations represent the forest (Ibadan), forest savanna transition (Ubiaja), Guinea savanna transition (Abuja) and the mid-altitude savanna (Jos). Two known virus-susceptible genotypes (breeder's lines) were included as checks in all the locations. Also 16 landraces and two breeder's lines of *D. alata* were planted at Ibadan for virus-resistance assessment. A robust scoring system for a range of virus disease symptoms occurring in yams was developed and used in assessing monthly symptom expression for a period of four months (July-October). Statistical analysis of the symptom severity scores is in progress.

A total of 404 leaf samples collected in the four locations were indexed serologically to determine the incidence of the viruses that infect yams in the field trials. Yam mosaic virus, genus Potyvirus (YMV) was found to have 41.5% incidence while Dioscorea alata virus (DAV), genus Potyvirus had 20.8% incidence.

Different aphid species were collected from their natural habitat and maintained as cultures in the screenhouse on appropriate host plants. These were used as vectors in the transmission of yam viruses. The study confirmed *Toxoptera citricidus, Rhopalosiphum maidis* and *Aphis craccivora* as vectors of YMV as previously reported, while the ability of other aphid species to act as virus vectors is still being investigated.

Several accessions of wild *Dioscorea* sp. maintained in the field at IITA were subjected to preliminary screening for virus infection using ELISA. The accessions screened were from the following: *D. praehensilis, D. togoensis, D. dumetorum, D. bulbifera, D. abyssinica, D. mangenotiana, D. sansibarensis, D. burkilliana* and *D. minutiflora*. The goal of this aspect of the study is to identify the wild relatives that have a high resistance to known yam viruses.

13.2.2. Characterize yam pathogens; study the etiology and epidemiology of pests and diseases of yams

by J.d'A.H. - in collaboration with L.N. Dongo, G.I. Atiri*

The three new isometric virus isolates from yam, Dioscorea mottle virus, Dioscorea mild chlorosis virus and Dioscorea necrosis virus were studied. They were found to be serologically related to cowpea mottle virus (CPMoV), genus Carmovirus by immunosorbent electron microscopy (ISEM), protein A sandwich (PAS-) enzyme-linked immunosorbent assay (ELISA) and Ouchterlony agar double diffusion test. The three viruses are now considered as strains of a new virus of yam based on confluent precipitin lines observed when antibodies to each of the isolates was put in the central well of gel diffusion slides and the antigens in the peripheral wells. Based on this, the new virus is proposed to named Dioscorea mottle virus (DMV) and the strains as DMV (mottle strain), DMV (mild chlorosis strain) and DMV (necrosis strain).

As CPMoV has been reported to cause significant yield losses on cowpea (*Vigna unguiculata*) in Nigeria, the potential yield losses in yam due to DMV cannot be ignored. To facilitate further studies, rabbit polyclonal antibodies have been raised against DMV (mild chlorosis strain) as well as murine polyclonal and monoclonal antibodies. The monoclonal antibodies are undergoing screening but several lines appear to have potential for use in diagnostics.

13.2.3. Conduct yield loss studies

by J.d'A.H. - in collaboration with A. Minamor, E. Acheampong, L. Kenyon*

The donor terminated this study early in the year. During the study it was found that the multiplication of virus-tested stocks of IITA yams at the University of Ghana was relatively slow with difficulties being found with establishment of the tissue culture plantlets in the screenhouse. It was also clear that the re-infection rate of the virus-tested plantlets was very high, with the plantlets in the field developing mosaic symptoms of yam mosaic virus, genus Potyvirus infection within a few weeks.

13.2.4. Improvement of the methodologies for screening of yam host plant response to nematodes.

*by J.C.M., P.R..S, R.A. - in collaboration with R. Plowright, C.Kwoseh**

In the process to develop a reliable and quick method for the accurate evaluation of yam germplasm for resistance to plant parasitic nematodes in the field, artificial inoculation (using yam peels) and natural infestation were compared.

Artificial inoculation, using yam peels, of germinated yam tubers in small planting bags prior to planting into the filed was the more effective method.

In the screenhouse trials were set-up with botanical seeds, minisetts, and tissue culture plantlets using different levels of nematode densities (in a suspension as well as infested yam peels). Preliminary results suggest that the use of infested yam peels leads to a better infestation of the test material, when compared to the use of nematode suspensions.

Single species cultures were established for *Scutellonema bradys*, and *Meloidogyne* spp, but the establishment of an *in vivo Pratylenchus* sp.culture has not been successful yet. Tests to establish *in vitro* cultures of *S. bradys* have been set up using sterilized callused yam tissue on water-agar in petri dishes and sterile nematode-water suspension inoculated in sterilised tubers

13.2.5. Participatory impact assessment of hot water therapy of seed yams on field and storage of yam tubers.

by J.C.M., P.R.S., R.A. - in collaboration with S. Akele, K. Green, A. Nwankpuma, Y. Taylor, A. Yussuf

A field trial with TDr131 (white yam) was set up on-station in Ibadan to determine the optimum time and temperature for the hot water treatment. Tubers were treated for 20, 30, or 40 minutes in water of 45°C, 53°C, or 60°C and then planted in the field naturally infested with yam nematodes. Optimum treatment duration was 20 minutes at a temperature of 53°C for 20 minutes. Tubers are stored into 1999 to assess the effect of the hot water treatment on losses during storage.

Results of an on-farm experiment in Kwara State in 1997-98 (Table 2) suggested that hot-water treatment of yam planting material can result in an increase of the number of harvestable tubers, compared to the use of standard planting material. Therefore similar trials were established 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. Greater differences, as a result of less storage loss, are anticipated after three months storage. Farmers are impressed with the positive effect of the hot-water treatment. 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 will be 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. The method is ready for use on research stations and multiplication farms.

Table 2 - Effect of hot-water treatment (53°C for 20, 30, or 40 minutes) on nematode infestation and yield of three cultivars of *D. rotundata* (white yam) averaged for five farms in Ilesha-Baruten, Kwara State, Western Nigeria, 1997. [TT:Treatment time (min), YP Yam plants (stands), HTP: Harvested tubers per stand (n), TWS: Tuber weight per stand (kg), P5000: Production for 5000 plants (kg), MEL: *Meloidogyne* spp.[1],SCU *Scutellonema bradys*

Cultivar	TT	YP	HTP	TWS	P5000	MEL	SCU	
							Score[1]	Density[2]
Gbapikimu	0	11	4.9	3.3	4538	1.0	2.3	15,250
	20	34	4.5	3.0	12750	1.0	1.7	250
	30	37	4.9	3.3	15263	1.0	1.5	0
	40	40	4.3	2.6	13000	1.0	1.5	-[3]
Gomiya	0	5	4.4	1.6	2000	1.0	2.3	
	20	20	4.9	2.0	10000	1.0	1.9	
	30	19	4.2	2.0	9500	1.0	1.7	
	40	20	4.1	2.4	12000	1.0	1.6	
Wokonu	0	5	1.2	-[3]	3042[4]	1.0	2.1	32,917
	20	18	1.7	2.3	10350	1.0	2.2	750
	30	16	1.5	2.8	11200	1.0	1.7	0
	40	16	1.4	2.2	8800	1.0	1.4	-[3]

[1]: Scoring of symptoms on tuber on a 0 to 3 scale (0: no damage, 1: symptoms on <5% of the tuber skin, 2: symptoms on 5-50% of the tuber skin, 3: symptoms on >50% of tuber skin). [2]: Nematodes per 100 g skin and tuber tissue. [3]: missing data, [4]: using average tuber weight of other treatments

13.2.6. Screening for resistance in yam germplasm to nematodes affecting yam in Nigeria

by J.C.M., P.R.S, R.A. - in collaboration with R. Plowright, C.Kwoseh, J. Mudiope*

A reference trial, including 17 breeder lines of *D. rotundata*, and landraces of *D. rotundata* (18), *D. esculenta* (3), and *D. alata* (14) was planted at Ibadan.. The trial design was a split plots, one being artificial inoculated with yam peel infected with nematodes (mainly *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. The 1999 reference trial will include a selection, based on broad representation of host-plat responses of '98 material, complemented with selected land races from Benin and new breeder lines.

Progenies of 3 crosses (CR2= TDr93-2* TDr87/00211 (1995), CR6= TDr87/00571 *TDr89/01444 and Cr7=TDr93-2 * TDr87/00211 (1996) obtained from tissue culture were inoculated with single species suspensions of *S. bradys* and a *Meloidogyne* sp.. The differences in host plant responses will be linked to possible molecular markers.

13.2.7. Screening for resistance in yam germplasm to nematodes affecting yam in Uganda

by J.C.M., P.R.S, R.A. - in collaboration with R. Plowright, C.Kwoseh, J. Mudiope*

A field trial was established to evaluate the host plant response of yam lines, developed by the International Institute of Tropical Agriculture, to natural nematode infestation at Sendusu, 40 km north of Kampala, in Uganda. The field was naturally infested with nematodes and plants were established from tissue culture. The harvested yam tubers were observed to be infested with mainly *Meloidogyne javanica* and lower levels of *Pratylenchus* spp.. Occasionally, *Scutellonema* sp.

Rotylenchulus sp. and *Helicotylenchus* sp. were found. Significant differences ($P<0.05$) were obtained for *Meloidogyne javanica* juveniles (J_2) densities and for the incidence of root knot galls on the yam tubers. Line TDR 87/00559 OP (38) supported the highest population of *Meloidogyne javanica* juveniles, while lines TDR 87/00571 OP (71) and TDR 91/00121 OP (22) did not support any nematode species at all. The observed host plant responses will need confirmation in further trial work. The absence of nematodes on TDR 87/00571 OP (71) and TDR 91/00121 OP (22) indicates possible sources of resistance to root knot nematodes in the IITA germplasm collection.

Mini-setts of seven hybrid yam lines (TDR 87/00571 OP (74), TDR 91/00047 OP (87), TDR 91/00658 OP (44), TDR 91/00212 OP (23), TDR 89/01537 OP (51), TDR 89/01892 OP (19) and TDR 91/00658 OP (34)) and five land races (Ndaggu Nganda, Ndaggu Nziba, Masebe, Kyetutumula and Nandigoya) were planted in sterilised soil and inoculated one month after planting with *Pratylenchus sudanensis* and *Meloidogyne javanica*. For each line, six plants were chosen randomly and inoculated with 1,000 *M. javanica* juveniles, another six with 1,000 *P. sudanensis* and six plants were left as controls. After three months from planting time, the plants were harvested and nematode damages were scored. Also, nematode densities from roots and tubers were counted. All the lines were found susceptible to both species of nematodes with *P. sudanensis*.. Also, there was variation in host plant response among the various lines suggesting that there is relative susceptibility to nematode attack among the various lines under investigation. The cultivar Ndaggu Nganda supported highest *M. javanica* (24,615 per 100g fresh root weight) and *P. sudanensis* (206,542 per 100g fresh root weight) densities, while Keyetutumula supported lowest *M. javanica (42 per 100 g fresh root weight) and* Nandigoya lowest *P. sudanensis* 2,527 per 100g fresh root weight).

