Project 5

Integrated Management of Maize Pests and Diseases

Annual Report 1998

International Institute of Tropical Agriculture

Preface

The research agenda of IITA is subdivided into a portfolio of 16 projects (Annex 1), around which these Annual reports are prepared. These projects address different aspects of attaining sustainable increases in productivity of dominant farming systems and utilization practices in the various agroecologies of sub-Saharan Africa (SSA). Research and training activities carried out in the 16 projects are being implemented together with national program partners in order to increase the well-being of poor people in SSA through higher levels of food production, better income and nutritional status, and reduced drudgery—particularly for women. Additionally IITA serves as the convening center for the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA) and the Systemwide Project on Integrated Pest Management (SP-IPM).

The institute-wide log frame (Annex 2) shows the expected contribution of each project to the overall institute goal, with the specific project log frame presented in Annex 3.

Highlights from all these projects can be found in Annex 4, which thus provides an illustrative overview of IITA's research activities and achievements of the year.

Annex 5 shows all the agroecological zones of sub-Saharan Africa in which IITA conducts research.

The project management arrangement for implementing IITA's research agenda is relatively new, and continues to evolve from a divisional/program structure. In earlier years, detailed research outputs and achievements were reported in divisional reports; this is the third year that implementation of IITA's research agenda is being presented in individual project reports. To satisfy the continuing needs of disciplinary groups in partner and other interested institutions, portions from the individual project reports will be collated into subject matter reports corresponding to current research divisions—Crop Improvement, Plant Health Management, and Resource and Crop Management.

Contents

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 postharvest, far outweigh any reasonable hope for increases in productivity through improved germplasm and pre-harvest management. There are reports from Africa of postharvest 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 postharvest 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.

Ongoing 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 savanna 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 and 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 pluså 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 suboptimal 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 likelihood 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 suboptimally 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 stemborers 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 stemborer levels in the field had any impact on postharvest quantities of *F. moniliforme* and fumonisin contamination of the ear. In a field to store study of maize in Cameroon from 1996 until 1998, no field factor was found to be significantly related with postharvest 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 °C were significantly smaller than mycetomes in females reared at 30 °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 agroecologies 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*. Teh 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 postharvest)

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 stemborers 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.

Ongoing 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. poephaga* (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 entomologists from AMS target countries was held in Ibadan to discuss techniques to increase uniformity of field infestations.

5.2.2. Improve stemborer 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 stemborer 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 stemborer 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) d-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, 10 mg/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 0.4 mg/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 2 mg/ ml, 93% of mortality on *E. saccharina* 42.4% and 35.6% on *B. fusca* and *S. calamistis*, respectively. Only the CryIAb at 0.016 mg/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 midaltitude 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 midaltitude 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 Côte 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 backcrosses 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 2.2×10^5 to 7.1×10^5 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 postharvest 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 origins, including coevolved 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 stemborers, 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.

Ongoing 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 stemborers 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 consignments 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 South Africa is *Arctia* sp. another tachinid commonly found in Cameroon.

In 1998, further consignments of *S. calamistis* pupae parasitized by *Pediobius furvus* were shipped to Brazil to be tested on the sugarcane 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 stemborers 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 stemborers

*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 stemborers, 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 Deuteromycete fungus, *Beauveria bassiana*, may have potential as a biological alternative to chemical insecticides or adjunct to *T. nigrescens*.

Laboratory tests 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 19 °C, while its prey, *P. truncatus*, can survive and develop at temperatures as low as 12 °C. 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 midaltitude 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 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 extension workers 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.

Ongoing and future activities

5.4.1. Assessment of impact of 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 10 g/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 bottleneck 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, 0.23% of maize plants in research plots were found to be infected and by 1997 incidence of infected plants on the campus was at 0.07%. The average spore catch in a Burkhard spore trap in the center of the 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 0.8 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 the 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 the IITA campus showed that 71% of the total farms surveyed had no infection while the remaining 29% had infection ranging between 0.03 and 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 and 0.8 spore/mm^2/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 postharvest 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 NGOs 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 multidisciplinary 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 savanna and the highlands of Cameroon. The survey has been carried-out in benchmark sites or representative recommendations domains delineated in each agroecological zone and a sample of 178 farm households 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 grasshoppers 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* spp. 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 recommendations of cost effective and adapted integrated pest management technologies.

Uganda: The multidisciplinary 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 recommendations domains have been identified and in which 144 farm households 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 cobs 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 Longel which is resistant to streak virus 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 2.5h 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 semiarid 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 regions 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 the 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 600–1200 m) both maize and sorghum were infected, and disease incidence was invariably low (< 5%). Systemic SDM incidence on maize was negatively 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 infection 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 ± 2 ºC, 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 Stemborer: 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*** **Meharrhizium anisopliae** ***(Metschnikoff) Sorokin on the larger grain borer,*** **Prostephanus truncatus** ***(Horn) (Coleoptera: Bostrichidae), and its predator,*** **Teretriosoma nigrescens** ***Lewis (Coleoptera: Histeridae). Journal of Invertebrate Pathology (submitted).***

Four strains of entomopathogenic fungi, three of *Beauveria bassiana* and one *of 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 agroecological 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 reabsorb 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 agroecological 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 agroecological zones in Nigeria. Maize storage in plastic bags was the most common among all farmers. The clay *Rhumbu* was used in 4 out of 5 agroecological zone by both male and female farmers. The woven *Oba* was found only in the southern Guinea savanna and was used predominantly by women. Only 13% of the male farmers in the southern Guinea savanna and none in the other zones stored in an improved *crib* while no female farmers across all the zones used the crib system of storage. Male and female farmers across all the zones identified insect infestation, fungal and rodent attack as primary constraints in their stored maize. Insect infestation was reported by 83% of the female farmers in the southern Guinea savanna zone who stored maize in bags. The highest fungal attack on stored maize was reported by 71% of the male farmers who stored maize in bags in the Humid Forest zone, while 75% of the male farmers, (the highest percentage), who stored in bags in the Sudan Savanna zone complained of rodent attack. Across all zones, farmers of both genders identified insects as the most common storage problem. Farmers who reported insect problems were significantly more likely to have aflatoxin in their stores. The highest zonal mean aflatoxin level of 125.6 mg/kg was obtained from maize samples provided by male farmers in the Sudan savanna zone who stored maize in bags or in a *Rhumbu*. Across the storage systems, 33% were contaminated with detectable levels of aflatoxin. No aflatoxin was detected in the storage systems of male or female farmers in the northern Guinea savanna zone in 1994. Storing maize in plastic bags is probably a relatively new practice in Nigeria, having replaced more traditional materials. It apparently is a practice that should be discouraged because of the negative effect on grain quality.

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

are discussed.

Conference papers, workshop proceedings, 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 2 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: untreated 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 50th 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 cannot 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 buildup, 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 to 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 agroclimatological 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 agroecologies 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.

IITA/PHMD postgraduate training

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
MSc/MPhil completed				
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-Olaye A.	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
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

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

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	-
Traoré, Landiné	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

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.	Nigeria	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
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

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*

Action Aid, Blantyre, Malawi: *E. Musopole*

Agricultural Research Council, Plant Protection Institute, Pretoria, South Africa,

Agriculture Canada, Centre for Land and Biological Resources Research, Ottawa, Canada: *L. LeSage, L. Masner*

Agriculture Canada, Saint-Jean sur Richelieu Research Station, Monréal, Canada: *G. Boivin*

Agriculture Canada, Vancouver Research Station, Vancouver, Canada: *R.I. Hamilton, C. Huguenot*

Ambo Research Station, IAR, Plant Protection Services, Ambo Ethiopia: *M. Bogale*

Asian Vegetable Reseach and Development Center (AVRDC), Taipei, Taiwan: *N.S. Talekar*

Association de Dévéloppement de Tobe, Banté, Bénin: *K. Ostertag, A. Ratié*

Auburn University, Alabama, U.S.A. *W. Moar B. Bouwman, G. Pietersen, E. van den Berg*

Bauchi State Agricultural Development Project (BSADP), Bauchi, Nigeria: *R. Yakubu*

Biologische Bundesanstalt, Deutsche Sammlung von Mikroorganismen und Zellkulturen, (DSMZ) Braunschweig, Germany: *S. Winter*

Biologische Bundesanstalt, Institut für biologischen Pflanzenschutz, Darmstadt, Germany: *J. Huber, R. Kleespies, J. Zimmermann*