13.3. Evaluation of integrated soil and crop management practices for soil fertility maintenance and pest control in yam-based systems

On-going and future activities

13.3.1. 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.

There is increasing intensification of production in many yam-producing areas of West Africa. In order to maintain productivity of yam-based production systems, strategies are being developed which include the use of cover crops in a crop rotation. However, some of the cover crops selected for their contribution to restoring soil fertility and organic matter, may support damaging levels of nematodes. The nematodes (mainly *S. bradys* and *Meloidogyne* spp.), may nullify or even further reduce the production of a yam crop grown after the cover crop. A Ph.D. proposal has been prepared and implementation is anticipated for 1999.

13.3.2. Monitoring nematode population dynamics under various cropping systems and fallow periods in Benin
by J.C.M., P.V., G.T., P.R.S., R.A.

In Benin in subsequent crop cycles after a slash and burn farm establishment, farmers grow different yam cultivars in each cycle. Also farmers grow different cultivars depending on the intensification of the land use. Therefore the following hypotheses were developed: 1. Nematode species profile in plant crop after slash and burn depends partly on the level of infestation of the planting material used. 2. Yam cultivars grown in subsequent crop cycles and under increasing levels of land use intensification increase in levels of susceptibility to various nematodes species. In December 1998, during the second harvest of the yams, two locations around Parakou, Sonoumon in the Northern Guinea Savanna, and Kinnoukpannou in the Southern Guinea Savanna were surveyed. Two early maturing (with double harvest) and three late maturing (single harvest) varieties were selected for the study with five replicates per location. Per location two cropping systems were investigated: type 1 (slash and burn) and type 2 (yam cultivation in rotation with a cereal crop). The surveyors collected tuber samples and used questionnaires for each variety*cropping system to collect data on farmers' perception on the conditions of their yam crop. 37 samples were collected from Sonoumon and 37 from Kinnoukpannou. Nematode samples will be taken from tubers after storage early '99, and the data collected in the questionnaires will be analyzed during 1999. Two field visits to collaborating farmers at the start of the survey suggest that at harvest few symptoms associated with yam nematodes (*S. bradys*) or root knot nematodes (*Meloidogyne* spp.) can be found in the region. The low nematode damage may be explained by the farmers' practices of sufficient fallow, milking of yams and farmers selection of resistant/tolerant

varieties. Further research will be conducted to confirm these observations and if true, to develop components of an IPM package, which can be tested in other yam growing regions.

13.4. Production of pest- and disease-free germplasm

13.4.1. Produce disease-free virus tested propagules of selected genotypes for international distribution

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

The virus testing procedure developed for the production of virus-tested *Dioscorea* spp. germplasm (pre-tissue culture, during tissue culture and post-tissue culture testing) has been initiated. Pre-tissue culture indexing done in 1997 was used as the basis for post-tissue culture testing of five *D. rotundata* and 11 *D. alata* clones. The plants were tested by enzyme-linked immunosorbent assay, with further confirmatory testing by immunosorbent electron microscopy where appropriate.

Three of the five *D. rotundata* clones had pre-tested positive for yam mosaic virus (YMV), genus Potyvirus. The two that had pre-tested negative were confirmed to be free of YMV, while only one of the three that tested positive was found to be free of YMV. Those that were free of YMV were also confirmed to be free from Dioscorea alata virus (DaV), genus Badnavirus; Dioscorea alata virus (DAV), genus Potyvirus; Dioscorea bulbifera virus (DbV), genus Badnavirus; and Dioscorea dumetorum virus (DdV), genus Potyvirus. Two of the three previously untested clones also appear to be free of viruses. One of them was infected with YMV.

Seven out of 11 *D. alata* clones that had been pre-tested had tested positive for Dioscorea latent virus, genus Potexvirus; DaV, DbV, DAV or DdV. After tissue culture all 11 clones were found to be free of these viruses in addition to YMV.

A further 54 yam samples were tested for the presence of YMV and DAV during the year as part of the virus-indexing procedure for the production of virus-tested propagules for international distribution.

Completed studies

Conference papers, workshop proceedings, abstracts, newsletters

Dongo, L.N., J.d'A. Hughes & G.I. Atiri, 1998. Three new isometric viruses infecting yams in Nigeria. International Society for Tropical Root Crops - Africa Branch Meeting, Cotonou 12-16 October 1998.

Leaves of *Dioscorea* spp. with virus-like symptoms from the major yam growing areas in Nigeria were tested by enzyme-linked immunosorbent assay (ELISA) for known viruses infecting yams: yam mosaic, *D. alata* and *D. dumetorum* potyviruses, dioscorea latent potexvirus, *D. alata* and *D. bulbifera* badnaviruses and cucumber mosaic cucumovirus. Some samples with mosaic, mottling, leaf necrosis and distortion did not test positive for these viruses. *Vigna unguiculata* cvs 2657 and 84s-2114, and *Glycine max* cv. Malayan, were diagnostically susceptible by mechanical inoculation, to three potentially distinct 17-22 nm isometric viruses (tentatively named dioscorea mild chlorotic mosaic (DMCV), dioscorea mottle (DMV) and dioscorea necrosis (DNV) viruses respectively). The viruses were transmitted mechanically back to *Dioscorea* spp. seedlings. Spur formation in agar gel double diffusion tests indicated that some of the viral antigens are related, but not identical. ELISA diagnostic tests have been developed for these viruses.

Kwoseh, C., R.A. Plowright, J. Stanfield & R. Asiedu, 1998. Culturing* Scutellonema bradys *on yam tuber slices. In: Proceeding of the 7th Triennial Symposium of the International Society for Tropical Root Crops - Africa Branch, Cotonou, Benin, 11 - 17 October 1998. Poster.

A reliable and high yielding technique to mass-reproduce the yam nematode, *Scutellonema bradys* for screening has been developed. A nematode-free tuber of white yam (*Dioscorea rotundata)* cultivar 'Puna' was washed, peeled, cut into slices and treated separately with Bio-Supercarb and sodium hypochlorite. Each slice, weighing 3-6 g was plated on 1% water agar and kept for three weeks to produce callus. The plates were then each inoculated with 20 to 30 juveniles and adults of *S. bradys*. The nematodes were sterilised in 5 drops of 0.1% malachite green for 5 minutes and then rinsed 10 times with sterilised distilled water. Inoculated plates were kept at 25°C in the dark. *S. bradys* populations increased by 10 to 170 times over a five-month period and 340 to 820 times over twelve months. Sterilised yam tuber slices on water agar medium has been shown to support high reproduction of *S. bradys* and can be used to mass-produce *S. bradys* for screening purpose.

Meerman, J.C. & P.R .Speijer, 1998. Perspectives for large scale distribution of nematode disinfested yam planting material in Southern Nigeria. In: European Society of Nematologists (eds). Proceedings of the 24th Conference, held at Dundee, Scotland, UK 3-9 August 1998: p69.

Approximately 90 % of the world yam (*Dioscorea* spp.) production is in West and Central Africa. Major constraints to production include the high costs of planting material and storage losses. The yam nematode *Scutellonema bradys* is highly associated with dry rot of stored yam tubers, resulting in loss of food quality and quantity, and also in loss of planting material for the following growing season. A strategy for control is thermotherapy of stored tubers. Studies at the IITA station in Ibadan, Nigeria, showed that submersion of tubers prior to planting for a period of 25 minutes in water at 53 °C reduced storage losses of the harvested crop by 30% to 60% and prevented loss of planting material for the next season, when compared to untreated tubers. In 1996 thermotherapy of yam planting material was introduced at five pilot farms in Kwara State, Western Nigeria. Records of 1997 showed a lower nematode density in the harvested tubers and a reduction in tuber decay over two months storage ($P<0.05$), compared to farmers standard planting material. Large scale thermotherapy of seed yams has been initiated in 1998 in collaboration with the NAOC-Agip-Green River Project, at Obrikom, River State and SUM-NRC at Izi, near Abakaliki, Ebonyi State, where 3000 and 1800 seed yams were treated respectively. Farmers and extension officers are involved in the evaluation of the effectiveness of the technology. An economic assessment of thermotherapy costs and farmers gain will be made to determine if in the following year similar projects could be initiated in Benin and Ghana.

Mudiope, J., P.R. Speijer, R.N. Maslen & E. Adipala, 1998. Pratylenchus, the dominant genus affecting yam (*Dioscorea *spp.) in Uganda. In: European Society of Nematologists (eds). Proceedings of the 24th Conference, held at Dundee, Scotland, UK 3-9 August 1998: p76.

Yam (*Dioscorea* spp.) is an indigenous tuber crop in tropical Africa and a main source of carbohydrates. Crop yields are generally low, whereby a susceptibility to nematodes is expected to be one of the important causes. A survey was undertaken in the major yam growing regions of Uganda to establish the nematode species association with this crop. Samples were collected of various cultivars and included mature tubers, their fibrous roots and the soil surrounding these tubers. Tubers were observed for incidence of root-knot nematode galls and tuber skin cracks. Nematodes were extracted from tissue blocks of 1 cm^3 taken out of the tuber surface. Incidence of root-knot symptoms and tuber cracks were low, not exceeding 1 on a scale of 0 (no symptoms) to 3 (severe symptoms). *Pratylenchus sudanensis* dominated the samples followed by *Meloidogyne* spp.. Significant positive correlations ($P<0.05$) between *Pratylenchus* spp. densities and severity of cracks were observed. Improvement of yam production in Uganda should include the search for sources of *Pratylenchus* spp. resistance and other control measures as selection of symptom free tubers and or heat therapy of yam planting material.

Odu, B.O., J.d'A. Hughes, N.Q. Ng & R. Asiedu, 1998. Identification of resistance to yam viruses in* Dioscorea *species and genetic analysis of resistance to yam mosaic potyvirus in* Dioscorea rotundata *Poir. IITA-JIC-NRI Gatsby-funded Biotechnology Projects Collaborators Meeting 2-3 July 1998, John Innes Centre, UK.

Odu, B.O., S.A. Shoyinka, J.d'A. Hughes, R. Asiedu & O.A. Oladiran, 1998. Yam viruses of Nigeria. International Society for Tropical Root Crops - Africa Branch Meeting, Cotonou 12-16 October 1998.

Yams are an important staple food in Africa. Nigeria produced about 70% of 33 million MT of yams produced globally in 1996. Pests and diseases are still major production constraints. Five viruses have been reported to infect yams in Nigeria: yam mosaic potyvirus (YMV), *Dioscorea alata* potyvirus (DAV), cucumber mosaic cucumovirus (CMV), *Dioscorea dumetorum* potyvirus (DdV) and *Dioscorea alata* badnavirus (DaV). YMV, infecting *D. rotundata* and *D. alata* in all the yam-growing areas of Nigeria, was found to cause severe chlorosis, veinal chlorosis, green vein banding, shoe-stringing, leaf distortion and severe stunting. It is transmitted both mechanically and by *Aphis* spp. DAV is transmitted to test plants by *A. craccivora* and *Rhopalosiphum maidis*. It causes mottling, green vein banding, severe chlorosis and leaf distortion. DaV-infected plants have distorted and crinkled leaves. The symptoms of the viruses, their transmission, diagnosis, distribution and possible effects on yam production in Nigeria are discussed.

Olatunde, O.J., L. Kenyon, J.d'A. Hughes & S. K. Offei, 1998. Viruses of yam in Ghana. International Society for Tropical Root Crops - Africa Branch Meeting, Cotonou 12-16 October 1998.

A survey was carried out for viruses infecting yams in the major yam growing areas of Ghana. Leaf samples were collected from *Dioscorea* spp. with virus-like symptoms of mosaic, mottling, chlorosis, leaf distortion and shoe-stringing. Leaf samples from symptomless *Dioscorea* spp. were also collected for virus indexing. Detection of viruses in the leaf samples was done by enzyme linked immunosorbent assay (ELISA) using seven polyclonal antisera to viruses known to infect *Dioscorea* spp.: yam mosaic potyvirus (YMV), *D. alata* potyvirus (DAV), *D. alata* badnavirus, *D. dumetorum* potyvirus, *D. bulbifera* badnavirus, dioscorea latent potexvirus and cucumber mosaic cucumovirus. YMV monoclonal antibodies were also used where appropriate. YMV was the most commonly found virus followed by DAV. YMV was found more often in *D. rotundata* than *D. alata*. The latter was more susceptible to DAV. Confirmatory tests using herbaceous indicator plants and electron microscopy revealed some uncharacterised isometric particles. The majority of the *Dioscorea* spp. plants in Ghana have virus-like symptoms.

Plowright, R.A. & C Kwoseh. Farmer perceptions of nematode disease in yams in Ghana and the prevalence of endoparasitic nematodes in stored tubers. In: European Society of Nematologists (eds). Proceedings of the 24th Conference, held at Dundee, Scotland, UK 3-9 August 1998.

A farmer participatory appraisal of pests and diseases in stored yam was made in Ghana. The symptoms of nematode injury were clearly identified by farmers; there can be few cases where a nematode problem is culturally so important and so well understood. Most farmers were very familiar with both the dry rot of tubers, caused by migratory endoparasitic nematodes, and with the misshapen tuber surface caused by root knot nematode. In parts, more than 90 % of farmers had local names or terms for the disease symptoms e.g. 'nkronsa nkronsa' or 'adwie'(translates as rashes). Farmers could readily identify tubers with dry rot symptoms and these were rejected at planting or consumed early. Root knot nematode was generally considered to be unimportant since infected tubers rarely rot and knotted tubers were only observed on the fourth consecutive crop. Although most farmers had surplas yams, they remarked that losses from 'nkronsa nkronsa' or 'adwie' were high in some years. Farmers estimated losses from dry rot to be 21% (0-100) in the Forest zone and 30% (2-100) in the savannah. Losses from root knot nematode were estimated as 11% (0-40) in the forest and zero in the savannah. In most years farmers grew 10-15 yam varieties mostly of *Dioscorea rotundata*, but also *D. alata*, *D. cayenensis*, *D. dumetorum* and *D. bulbifera*. All were thought, by farmers, to be susceptible to dry rot but some varieties e.g. Lili and species *D. alata* were said to store better. Traditional yam varieties were often described to be free of dry rot. In all sites, dry rot symptoms were associated with *Scutellonema bradys*, never with *Pratylenchus coffeae* although known top be widespread in Ghana on *Musa*. The prevalence of *S. bradys* was 81% of sites, in the forest zone and 100% in the savannah, whilst the prevalence of root knot nematode was 72% and 24% in the respective zones.

Project 16

CONSERVATION AND GENETIC ENHANCEMENT OF PLANT BIODIVERSITY

by M. Ayodele, J.d'A. Hughes, L.E.N. Jackai, N.Q. Ng, 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

16.5. Strengthening diagnostic capacites for safe movement of germplansm

On-going and future activities

16.5.1. Assessment of seedborne microflora of cowpea, rice, soybean, and *Musa* and of the effect of seedborne pathogens on longevity of stored seed

by J.d'A.H., N.Q.N., L.E.N.J.

A total of 12,567 accessions from the Germplasm Resources Unit were screened for the presence of seed-borne virus infection. Uncharacterized accessions (2,868 accessions), early maturing types (1117 accessions), medium maturing (5117 accessions) and late maturing (3465 accessions) were all assessed for seed-borne virus incidence and severity. They were, approximately six weeks later, re-scored for incidence of virus infection. This will give an indication of the susceptibility to vector-borne infection. The data will be analyzed in 1999.

16.5.2. Isolation, detection and identification of viruses, bacteria and fungal pathogens in seeds and plant propagules of IITA mandate crops.

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

A total of eight (5 field and 3 screen house) active-growth health inspections and assessments were conducted. Lines/accession of cowpea (627), herbaceous legumes (17) and cassava (1), multiplied in the field at Ibadan to produce seeds free from viruses, bacterial and fungal diseases for distribution and conservation, were assessed visually for symptoms of seed-borne viral, bacterial and fungal diseases during active growth. Pathogens were isolated from leaf samples from diseased plants. The pathogens on cowpea were *Colletotrichum truncatum* and *C. lindemuthianumas* well as *Botryodiplodia theobromae,* while *Rhizoctonia solani, Phoma* sp., *Fusarium solani, C. gloeosporioides* and *Cercosporidum henningsii* were isolated from cassava plants. The Nigerian Plant Quarantine Service, with the objective of issuing Phytosanitary Certificates, also inspected the plants. The disease-free accessions were certified for international distribution.

16.5.3. Laboratory assessment of seed borne bacterial, fungal and viral pathogens in germplasm intended for distribution

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

Seed health testing using blotter and agar tests was carried out on 139 cowpea lines; 77 cassava families, one rice accession, 90 soybean lines, 4 accessions of herbaceous legumes, and one accession each of maize and yam. The fungi isolated and identified were *Colletotrichum truncatum, Pseudocercospora cruenta, C. sojina , C. kikuchii, C. gloeosporioides fsp manihotis, Cercosporidium heningsii and Fusarium oxysporum.* Recommendations for seed treatment of seeds prior to distribution and export were made.

16.5.4. Determining the health status of *Mucuna* spp. and *Canavalia ensiformis* (Cover Crops) in Benin

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

The use of cover crops to enhance and improve the soil structure, texture and fertility has become a popular practice because of the high cost and unavailability of the inorganic fertilisers. Forage legumes are being used also in the fallow cropping system for soil regeneration. The determination of the health status of the *Mucuna* sp. was conducted to ascertain that these legumes do not harbour pathogens that might infect the main subsistence and cash crops. Five species (*M. puriens* var

utilis, M. rajada, M. preta, M. cochichinensis and *Canavalia ensiformis*) were planted for multiplication in two provinces, Atacora and Borgou, in the Republic of Benin. About fifty farmers and students of the agricultural settlement scheme were actively involved in the multiplication of the seeds. Two field inspections were conducted during active growth and seed health testing of the seeds after harvesting. During the active growth inspection, plants with diseased leaves were collected and diagnosed in the laboratory for the presence or absence of fungal, bacterial and viral pathogens. Samples of harvested seeds were also seed health tested in the laboratory. The seeds were plated on NBY agar. Pathogens such as *Colletotrichum truncatum* (brown blotch), *C. lindemuthianum* (anthracnose), *C. gloeosporioides, Phoma* sp., *Macrophomina phaseolicola, Xanthomonas campestris pv phaseoli, Pseudomonas syringae pv phaseolicola* and several viruses were isolated and identified. The results obtained from the leaf and seed diagnoses, showed that the same pathogens infecting grain legumes also infect the forage legumes. The forage legumes act as alternate hosts for most of the pathogens in the absence of the main crops. There were instances where *C. truncatum* and *C. gloeosporioides* were isolated from sorghum inter-planted with *Mucuna* sp. It was also observed that M. *puriens* var *utilis* harbours more pathogens than all other *Mucuna* species inspected and tested and the species was found to be susceptible to all diseases of legumes. During this field inspection, *Pennisetum polystachium*, a weed in the *Graminea* family, and *Hyptis suaveolens* were also found to be alternate hosts to pathogens infecting the *Mucuna* species.

16.5.5. Use of selective media for the isolation and identification of *Pseudomonas syringae* pathovars

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

During the year, an *in vitro* technique for the isolation and identification of the *Pseudomonas syringae* pv *syringae* was developed and standardised. For rapid identification, plant parts were first plated on the NBY media and incubated at 28°C for 48 hours. Colonies obtained were further re-isolated and streaked on NBY to obtain single and pure colonies. These plates were incubated for 24 hours.After which gram staining of the pure single colonies of all the cream-coloured colonies was performed. All the gram-negative cream / white colonies are further plated on the M71 and MSP selective media. The MSP media which is greenish /blue in colour turns into yellow within 24hours if the bacterium is *Pseudomonas syringae pv phaseolicola*. More selective media are being tested for isolation and identification of other plant pathogenic bacteria such as the *Xanthomonas campestris* pathovars, *Clavibacter, Erwinia* and *Bacillus* species which are frequently isolated from plants and seeds and found to be causing seed decay.