British Museum, London, U.K.: *J. Noyes, A. Polaszek*

CARE International, Lusaka, Zambia: *G. Mitti*

Carelton University, Ottawa, Ontario, Canada: *J.D. Miller*

Centre Africain pour la Recherche et Formation en Protection des Végétaux (CARFOP), Dschang, Cameroon: *J. Foko*

Centre d'Action Régionale pour le Développement Rural (CARDER) Atacora et Borgou, Benin: *R. Tocloe, S. Challa*

Centre d'Action Régionale pour le Développement Rural (CARDER) Atlantique, Benin: *A. Aklamavo*

Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Laboratoire de Faunistique, Montpellier, France: *G. Delvare*

Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Paris, France: *G. Delvare, J. Fargues*

Centre for Research on Bananas and Plantains (CRBP) Njombe, Cameroon: *H. Ysenbrandt*

Centro Internacional de Agricultura Tropical (CIAT), Calí, Colombia: *E. Alvarez, A.C. Bellotti, A. Braun, M. El-Sharkawy, M. Fregene*

Centro Internacional de Agricultura Tropical (CIAT), Uganda Station: *M. Fischler, C. Wortman*

Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), El Batán, Mexico: *D. Bergvinson, G. Edmeads, D. Hoisington, Y. Savidan*

Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Nairobi, Kenya: *J. Ransom*

Commercial Oilseed Production Company, Harare, Zimbabwe: *C. Levy*

Commonwealth Scientific and Industrial Research Organisation (CSIRO), Long Pocket Laboratories, Indooroopilly, Brisbane, Australia: *K.L.S. Harley*

Copersucar Technology Center, Entomology Division, Piracicaba, Brazil: *E. De Bni Arrigoni.*

Crops Research Institute (CRI), Kumasi, Ghana: *J.K.V. Afun, R. Awuah, J. Otoo, M. Owusu-Akyaw, J. Twumasi*

Crops Services Department, Ho, Volta Region, Ghana: *N. Oware-Owusu*

Danish Insitute of Agricultural Sciences, Flakkenberg, Denmark: *N. Holst*

Departamento de Sanidade Vegetal, Maputo, Mozambique: *A.A. Jones*

Département de Formation en Protection des Végétaux (DFPV), Niamey, Niger: *C. Kooyman, E. Sarr*

Direction de la Protection des Végétaux et du Conditionnement (DPVC), Ouagadougou, Burkina Faso: *J.B. Toe*

Direction de la Protection des Végétaux (DPV), Niamey, Niger: *S. Gan-Bobo*

Direction de la Protection des Végétaux (PV), Conakry, Guinée-Conakry: *S. Baldé, M. Camara, A. Fofana, K. Kalivogui, P. Moriba, T. Lancine*

Dupont Company, Stine-Haskell Research Center, Delaware, U.S.A.: *J. Green*

Ecole Nationale Supérieure Agronomique (ENSA), Yamoussoukro, Côte d'Ivoire: *K. Foua-Bi*

Ecole Nationale Superieure Agronomique, Montpellier, France: *S. Kreiter*

Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland: *S. Dorn*

Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Brazil: *A. Maps, B. Ospina, J.T. Yorinori*

Environmental Management Associates (EMA), Accra, Ghana: *R. Hoevers*

Escuela Agrícola Panamericana (EAP), El Zamorano, Honduras: *S. Gladstone, V.F. Wright, M. Zeiss*

Federal University of Technology, Akure, Nigeria: *L. Lajide, T.I. Ofuya*

Federal University of Technology, Owerri, Nigeria: *C.C. Asiabaka, C.I. Ezendinma*

Food and Agriculture Organization (FAO), Rome, Italy: *G.G.M. Schulten*

Friedrich-Schiller-Universität, Jena, Germany: *B. Voelksch*

Fundación Hondureña de Investigación Agrícola, LaLima, Honduras: *A. Rafie, F. Rosales, P. Rowe*

Gesellschaft für technische Zusammenarbeit (GTZ), Eschborn, Germany: *A. Bell*

Ghana Atomic Energy Commission, Accra, Ghana: *R. Ahiabu, E. Dinku*

Horticulture Research International, Welletbourne, U.K.: *A.A. Brunt*

Imo State University, Okigwe, Nigeria: *G. Mbata*

Imperial College, Silwood Park, England: *S. Leather*

Institut d'Etudes et de Recherches Agricoles (INERA), Kamboinsé, Burkina Faso: *C. Dabire, I. Drabo*

Institut d'Etudes et de Recherches Agricoles (INERA), Ouagadougou, Burkina Faso: *S. Paco*

Institut d'Etudes et de Recherches Agricoles (INERA), Ouahigouya, Burkina Faso: *D.F. Traore*

Institut des Savannes (IDESSA), Ferkessedougou, Côte d'Ivoire: *D. Acle, L. Akanvou*

Institut des Sciences Agronomiques du Burundi (ISABU), Bujumbura, Burundi: *P. Ndayiragije*

Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM), Montpellier, France: *C. Assigbetse, B. Boher, O. Bonato, V. Verdier*

Institut National des Recherches Agricoles du Bénin (INRAB), Cotonou, Benin: *P. Adegbola, D.Y. Arodokoun, G. Gbéhounou*

Institut National des Recherches Agricoles du Bénin (INRAB), Niaouli, Benin: *K. Aïhou, R. Dossou, N.G. Maroya, O. Sanni*

Institut National des Recherches Agronomiques du Niger (INRAN), Kollo, Niger: *A. Aboubakar, A. Basso, I. Germaine, P. Halidou, S. Maiga*

Institut National des Recherches Agronomiques du Niger (INRAN), Maradi, Niger: *Hamma Hassan, H.A. Kadi,*

Institut National des Recherches Agronomiques du Niger (INRAN), Niamey, Niger: *S. Ly*

Institut National pour L'etude et la Recherche Agronomique (INERA), Kinshasa, DRC: *T. Hangy, K.M. Lema*

Institute for Subtropical and Tropical Crops (ISTC), Nelspruit, South Africa: *S. Schoenen*

Institute of Agricultural Research and Training, College of Agriculture, Akure, Nigeria: *A.O. Adetoro*

Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria: *E. Iken, O. Obajimi, B.A. Ogunbodede*

Institute of Agricultural Research, Ahmadu Bello University (IAR/ABU), Zaria, Nigeria: *O. Alabi M.C. Dike, K. Elemo, A.M. Emechebe, S.T.O. Lagoke, O.O. Olufadjo, J. Voh*

Institute of Agronomic Research & Development (IRAD), Bamenda, Cameroon: *Z. Ngoko*

Institute of Agronomic Research & Development (IRAD), Maroua, Cameroon: *G. Ntoukam*

Institute of Agronomic Research & Development (IRAD), Yaoundé, Cameroon: *J. Ayuk-Takem, J. Ngeve*

Institute of Agronomic Research, Ekona, Cameroon: *J. Ambe Tumanteh, B. Bakia, M. Besong, E. Awah, R. Ndemah, Z. Ngoko, C. Poubon, M. Tchuanyo*

Instituto Nacional de Investigaçao e Desenvolvimento Agraria (INIDA), Sao Jorge, Cabo Verde: *M.-L. Lobo-Lima*

Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), Mexico: *R.M. Ríos*

Instituto National de Investigaçao Agronomica (INIA), Maputo, Mozambique: *J.S. Baciao, A.M. Zacarias*

International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria: *K. Makouk*

International Center of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya: *A. Hassanali, Y. Khan, S. Lux, E. Osir, W.A. Overholt, K.V. Seshu Reddy, J. Ssenyunga*

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Bagauda, Nigeria: *O. Ajayi*

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Bamako, Mali: *D. Hess*

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Bulawayo, Zimbabwe: *K. Leuschner*

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India: *T. Shanower*

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Sahelian Center, Niamey, Niger: *D. Hess, O. Youm*

International Institute of Biological Control, (IIBC), C.A.B. International, London, U.K.: *R. Bateman, M. Cock, D. Greathead, N. Jenkins, D. Moore, C. Prior, M. Thomas, J. Waage*

International Institute of Biological Control (IIBC), C.A.B. International, Nairobi, Kenya: *G. Allard, G. Hill*

International Institute of Entomology (IIE), C.A.B. International, London, U.K.: *T. Jones*

International Institute of Parasitology (IIP), C.A.B. International, London, U.K.: *J. Bridge, R. Plowright*

International Livestock Research Institute (ILRI), Ibadan, Nigeria: *S. Tarawali*

International Mycological Institute (IMI), C.A.B. International, London, U.K.: *M. Holderness, M. Rutherford, J. Waller*

International Network for the Improvement of Banana and Plantain (INIBAP), Montpellier, France: *D. Jones*