16.5.6. Creating a database for all germplasm import and export

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

The collation of information for the creation of a database for all IITA's plant germplasm imports and exports has commenced. Six import permits were obtained from the Nigerian Plant Quarantine Service to cover 9 plant genotypes, as well as cocoon mass of *Cotesia sesamiae,* from five collaborating countries.

16.6. Ensuring the availability of disease-free germplansm

On-going and future activities

16.6.1. Introduction and evaluation of improved germplasm

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

During 1998, 77 accessions of *Manihot esculenta* were imported as true seed from Colombia. These were released from the Nigerian Plant Quarantine Services, after which they were tested by the Germplasm Health Unit for the possible occurrence of quarantinable pathogens. Five accessions were infected with *Fusarium* spp. and the affected plants were destroyed.

One accession of *Arachis pintoi* was imported as seed from South America. The seeds were found to be free of quarantinable pathogens and released from the Unit.

16.6.2. Distribution of healthy germplasm (including international and Nigeria National Coordinated Trial)

by N.Q.N., J.d'A.H, M.A. in collaboration with O.T. Yusuf, G.I. Atiri*

In order to speed up the screening of seed lots of *Vigna unguiculata* and *Glycine max* for seed-borne viruses, a field-screening plot was used. Five hundred seeds of each line were grown in the

field under irrigation. Each line was scored for percentage germination and percentage seed-borne virus. The seedlings were scored at the primary leaf stage and at the first trifoliate leaf, after which the seedlings were discarded. In 1998, 139 lines of *V. unguiculata* were screened for seed-borne viruses before international distribution. No seed-borne virus was observed in 82 lines, but the other 57 lines had seed-borne virus infection. IT95K-1156-3, IT95K-207-21, IT93K-513-2, IT96D-610 and IT95K-207-7 had 0.2% seed-borne infection. The highest percentage of seed-borne virus, 20.1%, was found in IT96D-693. The cowpea lines with seed-borne virus infection were rejected from being distributed. None of the 55 *G. max* soybean lines had seed-borne virus infection.

Vigna spp. accessions from the Germplasm Resources Unit, undergoing regeneration and 'cleaning-up' from seed-borne virus, were inspected. Seed-borne viruses were found in four of the 134 cowpea lines. The affected plants were tagged so that the seeds would be separated from the 'virus-free' seed lots.

Cowpea and soybean lines destined for international trials, multiplied at Ikenne, were tested for seed-borne pathogens by the Germplasm Health Unit. Both cowpea (139 lines) and soybean (55 lines) were tested by agar and blotter tests for fungal and bacterial contamination. A further 77 soybean lines multiplied at Mokwa and Zaria were also tested by agar and blotter tests. Recommendations for treatment of the seeds prior to distribution were made.

Four accessions of *Mucuna* spp. and one accession of *Canavalia ensiformis* were released from the GHU for CIEPCA trials in the Republic of Benin. A further 20 accessions of forage legumes (*Pueraria* sp., *Mucuna* spp., *Centrosema* spp. and *Lablab* sp.) were tested in preparation for potential export from Nigeria.

To maintain the health of germplasm at IITA, routine germplasm health tests and virus-indexing were also done, on request, on *Manihot esculenta, Vigna unguiculata, Zea mays, Panicum* spp., *Sorghum bicolor, Colocasia esculenta, Capsicum annuum, Dioscorea* spp. and *Musa* spp.

There is little information available on the viruses infecting herbaceous legumes and their seed transmission. Preliminary work has shown that the most common viruses are blackeye cowpea mosaic virus, genus Potyvirus, cowpea mottle virus, genus Carmovirus, cowpea mosaic virus, genus Comovirus and tobacco mosaic virus (TMV), genus Tobamovirus. Infection by more than one virus have also been found, especially in *Centrosema sp.*, *Chamaecrista* sp. and *Mucuna pruriens*. *M. cochinensis* was found to be heavily infected with TMV. Other viruses including southern bean mosaic virus, genus Sobemovirus, cucumber mosaic virus, genus Cucumovirus and bean yellow mosaic virus, genus Potyvirus were also found, and the presence of cowpea severe mosaic virus, genus Comovirus and bean pod mottle virus, genus Comovirus are suspected. Further studies are in progress to study seed transmission characteristics.

Seed transmission of TMV in herbaceous legumes is considered to be a potential problem. Seeds (100 of each accession) of *Aeschynomene aspera, Clitoria ternata, Chamaecrista rotundifolia, Indigofera hirsuta, Mucuna pruriens* and *M. cochinensis* were planted to determine natural seed transmission. One plant of *M. cochinensis* was infected with TMV. Further studies are in progress to assess the infectivity of the TMV – Mucuna strain and to determine its host range (particularly in other crop species) and seed transmission characteristics.

16.6.3. Virus indexing of vegetatively propagated plant material

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

During 1989, four of IITA's plantain hybrids that had been sent to the INIBAP International Transit Centre (ITC) in Leuven, Belgium were retrieved for further virus testing at IITA, Ibadan. TMPx 4479-1, TMPx1621-1, TMPx7152-2 and TMPx 4479 were sent to IITA from the ITC Stock Collection and the ITC Medium Term Storage (MTS) facility. They were subjected to the standard indexing protocols for banana streak virus (BSV), genus Badnavirus. This comprised of growing at 22-24°C in a controlled environment room for six months with regular observations and indexing by enzyme-linked immunosorbent assay ELISA) and immunosorbent electron microscopy (ISEM). Only three plants out of five each of TMPx 44879-1 from ITC Stock and MTS remained free of BSV, one and three out of five respectively of TMPx1621-1 and five out of five TMPx7152-2 from ITC Stock but none of the five from MTS were free of BSV.

Sixteen lines were received from IITA Onne for virus indexing. Of all the TMPx lines, at the second test after four months, some plants tested negative for BSV (TMPx2829-62: 2/3; TMPx15108-6: 3/12; TMPx1297-3: 2/3; TMPx1378: 2/9; TMPx 4479-1: 7/7 and TMPx5295-1: 1/8). Three out of nine TMPx 7152-2 also test negative at the first test. TMPx4479-1 is

remarkable in that it is the only clone in which all the plants have tested negative for BSV at the second test. Eight further lines are being prepared for indexing: Ney Poovan, Highgate, Bobby Tannap, Obino l'Ewai, Mun, Gros Michel, Guyod and Big Ebanpa.

All *Musa* clones originating from IITA are checked, in addition, for cucumber mosaic virus, genus Cucumovirus and banana die-back virus by ELISA and ISEM. There is also a final check by electron microscopy for the putative potyvirus that may be present in Nigeria, 'Ducasse' 'potex'virus, and any other virus-like particles.

A total of 77 cassava samples from the Tissue Culture Laboratory were tested for the presence of cassava mosaic viruses (African cassava mosaic virus, genus Geminivirus and East African cassava mosaic virus, genus Geminivirus) by ELISA using monoclonal antibodies. The herbaceous indicator hosts, *Nicotiana benthamiana*, that had been inoculated with sap extracts from the cassava plants, were also tested by ELISA. Only four of the 77 cassava plants were infected with cassava mosaic.

The virus testing procedure developed for the production of virus-tested *Dioscorea* spp. germplasm (pre-tissue culture, during tissue culture and post-tissue culture testing) has been initiated. Pre-tissue culture indexing done in 1997 was used as the basis for post-tissue culture testing of five *D. rotundata* and 11 *D. alata* clones. The plants were tested by enzyme-linked immunosorbent assay, with further confirmatory testing by immunosorbent electron microscopy where appropriate.

Three of the five *D. rotundata* clones had pre-tested positive for yam mosaic virus (YMV), genus Potyvirus. The two that had pre-tested negative were confirmed to be free of YMV, while only one of the three that tested positive was found to be free of YMV. Those that were free of YMV were also confirmed to be free from Dioscorea alata virus (DaV), genus Badnavirus; Dioscorea alata virus (DAV), genus Potyvirus; Dioscorea bulbifera virus (DbV), genus Badnavirus; and Dioscorea dumetorum virus (DdV), genus Potyvirus. Two of the three previously untested clones also appear to be free of viruses. One of them was infected with YMV.

Seven out of 11 *D. alata* clones that had been pre-tested had tested positive for Dioscorea latent virus, genus Potexvirus; DaV, DbV, DAV or DdV. After tissue culture all 11 clones were found to be free of these viruses in addition to YMV.

A further 54 yam samples were tested for the presence of YMV and DAV during the year as part of the virus-indexing procedure for the production of virus-tested propagules for international distribution.

Completed studies

Ng, S.Y.C., J.d'A. Hughes, D.K. Berner, N.Q. Ng & K. Cardwell, 1998 Germplasm health at the International Institute of Tropical Agriculture. 7th International Congress of Plant Pathology, 9-16 August 1998, Edinburgh, Scotland. Abstract 4.6.5

For the international movement of vegetatively propagated crops (cassava, yam, banana and plantain), virus-tested *in vitro* plantlets or propagules derived from them (minitubers and ministakes produced under quarantine screenhouses) and true seeds are used. For cowpea, soybean, maize and herbaceous legumes, true seeds are the means of germplasm exchange.

In vitro plantlets are produced through meristem culture to eliminate viruses and other diseases and pests. Regenerated plants are tested for viruses in collaboration with NPQS by symptom expression, the use of indicator plants, enzyme-linked immunosorbent assay (ELISA), electron microscopy, immunosorbent electron microscopy and polymerase chain reaction. Prior to packaging, cultures are examined for possible contamination by fungi and bacteria.

For production of disease-free seed, germplasm is planted in areas free from diseases (*e.g.* downy mildew - maize, *Striga* - maize, cowpea) and, if possible, in quarantine screenhouses (*e.g. Vigna* spp). Pre-harvest inspection of the plants is done in collaboration with NPQS. Harvested seed are cleaned, dried and fumigated. Cassava seeds are also treated with hot air. A sub-sample of the seed lots is tested for pests, nematodes, fungi, bacteria and *Striga* by visual inspection, seed washing tests, agar and blotter tests and seed maceration and streaking on differential media. For viruses in legumes, growing-out tests and ELISA are performed. Seeds are then dressed with fungicides and insecticides and packaged for export.

Imported germplasm is treated in the same manner after the materials are released by the NPQS. Seed samples are randomly taken for various tests, the germplasm is planted in quarantine screenhouses for observation and further testing before planting out in the field. Follow up inspections are also carried out.