International Network for the Improvement of Banana and Plantain (INIBAP), Los Banos, Philippines: *R. Valmayor*

International Plant Genetic Resources Institute (IPGRI), Rome, Italy: *M. Dickmann*

International Rice Research Institute (IRRI), Los Baños, Philippines: *A. Baniou*

John Innes Centre (JIC), Norwick, U.K.: *G. Harper, R. Hull*

Justus Liebig Universität, Giessen, Germany: *H. Hummel, H. Schmutterer*

Kabwe Research Station, Kabwe, Zambia: *E. Munsanje*

Kano Agricultural Research and Development Association (KNARDA), Kano, Nigeria: *S. Dantata, S. Gaya, U. Ibrahim, A. Ma'aruf*

Kasetsart University, Bangkok, Thailand: *M.. Weerwit*

Katholieke Universiteit, Leuven, Belgium: *R. Swennen, K. de Waale*

Kenya Agricultural Research Institute (KARI), Kakamenga, Kenya: *O.M. Odongo*

Kenya Agricultural Research Institute (KARI), Nairobi, Kenya: *C. Kariuki*

Livestock and Pest Control Division, Federal Ministry of Agriculture and Natural Resources, Lagos, Nigeria: *J.J.A. Akinnibagbe*

LOCUSTOX, FAO, Dakar, Senegal: *H. van der Valk*

Louisiana State University, Baton Rouge, Louisiana, U.S.A.: *K. Fischer*

Makerere University, Kampala, Uganda: *E. Adipala, S. Kyamanywa, M. Ogenga-Latigo, P. Rubaihayo*

Makoka Research Station, Thondwe, Malawi: *G. Phiri*

Malawi-German Plant Protection Project, Lilongwe, Malawi: *J. Gwinner*

McGill University, Monréal, Canada: *V. Rahavan*

Ministry of Agriculture and Livestock Development (MALD), Dar es Salaam, Tanzania: *F. Katagira, O. Mfugale, B. Pallangyo*

Ministry of Agriculture, Extension Service, Kampala, Uganda: *B. Byarugaba*

Ministry of Food and Agriculture, Accra, Ghana: *D.Q. Annang, E. Dosoo, O. Ofori*

Montana State University, Bozeman, Montana, USA: *W. Swearingen*

Mt. Makulu Research Station, Chilanga, Lusaka, Zambia: *M.A. de Vos, F. Javaheri, E. Musonda, A. Sumani*

Mycotech Corporation, Butte, Montana, USA: *C. Bradley, S. Jaronski*

National Agricultural Research Organisation (NARO), Kawanda, Kampala, Uganda: *F. Bagamba, E. Karamura, I. Kashaija, J. Namaganda, C. Nankinga, W. Tinzaara, M. Wejuli*

National Agricultural Research Organisation (NARO), Namulonge, Kampala, Uganda: *Y. Baguma, G. Bigirwa, S.C. Jeremiah, T. Kalule, J. Kamau, R. Mayala, R. Molo, J. Ogwang, S. Ogwal, W. Otim-Nape, W. Sserubombwe*

National Banana Program, ISAR, Butare, Rwanda: *M. Cyubahiro Bagabe*

National Cereals Research Institute (NCRI), Badeggi, Nigeria: *A. Idowu, B.A.O. Okusanya, A. Uwala*

National Museums & Galleries of Wales, Cardiff, U.K.: *J.C. Deeming, P. Morgan, M.R. Wilson*

National Root Crops Research Institute (NRCRI), Umudike, Nigeria: *A.O. Ano, T.N.C. Echendu, A.A. Melifonwu, S. Orkwor, F. Ogbe, E.C. Nodu, J. Ikoorgu*

National Seed Service, Ibadan, Nigeria: *E. Adegbuyi*

Natural Resources Institute (NRI), Chatham, U.K.: *R. Coker, A. Cook, R. Cooter, J. Cropley, M. Downham, D. Hall, R. Gibson, J. Gilli, I. Gudrups, C. Haines, R. Hodges, A. Julian, L. Kenyon, F. Kimmins, R. Maslen, J. Orchard, W. Page, J.M. Thresh, H. Wainwright*

Nigerian Agip Oil Company-Agip Green River Project, Port Harcourt, Nigeria: *S. Akele, N.D.Onyeaghala*

Nigerian FDA Downy Mildew Task Force, Ibadan, Nigeria: *O.A. Adenola*

Nigerian Federal Department of Agriculture (FDA), Abuja, Nigeria: *Dr. Edache*

NOVARTIS (Ciba-Geigy) Ltd., Basel, Switzerland: *H. Elmsheuser, H.C. van den Maarel, K. Müller*

NOVARTIS-Nigeria, Lagos, Nigeria: *P.N. Ikemefuna*

Obafemi Awolowo Univerity, Institute for Agricultural Training, Moor Plantiation, Ibadan, Nigeria: *B. A. Ogunbodede*

Obafemi Awoluwo University, Ile Ife, Nigeria: *A.E. Akingbohungbe, M.A.B. Fakorede, S.A. Shoyinka*

Old Dominion University, Virginia, U.S.A.: *L.J. Musselman*

ONFARM (NGO), Kisumu, Kenya: *M. Onim*

Orange Free State University, Bloemfoentein, South Africa: *M. Labushagne, S. Loew, M. Wingfield*

Organization of African Unity/Inter-African Phytosanitary Council (OAU/IAPSC), Yaoundé, Cameroon: *N. Nkouka*

Oyo State Agricultural Development Project (OYSADEP), Ogbomosho, Nigeria: *E.I. Bolaji*

Pan African *Striga* Control Network (PASCON), IAR, Zaria, Nigeria: *S.T.O. Lagoke*

Pennsylvania State University, University Park, U.S.A.: *P.E. Nelson*

Plant Protection and Regulatory Services Department, Pokuase/Accra, Ghana: *E. Blay, G.A. Dixon, A.R. Cudjoe*

Plant Protection Research Institute, Pretoria, South Africa: *R. Kfir*

Plant Protection Service, Department of Bacteriology, Wageningen, Netherlands: *J. Janse*

Post Harvest Development Unit, Min. of Food and Agriculture, Ho, Ghana: *T. Ofosu, F. Motte, K. Acquaye, and S. Addo*

Programme on Mycotoxins and Experimental Carcinogenesis Medical Research Council, Tygerberg, South Africa: *W.F.O. Marasas*

Project Planning and Implementation Consultants, Accra, Ghana: *D. Inkoom, O.C. Nkum*

Projet de Gestion des Ressources Naturelles (PGRN), Cotonou, Bénin: *N. Ahouandjinou*

Purdue University, Indiana, U.S.A: *P.M. Hassegawa, L.L. Murdock, R.E. Shade*

Queensland Department of Primary Industries, Brisbane, Australia: *J. Thomas*

Queensland University of Technology, Brisbane, Australia: *J. Dale*

Reading University, Reading, U. K.: *C. Birch, M. Deadman, H. van Emden, S. Gowen, A. Julian, J. Peters, B. Pickersgill*

Research Institute for Plant Protection (IPO-DLO), Wageningen, The Netherlands: *H. Huttinga, E. van Balen, J. Vink*

Rice Research Station, Rokupr, Sierra Leone: *S.N. Fomba*

Santé Maternelle et Infantile, Soins de Santé Primaires, Cotonou, Benin: *E. Gbaguidi*

Sasakawa Global 2000, Benin: *M. Galiba*

Savannah Agricultural Research Institute (SARI) Nyamkpala, Tamale, Ghana: *S. Asante, R. Kanton, K.O. Marfo, A.B. Salifu*

Scottish Crops Research Institute (SCRI), Dundee, Scotland: *B.D. Harrison*

Service de la Protection des Végétaux, Cacaveli/Lomé, Togo: *D. Agounké, A. Biliwa, Y.S. Gogovor*

Service de la Protection des Végétaux, Porto-Novo, Benin: *A. Bokonon-Ganta, M. Bouraima, C. Lawani, S. Saïzonou*

Simon Frazer University (SFU), Vancouver, Canada: *M. Mackauer*

Solok Research Institute for Fruit, Solok, Indonesia: *A. Hasyim*

South African Sugar Experiment Station, Mount Edgecombe, Durban, South Africa: *D. Conlong*

Station de Recherche sur les Cultures Vivrières, Niaouli, Benin: *K. Aïhou, B. Maroya*

Sudan United Mission - Nigeria Reformed Church-branch, Abakaliki, Nigeria: *A. Nwankpuma, L. de Wit*