About 40 genotypes of cassava and 10 of yam are disease-tested and certified yearly. IITA has more than 340 selected cassava genotypes and more than 45 yam genotypes available for distribution. Virus-tested

germplasm had been distributed to collaborators in more than 40 countries. During 1997, 6767 yam plantlets, 6927 yam minitubers, and 21040 cassava plantlets were distributed to NARS collaborators.

In 1996 over 360 imported seed lots of cowpea, soybean, maize, velvet beans and cassava, and 131 yam accessions were tested. Over 330 seed lots of various crops species were processed for international distribution and about 1500 *Vigna* lines were cleaned from seed-borne virus infection.

Through the introduction of IITA's improved germplasm to NARS in various countries in sub-Saharan Africa, high-yielding and disease-resistant varieties have been selected and released to farmers, thus contributing immensely to the alleviation of poverty in the region.

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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 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 ESCaPP, 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

43 National Experts with a level of "Ingénieur Agronome" & BTA benefited from TT&TU support. Those young experts were trained in the following 6 areas : biological control of cassava

pests (13), maize (21), cowpea (3), plantain (1), biological control of termites (2) and water hycinth (3)

2.3. Group training

- Financial Reporting Official Procedures: 12 participants from Burkina Faso, Côte d'Ivoire and Mali (1997).
- Multivariate Statistical Analysis Training Course : 10 National Project Coordinators from EscaPP, IMP-Cowpea & Cassava, IMP-Maize, LGB, LUBILOSA, PEDUNE, TT&TU across Burkina Faso, Côte d'Ivoire, Guinée, Mali, Niger, Senegal, Togo (1998).
- Program Planning & Management Training Course: 14 National Directors/Coordinators from CBB, IMP-Maize, LUBILOSA, PEDUNE, TT&TU, PV/Guinea Bissau across Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Guinée Bissau, Mali, Niger, Senegal, Tchad, Togo (1998).
- Plant Quarantine Experts Technical Orientation visit to the IITA Seed Health Unit: 7, Phytosanitary Control Experts, Benin (1999).

2.4. Selected Proposals from NARS-ECSA & IITA-Uganda

- GIS Training & Ethiopia Enset survey Data Analysis IITA-ESARC, 1998
- GIS Training & Mozambique Cassava survey Data Analysis IITA-ESARC, 1998
- GIS Training & Zanzibar Musa survey Data Analysis IITA-ESARC, 1998
- Occurrence and Incidence of Mycorrhizae on East African Highland Banana (Musa AAA) and Pisang Awak (Musa AAB) in Uganda & Rwanda (1999)

3. Strenthening NARES and regional organizations

3.1. Strategic Training Workshops

- Creating an African Understanding on the Safe Introduction of Natural Enemies : Collaboration in the Field of Biological Control and Access to Biological Control Agents. 33 National Experts and Crop Protection Division Directors shortlisted by the Inter-African Phytosanitary Council (IAPSC/OAU) from the following African English speaking countries: Cameroon, Egypt, Ghana, Kenya, South Africa, Tanzania, Uganda, Zambia, Zimbabwe, 1997 [Co-sponsored by GTZ and SDC]
- Biological Control of Pests: An Africa-wide Integrated Strategy for the Introduction and Control of the Biological Control Agents 29 National Experts and Crop Protection Division Directors shortlisted by the IAPSC/OAU from the following African French speaking countries: Burkina Faso, Burundi, Cameroon, Central Africa, Congo, Côte d'Ivoire, Gabon, Gambia, Mauritius, Mauritania, Niger, Senegal, Seychelles, Tchad, Tunisia ; 1998 [Co-sponsored by GTZ and SDC]
- Second Regional Technical Meeting on the Biological Control of the Spiralling Whitefly *Aleurodicus dispersus*. 24 National Experts and Directors from the following countries: Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Mali, Niger, Nigeria, Togo, Senegal, Italy, United Kingdom ; [Co-sponsored by FAO and SDC]

3.2. 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 ; 1999 [Proceedings sponsored by SDC] ;
- General Assembly of the Interafrican Phytosanitary Council: 51 Experts and Crop Protection Division Directors from: Benin, Burkina Faso, Burundi, Congo, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Guinea, Kenya, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Tchad, Togo, Uganda ; 1998. [Co-sponsored by GTZ IAPSC and SDC]

- Joint Action to control Striga in Africa : Experience of Ghana 45 Experts from Benin, Burkina Faso, Cameroon, Germany, Ghana, Mali, Niger, Nigeria, Tanzania, The Gambia ; 1997[one Malian Expert sponsored by SDC]
- First Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth, Harare, Zimbabwe 16-20 November, 1998 [one Burkinabe Project Coordinator sponsored by SDC]
- Insect in African Economy and Environment. ESSA/AAIA, Stellenbosch, South Africa, 30 June - 4 July, 1997 [4 African Project coordinators sponsored by SDC]
- Retrospective & Planning Workshop SDC Ouagadougou (1997)
- Workshop on the Agricultural Policy in Africa, Burkina Faso (1997, 1998) ; Cameroun, (1998)

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/screenhouses 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 1997/98	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.	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	EC [Wydra]
	National Extension Service (CARDER) Plant Protection Service (SPV) National Institute of Agricultural Research (INRAB)	PEDUNE activities focused on transfer of the use of botanical extracts including neem and papaw leaves to control cowpea pests, the improvement of storage techniques for cowpea. It also emphasizes on its efforts on testing improved varieties in on-farm fields and training .	From 1999, PEDUNE activities will be essentially on large dissemination of the use of botanical pesticides, storage techniques, socioecomic assessment of technologies and continue training farmers, extension agents, NGOs agents and Technicians on-station trials. Farmers Fields School will be established	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.	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 be initiated.	Denmak IFAD [Hanna]

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]
	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]
2. Burkina Faso (cont.)	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	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. Post-graduate training will be continued.	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. Collaborative *Bemisia*/CMD research with the SW-IPM whitefly project and continued strategic laboratory and field cassava IPM studies. Impact assessment of *T. aripo* in the biological control of CGM were initiated, 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.	From 1999, PEDUNE will concentrate its activities on the large dissemination of technologies including improved storage techniques, improved resistant varieties. Socioeconomic assessment will be done. Work will continue on impact assessment of CGM biocontrol in several agroecozones. T. aripo releases will be conducted in areas where the predator has not colonizees. Interplanting experiments with T. aripo-preferred cassava varieties will be conducted to enhance CGM biocontrol. Cassava root scale species composition, distribution, host associations, and natural enemies survey will be conducted. 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.	SDC [Hammond] Netherland Denmark [Hanna]

5.Côte d'Ivoire	National Center for Agricultural Research . [K. Nguetta, M. Kehe]	Biological Control of Mango Mealybug: In order to map out the geographical distribution of the Mango Mealybug (*Rastrococcus invadens*) and of its two major parasitoïds (*Gyranusoïdea Tebygi and Anagyrus mangicola,*), a preliminary survey covering 24,000 Km2 was completed. Hence, two specific areas where selected, *based on the level of R. invadens infestations mango* : i) the first area includes Korhogo, Sinematiali and Ferkessedougou and covers about 3,000 Km2 while ii) the second area, which is estimated at 300 Km2, includes Tafiré, Ouangolodougou, Mbengué, Kouto, Boundali and Dikodougou. Sampling isolation and purification of the two parasitoïds resulted in a monthly production of 1,200 parasitoïdes per box. However, the release of the predators has been delayed due to a lack of equipment which was still retained by the customs. The close association of the pest and the parasitoïd is well established throughout the surveyed area.	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 Cassava Green Mite: The preliminary survey was meant to map out the geographical distribution of the pest (*Mononychellus tanajoa*), and to assess the presence of the predator *Typhlodronalus aripo*. From this preliminary maping, which covers the South-East, East and Center regions, could be highlighted the following key information : i) the highest levels of infestation were found in the Center, South-West and Western zones, but the number of mites per leaf turned out to be quite low (18 to 21). Moreover, the predator (*T. aripo*) was present in the area of Bonoua, Noe and Bingerville but its presence was observed only in 12% of the cases. The first technical training course was achieved with the following objectives : i) Biology and Ecology of Cassava Green Mite, ii) Development of monitoring strategies, iii) Biology and Ecology of the natural enemies with emphasis on *T. aripo*, iv) Field visit, diagnosis and identification of the major Cassava pests and of the major natural enemies with special emphasis on *T. aripo*.	Biological Control of Cassava Green Mite: (Current initial phase to be continued through special Cassava project) : - Map out of the Cassava Green Mite across the major Cassava production area in Côte d'Ivoire -Assessment of the economic importance of the Cassava Green Mite accross at least 75% of the major cassava production area - Monintoring of geographical and spreading speed of natural enemies	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. One entomologist participated in acarology and CGM biocontrol bench training. 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. Cassava root scale species composition, distribution, host associations, and natural enemies survey will be conducted.	Denmark [Hanna]
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]
6. 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] CRI Kumasi, SARI Tamale University of Cape Coast and Legon, World Vision, ACDEP MAID	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. PEDUNE: On-farm trials were well established including minimum insecticide application , solarization and storage techniques and the use of plant based insecticides as neem. Farmers Field Schools (FFS) were implemented in Northern Region	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 More efforts will be directed to extend FFS, to disseminate technologies such as 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.	BMZ CABI - Bioscience [Speijer] SDC [Hammond]

6. Ghana (cont.)	Crop Research Institute, Kumasi University of Ghana, Legon University of Cape Coast Plant Protection and Regulatory Services Department (PPRSD)	*Bemisia*/CMD research continued with the SW-IPM whitefly. Cassava green mite research continued at low level. Socioeconomic studies of cassava green mite biocontrol were completed. Mite identification was provided on demand.	A new IFAD-funded project will finance backstopping activities for NARS in cassava green mite biocontrol, LGB predator releases, and testing of termite entomopathogens. *T. aripo* impact and 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]
	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 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.	The IPM plantain project will come to an end in 1999. Production of training materials, continued support of the Farmer Field School and further impact assessment are planned for 1999.	BMZ [Green]
7. Guinea	The National Biological Control Program (PGLB) of the Plant Protection Service	TT&TU and CGM project supported a limited cassava green mite survey and *T. aripo* releases. One entomologist participated in acarology and CGM biocontrol training course. 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 postgraduate training.	Germany [Zweigert] Denmark [Hanna]
8. Kenya	Kenya Agricultural Research Institute (KARI)	Diagnostic surveys of whiteflies and whitefly-borne viruses of cassava and sweetpotato were conducted as part of the SP-IPM Whitefly IPM Project. The regional OFDA CMD project was initiated. CGM and T. aripo surveys were conducted in Coast and Western provinces. Mite identification and curation service was provided. Participatory evaluation of multiple pest and disease resistant varieties were initiated.	As part of the regional OFDA CMD project, 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 with new three-year program for implementation of CGM biocontrol, which includes T. aripo releases, spread and persistence surveys, impact studies, postgraduate training, and Farmer Field Schools.	Denmark USAID (OFDA) [Legg] [Hanna]

9. Madagascar	FOFIFA (National Research Centre)	Diagnostic surveys of whiteflies and whitefly-borne viruses of cassava and sweetpotato were conducted as part of the SP-IPM Whitefly IPM Project.	Diagnostic surveys of mites will be conducted in collaboration with EARRNET	Denmark [Legg, James, Hanna]
10. 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. Diagnostic surveys of whiteflies and whitefly-borne viruses of cassava and sweetpotato were conducted as part of the SP-IPM Whitefly IPM Project.	CGM project continues activities with new three-year program for implementation of CGM biocontrol with NARES and NGOs, which includes *T. aripo* (and other exotic phytoseiid) releases, spread and persistence surveys, impact studies, postgraduate training, and Farmer Field Schools.	Germany IFAD [Hanna] [Legg]
11. Mali	Institute of Rural Economy/I.E.R C. Diarra, B. Dembele, A. Coulibaly, P. Bengaly & K. Coulibaly	Integrated *Striga* management: Technical Index of the isolate M12-4A of *Fusarium oxysporum* had been developed and 60 have been distributed to the Cotton Company extension agents Technical Index on the integrated biological control management against *S. hermonthica* (Del.) Benth. in Mali had been developed and distributed More than 600 color posters were available and distributed by the IER Scientific direction to the farmers, NGOs, Extension CMDT, OHVN and the National Extension Service Isolate M12-4A had demonstrated again its efficacy to suppress *S. hermonthica* growth during cropping season in all tested sites In 1998, intercropping cereal-cowpea had shown competition between these crops because 50 days after planting and cowpea having well covered the soil. rains were very abundant at this moment. Much moisture into the mixed plots caused significantly reduction on cereal development and its grain yield. We suggested that a combination of intercropping cereal-cowpea could be recommended into the areas where rainfall was less than 650 mm.	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: Resistant improved varieties, use of botanical pesticides to control cowpea pests have been tested on-farm.	PEDUNE: Dissemination of iresistant mproved varieties; on-farm testing in controlling cowpea pests including *Callosobruchus maculatus* with neem extracts; improved storage techniques and benchmark studes will continue to be the principal activities. Training at different level will be held	SDC [Hammond]

12. 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]
12. Mozambique (cont.)	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.	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 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. A new 3-year project plan was initiated for the implementation of CGM biocontrol.	CGM biocontrol implementation will continue in collaboration with NARES and NGOs. Two postgraduate students will initiate their studies on cassava green mite ecology and biocontrol. Virtually nothing is known about the status of , cassava virus diseases in Mozambique, and an assessment will therefore be carried out in mid-1999. A cassava IPM training course will be conducted in Nov. 99.	Denmark [Hanna, Legg]

13. Niger	Crop Protection Division, DPV [Danga]	Biological Control of pearl millet head borer: - A training visit has been conducted by BARRE A.C. and A.S. KOGO at Nioro de RIP entomolgical research station in Senegal where *Bracon hebetor* was reared last years - A training session was realised for 6 technicians and 3 of the staff members at Agrymeth in Niamey on July 1998. The session was conducted by Dr Ball from DFPV.and it deals with mass rearing *of B. hebetor* and it's alternative host *Ephestia kuehniella* - A survey of pearl Millet head *borer (E. albipunctella)* was conducted in Tillabery, Kollo and Filingue. The Survey shows 50% to 90% infestation rate. - A rearing system of *B. herbetor* and an of his alternative host was *(E. kuehniella)* was improved.	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.	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.	SDC [Hammond]

14. 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]
	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.	PEDUNE: major activities will be the wide dissemination of technologies including the application of botanical products to control cowpea pests and diseases and conduct socioeconomic assessment to investigate the rate adoption of technologies. Nigeria will also concentrate efforts to validate on-farm severa resistant improved varieties.	SDC [Hammond]
	National Root Crop Research Institute, Umudike	Bemisia/CMD research within the SW-IPM whitefly project continued. Impact assessment of T. aripo in the biological control of CGM continued 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* impact studies and 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]

15. 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' is to be initiated in 1999 and will run for three years. It will involve a wide range of partners including 3 CGIAR centers, 6 regional research networks, and a number of local and international NGOs. PHMD will provide backstopping to the 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	CGM project provided backstopping mite identification service for TT&TU funding activities.	PHMD scientists will collaborate with newly established technology development and transfer project for increased income and sustainable food security.	Denmark USAID [Hanna]
16. 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	SDC [Hammond]
17. 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 to start in mid 1999.	USAID [Legg]
	University of Pretoria Plant Protection Research Institute(Dr. Rami Kfir)	PEDUNE: Joint surveys for legume thrips and pod borers.	PEDUNE: On-going MSc training of 4 students, continue surveys. Possibility of establishing quarantine station for parasitoids of M. vitrata	SDC [Hammond]

18. Tanzania	Root and Tuber Crops Programme	Diagnostic surveys of whiteflies and whitefly-borne viruses of cassava and sweet potato were conducted as part of the SP-IPM Whitefly IPM Project. 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	Mrs Kadija Rajab, spend four weeks At IITA-ESARC for data analyzes and paper writing of a 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	Mrs Kadija Rajab will conduct 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]
	Plant Protection Service in the Ministry of Agriculture and Livestock Development	Surveys of whiteflies and whitefly-born viruses of cassava were completed. *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 project will continue biocontrol implementation with new three-year program, which includes *T. aripo* releases, spread and persistence surveys, impact studies, postgraduate training, and Farmer Field Schools. CMD control campaign will continue.	IFAD Rockefeller USAID [Hanna]
19. Togo	Institut Togolais de Recherche Agricole (ITRA), Togo	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.	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	EC [Wydra]
	The National Plant Protection Service (SPV) Directorate of Agricultural Research	The spread of *T. aripo* was monitored and mite training was provided. *T. aripo* impact studies were initiated.	The impact of *T. aripo* will continue, and further CGM training is planned. Cultural practices will be tested to enhance CGM biocontrol. New EC project will focus on implementation of and adoption of CBB control technologies.	Denmark [Hanna, Wydra]

20. Uganda	National Agricultural Research Organization (NARO) Makarere University	Diagnostic surveys of whiteflies and whitefly-borne viruses of cassava and sweet potato were conducted as part of the SP-IPM Whitefly IPM Project. 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. Stakeholder and training workshops were held at the initiation of the OFDA regional CMD Project.	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.	Denmark USAID [Legg]
	National Agricultural Research Organization (NARO) Makarere University	CGM biocontrol implementation continued with assistance from TT&TU. PHMD scientists participated in country-wide surveys to determine spread of *T. aripo*. Participatory evaluation of multiple pest and disease resistant varieties were initiated.	CGM project continues activities with new three-year program for implementation of CGM biocontrol, which includes *T. aripo* releases, spread and persistence surveys, impact studies, postgraduate training, and Farmer Field Schools.	IFAD USAID [Hanna]
	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]
21. Zambia	Mt. Makulu Research Station, Department of Research within the Ministry of Agriculture	A diagnostic survey of sweetpotato virus diseases was conducted as part of the SP-IPM Whitefly IPM Project. *T. aripo* establishment and spread surveys were conducted. Seventy participants met for a SARRNET scientific workshop in Lusaka. Screening for resistance to major pests and diseases continued with assistance from SARRNET.	CGM project continues activities with new three-year program for implementation of CGM biocontrol, which includes *T. aripo* (and other exotic phytoseiid) releases, spread and persistence surveys, impact studies, postgraduate training, and Farmer Field Schools.	IFAD Germany Denmark [Hanna] [Legg]

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
Amifor, Philip Nwadei[3]	Nigeria	86/88	IITA	-
Anga, Jean-Marc	Côte d'Ivoire	89/91	IITA	Neuenschwander
Animashaun, A. M.	Nigeria	86/88	IITA	Yaninek
Anledu, C.	Nigeria	94/95	ESCaPP	Yaninek
Assogba, K. Françoise	Benin	94/96	ESCaPP/Winrock	-
Atanga, G.	Cameroon	95/96	ESCaPP/Winrock	-
Aylin, R.A.	Ghana	95/96	ESCaPP/Winrock	-
Baba-Moussa, A.A.	Benin	97/98	self	Cardwell/Schulthess
Bar, J.	Netherlands	94	self	Rossel
Bello, T.M.	Nigeria	94/95	WB	Schilder/Thottappilly
Boateng, Bernhard	Ghana	94/96	IITA/DANIDA	Meikle
Bourassa, Caroline	Canada	96/97	LUBILOSA	Lomer
Braimah, Haruna	Ghana	87/90	IITA	-
Calix, Carolina	Honduras	93/95	IITA/BMZ	Markham
Chabi-OlayeA.	Benin	92	self	Schulthess/Shanower
Changa, Charles	Uganda	90/92	IDRC	Rossel
Claudius-Cole, Biodun	Nigeria	96/97	self	Schilder
Czerwenka-W., Isabel	Austria	94	Austria	Berner/Kling
d'Almeida, Ivens	Benin	93/94	self	Neuenschwander
Dejongh, Katrien	Belgium	92/93	Belgium	Berner
Denké, Dossan	Togo	93/95	self	Schulthess
Diop, Khady	Senegal	94/97	IITA/Winrock	Tamò
Djaman, Kofi	Togo	96/97	self/IITA	Schulthess
Etebu, Ebimieowei	Nigeria	95/96	IITA	Pasberg-Gauhl/Gauhl
Ezirim, Lawrence	Nigeria	83/84	IITA	-
Fritzsche, Maria E.	Switzerland	95	self	Tamò
Garcia, Alex	Honduras	94/96	IITA/BMZ	Markham
Gerard, Sandrine	France	97	ORSTOM	deGroote
Heviefo, Gabriel	Benin	91/92	self	Lomer
Hordzi, W.	Ghana	98	IITA/IFAD	Schulthess
Kamara, Samuel T.[3]	Sierra Leone	87/89	IITA	-
Kambona, Kenneth O.[3]	Kenya	86/88	IITA	-
Kanu, A. Fonti [2]	Sierra Leone	87/89	IITA	-
Kasongo, Tata Hangy	Zaire	88/90	IITA	-
Konan, Kouamé	Côte d'Ivoire	88/90	IITA	-
Koona, Paul	Cameroon	94/95	self	Jackai
Kuklinski, Frank	Germany	93/94	self	Lomer/Schulthess
Kwaku, Kyei A.	Ghana	93/94	IITA/Austria	-
Lega, Kouassi	Togo	96/9	self/IITA	Schulthess
Leumann, Christoph	Switzerland	93/94	self	Tamò
Madojemu, Edwina	Nigeria	85/86	IITA	Neuenschwander
Malambo, Codrine	Zambia	91/94	IITA	-
Manuel, Bob Rosetta B.[3]	Nigeria	85/87	IITA	-
Mateo, Rafael	Honduras	95/97	IITA/BMZ	Markham
Mbapila, Jacob C.[2]	Tanzania	87/88	IITA	-
Mbofung, Gladys	Cameroon	95/97	ESCaPP/Winrock	Msikita
Mebelo, Milimo	Zambia	94/95	IFAD	-
Molino, Diego	Honduras	95/97	IITA/BMZ	Markham
Moors, Anita	Belgium	93/94	Belgium	-
Mtambo, Karim M.	Tanzania	93/94	IITA/Austria	Neuenschwander
Mudiope, Joseph	Uganda	96/98	NRI	Speijer
Mugalu, J. Samuel	Uganda	86/88	IITA	Neuenschwander
Ndayiragije, Pascal	Burundi	88/92	IITA	Yaninek
Ndirpaya, Yarama	Nigeria	92/94	IITA/USAID	Berner