Texas A&M University, College Station, Texas, U.S.A.: *J.W. Smith Jr.*

Tropical Fruit Research Station, New South Wales, Australia: *N. Treverrow*

Ugandan National Banana Research Programme, UNBRP, Kawanda, Uganda: *W. Tushemereirwe*

United States Department of Agriculture (USDA), Fredrick, Maryland, U.S.A.: *R. French, N. Schaad*

United States Department of Agriculture (USDA), New Orleans, U.S.A.: *P.J. Cotty*

Universidad Autonomo de Mexico, Estacion de Biologia Chamela, San Patricio, Edo. de Jalisco, Mexico: *F.A. Noguera*

Universität Bonn, Bonn, Germany: *R. Schuster, R.A. Sikora*

Universität Frankfurt, Frankfurt, Germany: *G. Kahl*

Universität Göttingen, Göttingen, Germany: *K. Rudolph*

Universität Hannover, Hannover, Germany: *H.-M. Poehling, C. Borgemeister*

Universität Hohenheim, Stuttgart, Germany: *H.H. Geiger, G. Welz, C.P.W. Zebitz, J. Zeddies*

Université de Monréal, Monréal, Canada: *J.G. Pilon*

Université de Nantes, Nantes, France: *A. Fer, P. Thalouarn*

Université de Niamey, Niamey, Niger: *T. Adam*

Université de Yaoundé I, Yaoundé, Cameroon: *A. Ngakou, D. Nwaga*

Université du Bénin, Lomé, Togo: *G. Lawson, Y. Smith*

Université du Québec, Monréal, Canada: *C. Vincent*

Université Laval, Québec, Canada: *C. Cloutier*

Université Nationale du Bénin (UNB), Cotonou, Benin: *B. Ahohuendo, S. Ambaliou, P. Atachi, G. Biaou, D.K. Kossou, A. Odjo*

Université Omar Bongo, Libreville, Gabon: *J. Boussienguet*

Universiteit Gent, Gent, Belgium: *P. Van Damme*

University of Agriculture, Abeokuta, Nigeria: *K. Okeleye, T. O. Tayo*

University of Agriculture, Makurdi, Nigeria: *A. Nwankiti*

University of Alexandria, Alexandria, Egypt: *O. Al-Menoufi*

University of Amsterdam, Amsterdam, The Netherlands: *F. Bakker, A. Janssen, M. Sabelis, L. van der Geest*

University of Buea, Buea, Cameroon: *N.N. Ntonifor*

University of California, Berkeley, U.S.A.: *N. Mills*

University of California, Davis, California: *F. Zalom*

University of California, San Diego, U.S.A.: *M. Chrispeels*

University of Cape Coast, Cape Coast, Ghana: *M. Botchey, J. Kwarteng, Y. Opoku-Asiama*

University of Dschang, Dschang, Cameroon: *J. Foko, I.A. Parh*

University of Florida, Homestead, U.S.A.: *J. Peña*

University of Ghana, Agricultural Research Station, Kade, Ghana: *K. Afreh-Nuamah, S. Quartey*

University of Ghana, Kpong, Ghana: *E.O. Darkwa*

University of Ghana, Legon, Accra, Ghana: *E. Acheampong, R.K.A. Ahiabu, J. Allotey, J.N. Ayertey, I. Egyr, S.K. Offei*

University of Ibadan, Ibadan, Nigeria: *S. Adesinyan, V. Adetimirin, T. Amusa, G.I. Atiri, E.A.J. Ekpo, F.K. Ewete, O.O. Fadina, O. Fagade, A.T. Hassan, T. Ikotun, M.F. Ivbijaro, J.A. Odebiyi, A.O. Oladiran, J.A.I. Omueti O.O. Tewe*

University of Idaho, Department of Plant, Soil, and Entomological Sciences, Moscow, Idaho, USA: *N.A. Bosque-Pérez*

University of Illinois, Urbana, Illinois: *S. Lazarowitz, H.T. Wilkinson*

University of Ilorin, Ilorin, Nigeria: *G. Olaoye*

University of Leiden, Leiden, The Netherlands: *C. van Achterberg, J.J. M. van Alphen*

University of Minnesota, St. Paul, U.S.A.: *B. Lockhart*

University of Nairobi, Nairobi, Kenya: *J.A. Chweya*

University of Natal, Pietermaritzburg, South Africa: *L. Haines*

University of Sao Paolo, Brazil: *G. J. de Moraes*

University of Science and Technology, Kumasi, Ghana: *R.T. Awuah*

University of Science and Technology, Port Harcourt, Nigeria: *L.A. Dan-Kalio, J.A. Osakwe, K. Zuofa*

University of Virginia, Charlottesville, Virginia, U.S.A. *M. Timko*

University of Wageningen, Wageningen, The Netherlands: *J. Bar, M. Dicke, A. van Huis, A. Loomans, D. Peters, A. Polaszek*

University of Wales, Cardiff, U.K.: *M.A. Jervis*

University of Washington, Pullman, U.S.A.: *L.K. Tanigoshi,*

Weizmann Institute of Science, Rehovot, Israel: *J. Gressel*

West Africa Rice Development Association (WARDA), Bouaké, Côte d'Ivoire

West and Central Africa Maize Network (WECAMAN), Bouaké, Côte d'Ivoire: *B. Badu-Apraku*

Winrock International, Abidjan, Côte d'Ivoire: *R. Agbassy-Boni, C. Djedji*

Winrock International, Arlington, Virginia, U.S.A.: *P. Craun-Selka, M.C. Peccoud-Diakité, T. Shah, E. Smith*

World Vision International, Mozambique: *C. Asanzi, V. Parkinson*

Annex 1

Research Projects

1. Short Fallow Systems
2. Agroecosystems Development Strategies and Policies
3. Biological Control and Biodiversity
4. Integrated Management of Legume Pests and Diseases
5. Integrated Management of Maize Pests and Diseases
6. Integrated Management of Cassava Pests and Diseases
7. Improving Plantain- and Banana-based Systems
8. Integrated Management of *Striga* and other Parasitic Plants
9. Improving Postharvest Systems
10. Farming Systems Diversification
11. Cowpea-Cereals Systems Improvement in the Dry Savannas
12. Improvement of Maize-Grain Legume Production Systems in West and Central Africa
13. Improvement of Yam-based Systems
14. Cassava Productivity in Lowland and Midaltitude Agroecologies of sub-Saharan Africa
15. Molecular and Cellular Biotechnology for Crop Improvement
16. Conservation and Utilization of Plant Biodiversity

CGIAR Systemwide and Ecoregional Projects

Ecoregional Program for the Humid and Subhumid Tropics of Africa (EPHTA)

Systemwide Program on Integrated Pest Management (SP-IPM)

Annex 2

Institute-wide logframe

Narrative summary	Indicators by the year 2000	Means of verification	Assumptions
Overall Goal: Increase the well-being of poor people in SSA	• Higher level of food production • Better income and nutritional status of poor people • Reduced drudgery for women	• National and regional statistics and other data	• Political conditions and macroeconomic environment remain stable
Purpose: Through research and related activities, in partnership with NARS and other institutions, develop and deliver technological options to increase food production in a sustainable manner in IITA's mandated zones for the benefit of farmers, other entrepreneurs, and consumers	• Adoptable technologies available and widely used • NARS delivery of technologies increased • Better access to food • Increased gender equity • Increased and sustainable production demonstrated	• NARS and IARC reports • Agricultural and anthropometric statistics • Impact studies	• Financial support to agricultural research and development maintained or increased • Favorable government policies and services • Enabling infrastructures
Outputs: Plant Biodiversity Improved availability and more efficient utilization of plant genetic resources by NARS and other partners	• Volume of germplasm exchange between IITA and research partners increased by at least 5% • Adoption of new breeding techniques and diagnostic tools for germplasm movement in at least 3 countries • Coordination of systematic plant collection and management in at least 5 countries • More breeding populations evaluated and disseminated by NARS	• NARS and IARC reports • Seed-sector reports • Workshop proceedings • NARS cultivar releases	• Countries' willingness to share plant genetic resources
Agroecosystem Development Strategies Functional ecoregional consortia directed at poverty alleviation through sustainable development of targeted agroecosystems	• NARS, IARCs, and ARIs working together in at least 4 benchmark areas in the humid forest and moist savanna of West and Central Africa. • Holistic, participatory research programs operational • Greater awareness of natural resource management for sustainable production increases	• IARC, NARS, and review reports	• All partners remain committed to an ecoregional approach

Narrative summary	Indicators by the year 2000	Means of verification	Assumptions
Musa Systems Integrated production technology developed and tested for plantain/banana-based production systems	• Feasibility of IPM strategies demonstrated in benchmark sites • Improved cultivars tested and released by NARS • Sustainable resource and crop management practices adopted in benchmark sites and by NARS	• Project and NARS reports and publications • Feedback from collaborators • Benchmark site survey reports	• Materials meet quarantine standards • Minimum NARS capacity
Maize-Grain Legume Systems Technologies that increase productivity of maize-grain legume systems in the Guinea savanna in a sustainable manner evaluated and disseminated	• At least 5% of farmers in benchmark areas using technologies which lead to greater and sustainable land productivity, including improved residue management, and use of grain legumes to increase nitrogen fixation • Nutrient-efficient improved varieties of maize, soybean, and cowpea grown by at least 5% of farmers in benchmark areas	• Survey of benchmark areas in collaboration with NARS	• Farmer has stake in long-term productivity • Market can absorb increased production of grain legume crops
Cassava Productivity Improved and adapted cassava germplasm and production practices developed and evaluated in collaboration with NARS for sustainable production and utilization systems	• At least 15 improved genotypes with superior yield performance and acceptable quality recommended for release in at least 6 countries in SSA • Potentially adoptable technologies for improved and sustained production demonstrated in long term on-station trials and in benchmark sites	• IITA, NARS and NGO reports	• Current strength and links with NARS maintained • Links with NGOs developed and strengthened
Yam-based Systems Improved technologies targeted at enhanced productivity of yam-based systems evaluated and disseminated by NARS	• Collaborative trials with NARS on improved technologies conducted in at least 10 countries in sub-Saharan Africa • Farmer participatory evaluation of improved technologies in at least 3 sites in 3 different countries	• NARS and project reports	• Effective networks in yam R & D

Narrative summary	Indicators by the year 2000	Means of verification	Assumptions
Cowpea-Cereals Systems Improved technologies that increase sustainable productivity of cereal/cowpea based cropping systems evaluated and disseminated by NARS	• Farmers in the dry savanna of at least 3 countries are adopting improved cowpea varieties and production systems • Soil nutritional status improved in selected farmer sites	• NARS and IARC reports • Adoption and impact studies	• Market can absorb increased cowpea grain and fodder
IPM Maize Reduced losses of maize to pests and pathogens through the use of IPM technologies	• Research on IPM of maize operational in at least 5 countries • Resistant germplasm adopted by NARS breeding programs in at least 5 countries	• Survey data comparing pre- and post-intervention status of losses in target countries	• Effective links with implementing agencies maintained
IPM Legumes Reduced crop losses demonstrated in farmers' fields through IPM technologies which increase cowpea and soybean productivity in a sustainable manner	• At least 10% of cowpea and soybean farmers in 3 target countries use IPM • Farmers obtain at least 25% higher revenue than those that do not use IPM	• NARS and NGO reports	• Conditions for adoption of IPM technologies remain favorable
IPM *Striga* Sustainable integrated parasitic plant management measures and components evaluated and disseminated	• NARS testing rotation-based integrated *Striga* spp. management in 15 SSA countries • NARS disseminating integrated *Striga* spp. management in at least 5 SSA countries	• Country, IITA and seed production agency reports	• Farmers continue to perceive *Striga* spp. to be problems for which adoption of new behavior/agricultural practices are worthwhile • Market can absorb increased production of and adequate demand for nonhost crops

IPM Cassava Sustainable cassava plant protection technologies developed, tested, and implemented in collaboration with NARS	• National programs in at least 6 countries have the knowledge and technology in biological control, host plant resistance and cultural practices for the control of 4 major pests. • Pest damage reduced by at least 20% for 2 of the major pests targeted in 6 countries, and cassava yield significantly increased in these countries.	• IARC, NARS, and NGO reports	• New major pests do not arise • Good links with NGOs
Biological control Biological control of pests and weeds in farming systems	• At least 1 pest species under biological control • Environmental quality safeguarded	• Socioeconomic and faunistic surveys and impact studies • Pesticide use statistics	• Efficient biological control agents continue to be identified
Improving Postharvest Systems Postharvest technologies to provide utilization options for the food, feed and agro-industrial sectors developed and disseminated in collaboration with NARS	• Increased number of end products • Increased range of technologies in use in collaborating countries • Improved NARS capacity for food systems research	• NARS and IITA reports • Monitoring tours and surveys	• Socioeconomic environment conducive to small business development
Short Fallow Systems Sustainable short fallow management systems developed in partnership with farmers	• Farmers in at least 30 communities in the benchmark areas and pilot sites are testing and evaluating short fallow systems • Farmers in the same 30 communities recognize improved soil conditions	• IARC and NARS reports, • Benchmark and pilot site surveys	• Farmers are receptive to longer-term land management interventions
Farming Systems Diversification New and complementary income generating enterprises developed and evaluated with farmers in benchmark areas	• Farmers in benchmark areas achieve higher productivity and cash incomes through integration of new production enterprises	• IARC and NARS reports • Benchmark site surveys	• Sustained market for enterprise outputs
Biotechnology Molecular and cellular tools and products, for germplasm enhancement and dissemination of IITA mandate crops, available to collaborating scientists	• Crop improvement programs in at least 5 countries in sub-Saharan Africa regularly employ techniques of cellular and molecular biology beyond the 1995 level	• IITA and NARS reports and publications • Training documentation	• Increased support of governments in the region to the use of molecular and cellular tools for improvement of crop plants

Annex 3

Project Planning Matrix: 5. IPM of Pests and Diseases of Maize

Date: January 1999

	Measurable indicators	Means of verification	Important assumptions
Developmental goal			
Reduce pre- and postharvest losses of maize to pests and pathogens in sub-Saharan Africa	Maize losses are reduced in 5 target countries in 10 years starting 1995	Survey data comparing pre- and postintervention status of losses in the target countries	Effective links with NARES and other implementing organizations (IO) are maintained. IOs remain positive in their attitude to IPM and are effective in transferring IPM message to farmers.
Project purpose			
1. Regional implementation projects are facilitated	1. By 2002, 2 regionwide plant protection programs are operational (storage pests, mycotoxins, stem borers)	1. NARES and coordinators reports, workshop proceedings & meeting reports	1. Resources are available for networking activities and there is policy level commitment by the various governments to be involved in regional initiatives.
2. NARES research and dissemination capacity strengthened	2. By 2002 country-specific research underway in at least 4 countries, and an IPM team (consisting of an entomologist, pathologist, & plant breeder) exists in each country	2. NARES annual reports	2. National governments policies committed to strong support to agric. sector.
3. NARES test, adopt, and promote resistant germplasm (from IITA) and use improved infestation/ infection methods to screen their local materials	3. NARES breeding programs in at least 4 countries have resistance germplasm and methods for adaptation of the material to their specific conditions	3. NARES reports, seed increase records, decrease in pests	3. Farmer preferences for varietal characteristics are taken care of by NARs breeders and seed multiplication distribution mechanisms are in place
4. Options for pre- and postharvest integrated management of pest and diseases are expanded	4. By 2002 IPM options available for two key pests/diseases per region	4. IARC and NARES reports	4. Socioeconomic thresholds for adoptability are understood (linkage with Farming Systems Diversification project)

	Measurable indicators	Means of verification	Important assumptions
Outputs/results			
1. Knowledge of pest and disease systems in pre- and postharvest maize	1. Regional databases and inventories and decision support tools (e.g., models)	1. Journal publications, concurrence of data predicted vs. observed	1. Effective research links with NARES and IARCs in the region; Biological constraints prioritized at NARES level
2. Disease and insect resistant germplasm (pre- and postharvest)	2. *Production and delivery systems* which are quantitatively better than natural infestation/infection levels and are sustainable and affordable to IARCs and/or NARES breeding programs Comparative damage levels across accessions showing a quantitative improvement in varietal performance when infested/infected with known levels of a pest or pathogen.	2. *Monographs, methods* demonstrations & training guides, reports from training workshops, publications IITA archival reports	2. Labs for mass rearing/inoculum production are adequate; sites with high inoculum pressure for testing germplasm are available; NARES resources for research, testing, and multiplication of breeder seed (RTM) are adequate; farmers are willing to adopt new varieties
3. Biological control and habitat/store management options	3. Agent parasitizes or infects the target maize pest or pathogen in *screenhouse and field*, and pre-introduction safety testing on host specificity/toxicity has been done for at least 3 biotic targets by 2002. On-farm trials have demonstrated the effectiveness of at least two feasible habitat/store management tactics in reducing pest populations and losses.	3. Publications	3. Effective agents can be found; import and release permits are granted; management tactics compatible with current socioeconomic constraints can be identified
4. Collaborative development and testing of IPM strategies for pre- and postharvest maize	4. Comparative advantage in reducing losses of new strategies over current farmer practices have been tested in benchmark sites and NARES (in at least 5 countries) are trained in systems analysis research.	4. On-farm participatory research, publications with NARES partners on the analyses of maize production systems.	4. NARES resources for RTM are available; socioeconomic context remains favorable for adoption of more sustainable crop protection strategies (i.e., IPM)

Annex 4

Research Highlights

IITA's work is organized around 16 multidisciplinary research projects. Some projects focus on production systems for specific crops or crop combinations, in some cases for a specific agroecological zone. Others are thematically oriented, cutting across commodities and agroecological zones.