MSc/MPhil, completed (cont.)

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Ngi-Song, Adèle[3]	Cameroon	87/88	IITA	-
Ntumngia, R.	Cameroon	95/97	ESCaPP/Winrock	-
Nwauzoma, Bartholomew	Nigeria	94/95	self	Gauhl/Pasberg-Gauhl
Nwofor, Edna Ch.[3]	Nigeria	85/87	IITA	-
Ochiel, G. Syarra[3]	Kenya	86/88	IITA	-
Odongo, Benson[3]	Uganda	86/88	IITA	-
Oduor, I. George	Kenya	87/89	IITA	Yaninek
Ogunkoya, Mary	Nigeria	93/95	IITA/GTZ	Cardwell
Okwuoma, Janet	Nigeria	95/96	ESCaPP/Winrock	-
Opoku-Asiama, Mary	Ghana	94/96	ESCaPP/Winrock	Yaninek
Ruffai, A.A.	Nigeria	93/94	self	Akem
Sangoyomi, Titilayo E.	Nigeria	94/95	self	Green
Sanyang, Sidi	Gambia	91/93	IITA	Herren
Sekloka, E.	Benin	96	self	Schulthess
Sémeglo	Togo	96/97	self/IITA	Cherry/Schulthess
Senkondo, T. Frank	Tanzania	86/90	IITA	Yaninek
Sétamou, Mamoudou	Benin	94/97	IITA/GTZ	Cardwell/Schulthess
Shamie, I	Sierra Leone	94/96	IITA/GTZ	-
Sotomey, Marcelle	Benin	95/97	ESCaPP/Winrock	James
Sumani, Alfred J.	Zambia	87/89	IITA	-
Talwana, Herbert	Uganda	94/96	NRI/ODA	Speijer
Tchuanyo, Martin	Cameroon	86/87	IITA	-
Togla, Innocent	Benin	94	self	Neuenschwander
Torto, Gertrude	Ghana	94/96	ESCaPP/Winrock	-
Traoré, Lanciné	Guinée Ck.	89/90	IITA/GTZ	-
Ubeku, Jackson	Nigeria	91/92	IITA	Bosque-Pérez
Udzu, Anthony	Ghana	95/96	IITA	Schill
Van Mele, Paul	Belgium	91/92	Belgium	Berner
Vowotor, Kwame	Ghana	91/92	IITA	Bosque-Pérez
Wilson, Victoria	Nigeria	95/96	self	Pasberg-Gauhl/Gauhl
Woode, Ruth	Ghana	94/96	ESCaPP/Winrock	-
Yared, Hailemichael	Ethiopia	90/92	IITA/GTZ	-
Young, V.L.	Cameroon	95/96	ESCaPP/Winrock	-

MSc/MPhil, in progress

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Alao, Janet	Nigeria	96/98	self	Berner
Baba-Moussa, A. A.	Benin	97/98	self	Cardwell/Schulthess
Brentu, Collison	Ghana	97/99	BMZ	Green/Speijer
Buadu, B.	Ghana	98	IITA/IFAD	Schulthess
Ephrance, Tumureeba	Uganda	97/98	Gatsby	Legg
Dingha, B. N.	Camreoon	97/98	ARPPIS	Jackai
Garcia, A.	Honduras	98	IITA/BMZ	Markham
Gbati, G.	Togo	98	IITA/self	Meikle
Gnago, Jean	Côte d'Ivoire	96-98	CARFOP	Lomer
Gounou, Saka	Benin	97/98	IITA/IFAD	Schulthess
Jericho, C.	Zambia	97/98	IITA/SARRNET	-
Jerome, Kubiriba	Uganda	97/98	Rockefeller	Legg
Kiggundu, Andrew	Uganda	97/99	RF	Gold/Vuylsteke
Labo, I.	Togo	98	IITA/self	Schulthess
Mochiah , M.	Ghana	98	IITA/IFAD	Schulthess
Ngoya, Japhet	Uganda	97/99	RF	Gold/Nokoe
Nteletsana, L.	Lesotho	97/98	IITA/SARRNET	-
Olatunde, Olusegun J.	Nigeria	98	NRI/DFID	Hughes
Olichon, Sébastien	France	98	ORSTOM	LeGall
Sintim, Henry	Ghana	98/99	BMZ	Green/Gold
Soko, M.M.	Malawi	97/98	IITA/SARRNET	-
Tounou, A. K.	Togo	98	IITA/self	Schulthess
van Woensel, Gerry	Belgium	98	KUL/IITA/self	Speijer
Yusuf, Olayinka Taofiq	Nigeria	97	self	Hughes

PhD, completed

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Abu Zinid, Ibrahim[3]	Sudan	88/92	IITA	-
Adejumo, Timothy	Nigeria	91/97	self	Florini
Adekunle, Adefunke	Nigeria	96/98	IITA	Cardwell
Adu-Mensah, Joseph	Ghana	92/93	IITA	Lomer
Agbaka, Alphonse	Benin	89/95	UNB	Borgemeister
Aigbokhan, Emmanuel	Nigeria	92/98	IITA/USAID	Berner
Ajayi, Victoria	Nigeria	93/96	self	Florini
Akanvou, Louise	Côte d'Ivoire	92/95	IITA/Winrock	Kling/Berner
Akpokodje, Georgina	Nigeria	86/91	IITA/GTZ	Yaninek
Ariga, Emmanuel	Kenya	92/95	IITA	Berner
Arodokoun, David Y.	Benin	91/96	IITA	Tamò
Asanzi, M. Christopher	Zaire	88/91	IITA/USAID	Bosque-Pérez
Bigirwa, George	Uganda	94/97	self	Cardwell
Boavida, Conçeicão	Portugal	89/96	SDC/self	Neuenschwander
Bock, Clive	U.K.	91/93	NRI/ODA	Cardwell
Bokonon-Ganta, Aimé H.	Benin	92/96	IITA/GTZ	Neuenschwander
Bolaji, Omobola	Nigeria	90/96	FF	Bosque-Pérez
Borowka, Roland	Germany	90/96	GTZ/self	Neuenschwander
Bruce-Oliver, Samuel	Gambia	89/93	IITA	Yaninek
Camara, Mamadou	Mali	92/96	IITA/BMZ	Borgemeister
Cudjoe, R. Anthony	Ghana	86/90	IITA/GTZ	Neuenschwander
Desmarais, Gaétan	Canada	94/96	IDRC	N'wander/Akinwumi
Dreyer, Hans	Switzerland	90/94	SDC	Herren/Tamò
Ebot, Martin	Cameroon	93/95	IITA	Dashiell/Florini
Fessehaie, Anania	Germany	93/97	BMZ	Wydra
Fokunang, Charles	Cameroon	93/95	IITA	Dixon/Florini
Goergen, Georg	Germany	90/92	IITA/GTZ	Neuenschwander
Hailemichael, Yared	Ethiopia	94/98	IITA/BMZ	Schulthess
Hammond, Winfred N.O.	Ghana	84/88	IITA	Neuenschwander
Hell, Kerstin	Germany	93/97	IITA/GTZ	Cardwell
Herrmann, Isabelle	Germany	93/96	IITA/GTZ	Cardwell
Igbinnosa, Imuetinyan	Nigeria	90/93	IITA	Cardwell
Kangire, Africano	Uganda	94/98	RF	Gold
Karamura, Deborah	Uganda	93/98	RF	Gold
Karamura, Eldad B.[3]	Uganda	86/89	IITA	-
Konan, Kouamé	Côte d'Ivoire	91/95	IITA	Schulthess
Langewald, Jürgen	Germany	90/93	GTZ	Lomer
Manuel, Bob Rosetta B.[3]	Nigeria	88/91	IITA	-
Meikle, William	U.S.A.	89/92	RF	Herren
Mih, Afui Mathias	Cameroon	89/93	self	Rossel
Mobambo, Kitume Ngongo	Zaire	90/93	IITA	Pasberg-Gauhl/Gauhl
Muaka, Toko	Zaire	90/92	IITA/USAID	Yaninek
Murega, Thomas N.[3]	Kenya	87/90	IITA	-
Ndonga, M.F. Millicent[3]	Kenya	86/89	IITA	-
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
Ojo, Joseph Bamidele	Nigeria	91/98	IITA	Yaninek
Oduor, I. George	Kenya	91/95	IITA	Yaninek
Ogwang, James[3]	Uganda	87/90	IITA	-
Olatinwo, Rabiu	Nigeria	95/98	IITA/NRI	Cardwell
Ouedraogo, Amidou	Burkina Faso	91/95	DFPV	Lomer
Phiri, S.N. Georges	Malawi	90/95	IITA/GTZ	Schulthess
Sagbohan, Jacqueline	Benin	91/97	LUBILOSA	Lomer
Sanyang, Sidi	Gambia	93/97	LUBILOSA	Lomer
Schaab, Ralf	Germany	91/96	GTZ	Neuenschwander
Schneider, Heinrich	Germany	94/98	GTZ	Markham/B'meister
Scholz, Dagmar	Germany	93/97	DBF/DAAD	Borgemeister
Schulthess, Fritz	Switzerland	82/87	FAO	-
Stäubli-Dreyer, Bettina	Switzerland	91/94	self	Neuenschwander
Tamò, Manuele	Switzerland	87/91	SDC	-

PhD, completed (cont.)