IITA also serves as the convening organization for two international programs of the CGIAR: the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa and the Systemwide Program for Integrated Pest Management.

The following section presents the goal and research highlights of each IITA project for 1998. The summaries are not exhaustive of the work begun or completed during the year; rather, they describe some key scientific results and are intended to give readers an idea of the breadth of research themes and problems being investigated by IITA scientists.

Project 1 Short fallow systems

Goal

To increase farm productivity and arrest resource degradation due to land-use intensification through sustainable short-fallow systems.

Highlights

- A survey of use of organic and inorganic inputs by 200 farmers in two villages in the northern Guinea savanna (NGS) showed widespread use of inorganic fertilizer (> 90% of farmers) though in small quantities (> 80% of fields received less than half of the recommended 120 kg N/ha), and little use of organic inputs (< 30% of farmers).
- About 355 seedlots of herbaceous legumes (*Mucuna pruriens*, *Aeschynomene histrix*, *Centrosema brasilianum*, *C. pascuorum*, *Lablab purpureus*, *M. pruriens utilis*, *Stylosanthes guianensis*, and *Stylosanthes hamata*), totaling over 300 kg, were distributed to IARCs, NARS, and NGOs in and outside Nigeria.
- The Cover Crops Information Center for Africa produced 2 newsletters that were each distributed to approximately 300 readers, mostly in Africa. Version 2.1 of LEXSYS, the decision support system for integration of herbaceous legumes into tropical farming systems, was sent to at least 30 users.
- A monograph on *Mucuna* cover cropping, with contributions from ILRI and WARDA scientists, was distributed to approximately 300 readers.
- A multilocational trial studying the impact of fertilizer N, organic material N, and their mixture showed that the combination of residue and urea both applied at 45 kg N/ha yielded similar amounts of maize as the treatment where urea was added at 90 kg N/ha.
- In a herbaceous legume-maize rotation experiment on a Ferric Acrisol with a P-sorbing petroferric phase in the NGS of Nigeria, rock P applied to *Mucuna* and *Lablab* at a rate of 90 kg P/ha in 1997 led to an 80% and 38% increase in maize yield in 1998, respectively, compared with no added rock P. The qualities and quantities of different legume residues (*Mucuna cochinchinensis*, *Cajanus cajan*, *Tithonia diversifolia*, and *Ricinus communis*) affected the soil P availability and maize yields.
- Sampling of *Mucuna* residue during the dry season along a transect in Benin Republic showed that residue disappearance is approximately 0.5 t/ha in the NGS. In the derived savanna, total mucuna residue increased during the same months at a nondegraded site and remained stagnant at a degraded site. The results are very useful for modeling and systems design.
- In trials in the 6 benchmark villages in the humid forest zones in Cameroon, cassava responded to K additions, but yields were

suppressed by both P and N additions. Sulfur had little effect, but NKS and PKS gave yield increases of over 2200 kg/ha compared with the control.

- A cost benefit analysis of technologies for *Imperata* management in the derived savanna of southern Benin indicated that net benefit return was highest in plots treated with glyphosate without cover crop. Plots planted to *Pueraria* and handweeded 4 times had a higher net revenue return than *Pueraria* plots treated with glyphosate. Plots that were handweeded and planted to *Mucuna* + *Pueraria* yielded the lowest revenue and had the highest cost of production per hectare.
- Ten *Mucuna* accessions were evaluated as possible candidates for the management of *Imperata cylindrica*. Twenty weeks after planting *Mucuna*, *Imperata* dry matter was significantly lower in plots seeded to *M. cochinchinenesis* and *M. veracruz* (white). *M. ghana* and *M. rajada* were ineffective against *Imperata* because they senesced midseason and did not leave any mulch on the soil surface.
- Field studies were conducted to evaluate the effect of green manure (*M. pruriens* var. *utilis*, *M. cochinchinensis*, *Centrosema pubescens*, *L. purpureus*, and *Pueraria phaseoloides*) and food cover crops (cowpea, egusi melon, sweetpotato) on *Imperata*, maize, cassava, and yam. Cover crops reduced *Imperata* shoot dry matter by 73–90% and rhizome dry matter by 32–74%, respectively, relative to the unweeded control. Maize and cassava yield was not affected by cover crops while yam yield was reduced (34–64%) by competition from cover crops.

Project 2

Agroecosystems development strategies

Goal

To guide ecoregional research and policies directed at poverty alleviation and sustainable development of agroecosystems in subhumid and humid zones of West and Central Africa.

Highlights

- Ex-post impact of the classical biological control of cassava green mite indicated the net present value at a discount rate of 10% between 1983 and 1997 to be about US$14 million for Benin, US$117 million for Ghana, and US$170 million for Nigeria.
- Social impact assessment confirmed that improved soybean varieties raised farmers' standard of living and children's nutrition in the southern Guinea savanna of Nigeria.
- Preschool children had better nutritional status in cassava-producing areas of Nigeria because of higher sales of and incomes from cassava.

- In the derived savanna benchmark, one cropping season of *Mucuna*-based fallow was shown to increase the technical efficiency of production factors, farm incomes, and returns to land and labor.
- In West and Central Africa, agroforestry-based systems and maize production versus imports benefited from recent currency devaluation, subsidy removal, and price liberalization.
- Estimates of environmental parameters and systems profitability in the forest margins benchmark indicated that increasing cropping diversity in plantain systems would provide food security while preserving the environment.
- Four recommendation domains were identified from a framework for characterizing farmers for impact-oriented research in the Guinea savannas.
- A study in relatively land-scarce labor-abundant areas of the forest margins benchmark identified new cropping sequences for increased revenue, more equitable intrahousehold income distribution, and higher level of soil protection.
- A detailed soil survey led to the selection and characterization of 24 representative farmers' fields for technology testing based on soil types in the derived savanna benchmark.
- After 3 fallow types, weed composition in the least intensified area of the forest margins benchmark was 82–94% dicotyledons and 6–17% monocotyledons.

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. Therefore it develops and implements biological control, including microbial control, of pests and weeds in farming systems, conducts biodiversity studies, and supports biosystematics.

Highlights

- A virulent isolate of the fungus *Beauveria bassiana* was selected as a biopesticide against the banana weevil *Cosmopolites sordidus*, and applied to the soil in a formulation based on oil palm kernel. The mortality of weevils released in the soil 14 days after application reached 80% 35 days after release.
- The reference collection of plant epidermis comprises more than 150 plant species. The collection permits the study of the diet of many phyllophagous insects living in the agrosystems from the humid savanna area.

- The general survey on grasshoppers from Benin is nearly completed; 127 species are now recorded.
- The LUBILOSA *Metarhizium* product was included on 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 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.

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 that increase cowpea and soybean productivity in a sustainable manner.

Highlights

- Advanced breeding lines of cowpea selected for low levels of resistance to *Maruca vitrata* were evaluated by collaborators in five countries. The best accessions, IT95M-21 in Zaria and IT95M-239 in Kano, gave grain yields of 462 and 662 kg/ha, respectively, under high natural infestations. These represent increases of more than 370% over local check varieties.
- One cross-compatible wild *Vigna* (TVnu 151, *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*) have been identified as potential genes for use in the transformation of cowpea for resistance to the pod borer *Maruca vitrata* and *C. tomentosicollis*.

- Systematic investigation of the legume entomofauna in southern Cameroon revealed a parthenogenetic strain of a thrips parasitoid very similar to the one found in India, and tentatively identified as *Ceranisus femoratus*. *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 lab and revealed to be quite effective in killing all stages of *M. sjostedti*.
- On-farm trials in Benin, Ghana, and Senegal revealed that neem applications (15 kg leaves/10 l water) could double cowpea yields.
- In Benin, participatory trials with aqueous applications of pawpaw leaf 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 semiselective 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.

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. In collaboration with NARES, IITA scientists identify major pest and disease constraints in maize production and storage, research sustainable integrated pest management (IPM)-based solutions, which include resistant varieties, forms of biological control, and habitat management options, and provide support for their implementation; and through collaborative activities build national and regional capacity to carry out these tasks independently.

Highlights

Preharvest maize

- Several exotic and East African species and strains of natural enemies of stem borers were received from ICIPE, one of which was released and established in Benin on *Sesamia calamistis*. Another strain which parasitizes both *S. calamistis* and *Busseola fusca* was introduced into Benin. 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 insects are found in plants infected with *F. moniliforme.*
- Trap plants that are too attractive can have negative effects. Data show a spillover of stem borers attracted to trap plants on to adjacent maize plots.

Postharvest maize

- A postharvest CD-ROM, a user friendly simulation of the grain store environment showing population dynamics of *Prostephanus truncatus*, *Sitophilus zeamais*, and *Teretriosoma nigrescens*, was developed and will be released in 1999. The CD will be a repository for data and a training tool. GIS and remote sensing are to be used to track and predict distribution of the larger grain borer (*P. truncatus*).
- New maize germplasm has been imported to improve 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.
- Work has started to establish on-farm trials and cost/benefit analyses on crop management practices to reduce risk of aflatoxin contamination. Medical impact studies will run concurrently.
- An IITA/CABI workshop on entopathology 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

Cassava productivity increased and sustained 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. *Typhlodromalus aripo* has shown excellent establishment and spread (up to 200 km per season) in West Africa, and parts of Central and East Africa, and is now found in 16 countries.
- Cost/benefit studies showed that biological control of CGM has resulted in farmer benefit of US$144, US$98, and US$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.
- Brazilian isolates of the fungus *Neozygites floridana* have been successfully released on experimental scale in southern Benin for the control of CGM.
- Biotechnological techniques were used to map the distribution of cassava mosaic geminiviruses, and showed that the current expansion of the cassava mosaic 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 found for protection against severe isolates of UgV in plants already infected with mild CMV strains.
- The identities of 4 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 *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 cassava bacterial blight (CBB) impact on 22 cassava varieties in 3 ecozones [forest–savanna transition (FST), dry savanna (DS), and rainforest (RF)], TMS 30572 showed the highest yield stability followed by I8800158, I8900854, and I8900914. However, in 1994 TMS 30572 suffered up to 50% and 38% yield losses in DS and coastal FST zones, respectively.
- 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 is destroyed with a 30-min hot water treatment at 60 °C, or a 4-day hot air treatment at 65 °C.

- Field and laboratory experiments and observations showed that cassava is a major component of the diet of the variegated grasshopper not only during the early part of the dry season, but also during the latter part and during the rainy season.
- In Uganda, root-knot nematode damage was associated with shortened crop rotation, and high root-knot nematode populations reduced the establishment of cassava cuttings.
- Five termite genera were identified causing damage to cassava in Zambia of which 3, *Microtermes*, *Ancistrotermes*, and *Odontotermes*, were consistently associated with severe damage. Losses ranged from 3 to 35% and were least in the local improved selections Bangweulu and Nalumino.
- Bench and on-site training courses in cassava pest management for NARS scientists were conducted. PhD students from various African countries began their research on CBB (3), root rot pathogens (1), and CGM (3). Seven postgraduate trainees were also involved in research on cassava pests.

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

- 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 3 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 were profitable over a 3-year period, resulting in returns of US$1300 per hectare, equivalent to US$475 compensation when compared to farmers' traditional practices.

- *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 5 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. Taste panel tests of such hybrids demonstrated that these have acceptable taste and texture when prepared in the traditional manner.
- Eleven triploid and 24 diploid plantain/banana hybrids were selected at the Onne station based on good bunch and agronomic traits and black sigatoka resistance.
- 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 BSV 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 publication entitled Striga *Research Methods: a Manual* on our web site resulted in over 222 'downloads' of the 1.34 Mb file in the first 2 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 very good agronomic characteristics from a wide range of maturities were identified that will be very effective at reducing the number of *S. hermonthica* seeds in the soil. These are available for testing.
- Early-maturing white-endosperm maize varieties 98SynWEC and EVDT97STRC1 and intermediate-duration maize hybrids showed high level of tolerance to *S. hermonthica* and high grain yield (6–9 t/ha) in Côte d'Ivoire and Burkina Faso.
- Test crosses with S3 lines, extracted from a backcross population derived from *Zea diploperennis* and three IITA inbred lines, revealed a large number of experimental hybrids that outperformed—for both yield and reduced *S. hermonthica* emergence—the standard tolerant hybrid. Similar results were obtained using new inbred lines derived from tropical populations.
- Chromatographic analyses of root exudates of different plant species and cultivars showed 4 common chemical compounds and a number of plant-specific compounds active in stimulating germination of *S. hermonthica* seeds.
- Studies on *S. gesnerioides* seeds suggested a plethora of specific stimulant receptors among isolates of *Striga* spp., and specific germination stimulants among host and nonhost plants.
- Studies in collaboration with the University of Virginia resulted in identification of a common molecular marker for *S. gesnerioides* susceptibility in 4 unique cowpea lines.
- Use of a simple screening procedure for ethylene-producing bacteria resulted in isolation of several nonpathogenic strains that are competent with both legume rhizospheres and nitrogen-fixing bacteria.

Project 9

Improving postharvest systems

Goal

To increase the income-generating capability and improve the nutritional status of farmers, processors, and consumers in the rural and urban communities of sub-Saharan Africa.

Highlights

- Screening and characterization of tropical germplasm to determine genotype variability for micronutrients was initiated. A total of 110 inbred lines were screened for iron and zinc levels: iron content ranged from 14.96 to 174.23 ppm and zinc ranged from 11.56 to 100 ppm. Twenty improved varieties were screened for total carotenoids content, which was found to range from 100 to 196 ppm.
- Fourteen new *Striga*-tolerant maize were characterized for physical, chemical, and pasting properties. Some varieties had characteristics comparable to the widely grown *Striga*-susceptible variety TZB-SR,

while others were similar to the *Striga*-tolerant commercial hybrid OBA SUPER-1. One of the new varieties had a protein content of 11.2%, compared to under 10% for the widely grown local and commercial varieties.

- The private sector began adopting high quality cassava flour (HQCF) as a raw material for processing into secondary products (biscuits, noodles) in Madagascar, Nigeria, Tanzania, and Uganda. The HQCF process has also been introduced in 6 other countries.
- A starch demand study in Uganda revealed a demand of 1500–2000 t/year with a value of US$1–1.5 million. Thus there is a high potential for small-scale processing of cassava into starch. The survey also revealed that cassava flour was sometimes substituted for starch, creating a new opportunity for HQCF.
- The use of soy milk to make tofu or soy cheese is expanding in northern Nigeria. A novel and cheaper method to coagulate soy milk has been found that uses an extract of the African star apple. Tofu made by the new method is as acceptable as the product obtained by conventional methods.
- A multidisciplinary study was carried out in Ososa, a village in southern Nigeria where 30 years ago the consumption of the popular fermented cassava food *gari* had been implicated in the etiology of tropical ataxic neuropathy (TAN). Cases of TAN were still prevalent in Ososa, and the diet was still dominated by *gari*, but dietary cyanide exposure was low, and there was no difference in exposure between TAN patients and healthy controls. It was concluded that *gari* consumption was not a causal factor for TAN and that cassava-processing methods used in Ososa reduced the cyanogen content to safe levels.
- Training in the use of improved postharvest technologies was provided to some 2000 staff of extension systems, NGOs, and the private sector. Regional workshops sponsored by WECAMAN and EARRNET were conducted in crop processing and utilization, product development, and equipment manufacturing. New recipe books for cassava and soybean were published and a short movie entitled *Manger l'igname autrement* (*Eating yam differently*) was produced.

Project 10

Farming systems diversification

Goal

To develop, in collaboration with NARES and farmers, new, diversified, and complementary income-generating enterprises in West and Central Africa.

Highlights

Multistrata systems

- In the forest margins benchmark of southern Cameroon, the returns per hectare and to labor of the mixed groundnut system were 36% and 72%, respectively, of the diversified multistrata cocoa system. An integrated management strategy is being developed to increase the productivity of the different land use systems.