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Traoré, Lanciné	Guinée Ck.	91/95	IITA/GTZ	Gold
Tuma, Yeti	Cameroon	92/95	IITA	Dashiell/Florini
Udoh, Janet	Nigeria	91/97	IITA/Winrock	Cardwell
Umeh, Vincent	Nigeria	91/94	IITA	Neuenschwander
Umorem, E.	Nigeria	93/95	IITA	Jackai
Yaninek, John S.	U.S.A.	83/85	IITA	-
Yayé-Dramé, A.	Senegal	93/98	IITA/Winrock	Youm/Schulthess

PhD, in progress

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Abdullahi, Ismaila	Nigeria	96/98	IITA	Thottappilly/James
Abera, Agnes	Uganda	98/03	RF	Gold
Afouda, Leonard	Benin	96/99	IITA	Wydra
Ahonsi, Monday	Nigeria	96/00	self	Berner
Akintobi, C.M.	Nigeria	92/97	IITA/Winrock	Jackai
Alabi, Martins	Nigeria	92/99	IITA	Berner
Alao, Janet	Nigeria	98/00	self	Berner
Anga, Jean-Marc	Côte d'Ivoire	91/96	IITA	Neuenschwander
Asiwe, Joseph	Nigeria	97/99	IITA	Jackai
Babalola, Olubukola	Nigeria	98/00	self	Berner
Banjo, D. M.	Nigeria	93/97	self	Jackai
Borketey-La	Ghana	98/00	IITA/IFAD	Schulthess
Botanga, Christopher	Cameroon	98/00	self	Kling/Berner
di Umba, Umba	DR Congo	95/99	IITA	Dashiell/Berner
Diarra Cheickna	Mali	98/99	SDC	Berner
Diop, Khady	Senegal	97/99	IITA/Winrock	Tamò
Dongo, Emily Ibitaijewa	Nigeria	97/00	self	Hughes
Dongo, Lelia Nkechinyere	Nigeria	96/00	IITA	Hughes
Ekundayo, O. Y.	Ngeria	97/99	self	Jackai/Lajide
Fanou, André	Benin	97/99	BMZ/SDC	Wydra
Gnanvossou, D.	Benin	98/00	DANIDA	Hanna
Gnego, Jean	Côte d'Ivoire	96/99	OAU	Lomer
Godonou, Ignace	Benin	95/99	IITA/GTZ	Lomer
Griesbach, Matthias	Germany	96/99	DAAD	Gold/Speijer
Haimanot Abebe	Ethiopia	98/00	SDC	Langewald
Kashaija, Ismelda	Uganda	91/96	RF	Speijer/Gold
Khatri-Chhetri, Gopal	Nepal	96/98	BMZ	Wydra
Kidza, Nakato	Germany	97/00	DAAD	Speijer
Koona, Paul	Cameroon	96/98	IITA	Jackai/Lajide
Kumbe, Lekia	Nigeria	95/98	self	Jackai/Tamò
Kwoseh, Charles	Ghana	96/99	IIP	Asiedu/Speijer
Mangana, Serafina	Mozambique	99/02	self	Speijer/Andrade
Masanza, Michael	Uganda	97/01	RF	Gold
Mebelo, M.	Zambia	97/98	IITA/SARRNET	-
Minamor, Andrew Amegbedzi	Ghana	96/98	DFID	Hughes
Mudiope, Joseph	Uganda	99/01	IITA	Speijer/Asiedu
Mungo, Catherine	Cameroon	92/97	IITA	Florini
Ndemah, Rose	Cameroon	96/99	IITA/IFAD	Schulthess
Ngoko, Zachée	Cameroon	96/99	IITA/IFAD	Cardwell
Niere, Bjoern	Germany	97/00	BMZ	Speijer
Nsibanda, L.	Swaziland	97/98	IITA/SARRNET	-
Odiye, A.	Nigeria	98/00	Self	Ajala
Odu, Babajide O.	Nigeria	98/01	Gatsby	Asiedu/Hughes
Ogu, C.	Nigeria	95/97	IITA	Hughes/Thottappilly
Oigiangbe, O.N.	Nigeria	96/98	self	Jackai/Lajide
Olojede. S.O.	Nigeria	97/99	IITA	Jackai/Thottappilly
Onzo, A.	Benin	98/00	DANIDA	Hanna/Yaninek
Rajab, Khadija	Zanzibar	99/04	IITA	Speijer/Vuylsteke
Rotimi, Omolara	Nigeria	96/00	BMZ	Speijer/Green
Rugutt, Joseph	Kenya	94/96	Rockefeller	Berner
Rukazambuga, N. D.	Tanzania	91/96	RF	Gold

PhD, in progress (cont.)

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Schade, Viola	Germany	91/96	GTZ/self	Neuenschwander
Sétamou, Mamoudou,	Benin	96/99	IITA/IFAD	Schulthess
Shobowole, A.A.	Nigeria	95/00	self/IITA	Cardwell
Sikirou, Rachidatou	Benin	96/98	BMZ/SDC	Wydra
Ssemakula, G.N.	Uganda	93/96	FF/IITA	Jackai
Talwana, Herbert	Uganda	97/00	RF	Speijer
Tushemereirwe, Wilberforce	Uganda	93/97	RF	Gold
Vowotor Kwame	Ghana	93/98	DANIDA	Meikle
Zenz, Nikolaus	Germany	94/98	UNIHO	Tamò/Bernhard

PhD, not completed

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Chalabesa, Albert	Zambia	86/89	IITA	Neuenschwander
Lorek, Christian	Germany	94/97	IITA/BMZ	Markham/B'meister
Marshall, Cosmos	Ghana	94/95	BMZ	Schill
Wamala, J.	Uganda	92/94	IITA/GTZ	Hammond

[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)

SCIENTIFIC COLLABORATORS

Abia State ADP, Umuahia, Nigeria: *E. Okoro*
Abubakar Tafawa Balewa University, Bauchi, Nigeria: *A. Adebitan*
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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 has been established 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).

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 IARCs and partners

Background

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). 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. Databases of CGIAR IPM projects and human resources are being developed in collaboration with IPM Europe and IPM Net, respectively.

Ongoing and future activities

1.1. Establishment of an IPM Project Database

by R.M. – in collaboration with B. James

A database has been established which will eventually provide information on all IPM-related projects being conducted by the participating IARCs. For each project, some 30 data fields

provide information on scope, targeting, objectives, progress and further contact details. Additional entries provide information on the place of IPM research in the agenda of each Center. At present, only a few Centers have provided a complete data-set but the printed version of the database has already been well-received in various fora. Once it is more complete, the entire database will be available on the Internet and searchable on line. For the moment, text extracts (summarizing log. frame information) are available on the web-site of the SP-IPM.

2. *Task Force Developments*

Background

As a general procedure, Task Forces are developed to respond to key IPM research challenges. 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.

Ongoing and future activities

2.1. International whitefly and geminivirus project

by R.M. - in collaboration with B. James, J. Legg, P. Anderson

Diagnostic surveys, using standardized methods, have been carried out by all four sub-projects, covering: the tropical highlands of Latin America; the tropical lowlands of Central America, Mexico and the Caribbean; Eastern and Southern Africa; and cassava and sweet potato in sub-Saharan Africa. The last sub-project, in which IITA is mainly involved, has defined the disease front of the severe African Cassava Mosaic Disease epidemic and is following the displacement of the old form of the virus by the new "Uganda variant". Resistant materials are being multiplied and deployed to respond to the epidemic. Virus incidence in sweet potato and parasitism of whiteflies on cassava have also been studied. Ten national organizations in Africa are actively involved in the project. At a global level, the project has established a database of "grey literature" relating to whitefly and geminivirus problems in the tropics and a directory of researchers working in the field.

2.2. Farmer participatory research methods

by R.M. - in collaboration with B. James, A. Braun

A listserver has been established and has stimulated lively debate relating to the role of farmer participatory research (FPR) methods in IPM. A "study tour" is being planned, in collaboration with the Global IPM Facility, to carry out a critical comparative study of different farmer participatory approaches, used in a range of projects, across Asia, Africa and Latin America. It is expected that, based on the outcome of the comparative study, the Task Force will provide recommendations on how best to incorporate FPR methods into other IPM projects.

2.3. Beneficial microorganisms

by R.M. – in collaboration with C. Lomer

The Task Force on beneficial microorgamisms has published and distributed a leaflet on the role of "Microbial Control in Sustainable Pest Management". A website has also been set up by this Task Force to provide additional information on its activities and a point of interaction with a wider range of partners (www.cgiar.org/spipm/tf/bmo).

2.4. Other Task Forces

by R.M. - in collaboration with D. Berner, K. Wydra, F. Schulthess, and numerous researchers worldwide

Progress on other Task Forces was severely constrained by the uncertain financial status of the Program during 1998. However, the Task Forces on Rice Weed Management (an initiative led by WARDA), Soil-borne Pathogens (led by ICARDA), Parasitic Flowering Plants (led by IITA) and Cereal Stem Borers (led by CIMMYT) all completed work on proposals for inter-Center research

and submitted them to donors. A special presentation was also made to donors at International Centers Week, on behalf of these initaitives.

3. *Promoting wider awareness of IARC IPM research*

by R.M., L.B.

The first Annual Report of the SP-IPM was published during 1998 and widely distributed. As well as reporting progress on the SP-IPM's various initiatives, the report carried stories on IPM successes at individual Centers and highlights of each Center's IPM research and development work.

A major renovation of the SP-IPM's WorldWideWeb site (www.cgiar.org/spipm) was also carried out at the end of 1998 and this will now be updated at more frequent intervals, to provide a point of dynamic interaction with research partners and the general public.

Completed Studies

Copies of the Progress Report on Phase 1 of the "Whitefly Project" (Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics) are available from the coordinator of that Project, Dr. P. Anderson of CIAT. Copies of the SP-IPM annual report and of the Inter-Center Working Group on IPM are available from the SP-IPM coordinator (e-mail: ipm-center@cgiar.org) or from the Office of the Director, PHMD in Cotonou.

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