Mixed farming systems

- Crop residues can be used as a soil ameliorant or as manure from livestock. A study indicated no significant differences between using crop residues directly or returning it in the form of manure.
- A multisite trial comparing natural and improved fallow (*Lablab purpureus*) as a relay crop in a continuous cropping system, both with and without livestock grazing, showed that maize and fodder yields were higher in the improved plots. Sheep and cattle on improved plots gained more weight than on natural fallow. Grazing also had positive effects on subsequent maize yields, and this was to some extent reflected in soil chemistry.
- Sheep stocking rate (64 or 168 sheep/ha) on *Imperata cylindrica* associated with *Mucuna cochinchinensis* was evaluated as part of an integrated approach for the management of *Imperata* in crop–livestock systems. Four weeks after introduction of sheep, *Imperata* and dry matter were not reduced significantly by grazing. The percentage ground cover of *Mucuna* was significantly reduced at the higher stocking rate. At the end of the grazing period sheep live weight had increased at the low stocking rate but decreased at the high stocking rate.
- 58 farmers participated in a study to assess the feasibility of rearing pigs in enclosures under village conditions. The pigs were fed crop residues and surplus subsistence crops. About 94% of the farmers completed the 7-month feeding program; half (52%) of them have continued this system on their own. Parallel trials showed that pig manure collected from enclosures can increase the production of indigenous leafy vegetables 5-fold.

Project 11

Cowpea–cereals systems improvement in the dry savannas

Goal

To develop adaptable crop varieties and agronomic practices for the Sudan savanna and Sahel that will increase the total productivity of dominant farming systems. The project integrates research by scientists from IITA, ILRI, and ICRISAT who are working on grain legumes, cereals, and livestock in the dry savannas of West Africa. Research institutes in Nigeria (IAR, ABU) and Niger (INRAN) are also active members.

Highlights

- About 290 local cowpea landraces were evaluated at 3 locations and 5 were selected for further improvement; 9 are already being improved for resistance to diseases, insect-pests, and *Striga* by backcrossing.
- New grain type and dual-purpose cowpea varieties combining resistance to diseases, insect pests, and *Striga* were developed with 50–150% higher yields compared to local varieties. Some of these varieties yielded 500–900 kg/ha even without insecticide sprays.
- Improved cowpea varieties combining resistance to aphids, bruchids, bacterial blight, *Striga*, and drought tolerance were developed for the Sahel with grain yields over 1 t/ha and fodder yields over 3 t/ha. Also, new varieties were developed for dry season cultivation with grain yield of over 2.5 t/ha and fodder yields over 3 t/ha.
- In collaboration with ICRISAT, ILRI, the Nigerian Institute for Agricultural Research and the Kano Agricultural and Rural Development Authority, on-farm participatory evaluation of an integrated crop–livestock package involving improved cowpea and sorghum varieties, cropping systems, and livestock management with efficient nutrient cycling was conducted. The improved package was 100–300% more productive than local systems.
- An IITA/ILRI joint study indicated significant genetic variability for in sacco digestibility of cowpea fodder. Feeding trials of cowpea residues to small ruminants indicated IT81D-994 to be the best variety in respect of dry matter intake, digestibility, and net weight gain.
- Screening of 60 cowpea varieties under very low fertility revealed significant variability: IT96D-772 gave 1.5 t/ha grain yield and 1.3t/ha fodder while other varieties yielded below 500 kg/ha. The improved variety IT86D-715 performed best in low phosphorus soil.
- A pin board-root box method was developed to study variability of root characteristics in cowpea. Major genetic differences were observed for root distribution area and root length density.

- Shading of cowpea was observed to be 30% more under intercropping with sorghum than millet. Also, shading from local sorghum was 20% more than that from improved sorghum. IT89KD-349 cowpea was found to be the most shade-tolerant.
- The improved soybean variety TGx 1448-2E was found to be highly adapted to the Sudan savanna and it is gaining good popularity with farmers.
- The two extra-early maize varieties 95 TZEE-W1 and 95TZEE-Y1 showed best adaptation in the Sudan savanna.
- Farmer to farmer diffusion of improved cowpea seed was found to be quite effective. With 3 kg seed given to each of 36 farmers in 1997, over 300 farmers grew improved cowpea in 1998 and produced about 11 tonnes of seed.
- A total of 60 new breeding lines were distributed for regional trials in West Africa and 130 breeding lines were distributed for international trials.

Project 12

Improvement of maize–grain legume systems in the moist savanna of West and Central Africa

Goal

To enhance the productivity of maize–grain legume systems by developing crop varieties and management practices that promote efficient and sustainable use of resources and maximize synergies among components of the systems.

Highlights

- Two early, drought-tolerant varieties with white and yellow grain, and two white and yellow extra-early varieties developed from elite maize populations in 1997 showed outstanding performance in WECAMAN multilocational trials.
- Seven early, white maize inbred lines resistant to streak and tolerant to *Striga hermonthica* and drought have been developed from the variety 86 Pool 16 DT, following 6 cycles of inbreeding and selection under artificial *Striga* infestation.
- Multilocational trials validated the high yields (8–9.5 t/ha) obtained in the previous year from newly generated white- and yellow-grained maize hybrids of intermediate maturity.
- New, full-season maize inbred lines were evaluated in hybrid combinations in the Guinea and Sudan savannas and the midaltitude ecologies of Nigeria. Some lines generated hybrids with up to 28% higher average grain yield than the commercial hybrid check.

Research Highlights

- The African Maize Stress Project provided funds to national breeding programs in 6 countries in West and Central Africa to develop sites for screening for tolerance to drought and low N, and *Striga* resistance. Adapted varieties with improved stress tolerance will be generated through multilocational testing and enhanced exchange of germplasm between the national breeding programs, IITA, and CIMMYT.
- Twenty improved open-pollinated maize varieties, 20 hybrids, and 20 local varieties collected from the drier parts of Nigeria were compared under controlled moisture stress during the dry season. The best improved open-pollinated variety produced 29% and 20% higher grain yield than the best local variety under optimum moisture supply and stress conditions, respectively. The yield of the best hybrid was 78% greater than that of the best local, and 49% greater than that of the best improved open-pollinated variety under severe drought stress.
- Soybean lines and herbaceous legumes showed substantial genotypic variation in response to phosphorus deficiency. Varieties with efficient use of phosphorus could reduce requirements for fertilizer inputs by farmers.
- Labor and gender implications for postharvest processing of new soybean varieties resistant to pod-shattering were investigated in the northern Guinea savanna (NGS) of Nigeria. The improved variety TGX-1448 gave a 21% yield advantage over the farmers' variety. Women represented about 74% of the total labor for processing activities. No differences were found in labor inputs required for threshing the improved and the local varieties for either men or women.
- Two new improved cowpea varieties, IT95K-1072-52 and IT95K-52-34, gave between 1300 and 2100 kg/ha grain yield compared to the local variety which yielded 800–1200kg/ha at 3 locations in the moist savanna of Nigeria. The new varieties have combined resistance to major humid zone diseases including *Ascochyta*, bacterial blight, *Septoria*, and scab.
- On-farm trials were conducted in degraded fields in the NGS to evaluate the productivity of legume–maize double cropping systems. The total legume and maize grain yield of the double crop was compared to a full-season maize crop fertilized with 0–90 kg N/ha. The soybean–maize and the cowpea–maize double cropping systems produced similar grain yields to the full-season maize at 90 kg N/ha, which yielded 1.0 t/ha. The combined application of high quality (cowpea residue) and low quality (5 t/ha rice husks) organic amendments had a synergistic effect that increased maize grain yield by 50% in comparison to the cowpea/maize system.

Project 13

Improvement of yam-based systems

Goal

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

Highlights

- Analysis of the dynamics of cropping systems in yam-growing areas was completed using data from about 1300 agricultural development project cells in the middle belt agroecological zone of Nigeria.
- Economic returns from growing yams were estimated from a sample of 450 farmers in the low-intensification yam growing area in the western yam belt of Nigeria. Yam was found to be a major cash crop that can yield more than US$2000 gross margin per farmer. Despite the high labor cost (more than 70% of the total), yam is a highly profitable business with an average benefit/cost ratio of 2.98. Analysis by gender indicated that women had a higher benefit/cost ratio (women 3.43, men 2.94), fewer marginal yam growers, i.e., with a benefit/cost ratio below 1 (women 13.5%, men 21.4%), and more high performing yam growers, i.e., with a benefit/cost ratio above 2 (women 63.5%, men 49.4%).
- A simple nutrient balance model was used to estimate soil N and K depletion in yam production within 2 *Gliricidia sepium* agroforestry systems. The model predicts need for N and K fertilizer when *G. sepium* mulch is produced in the same field with yam, and for K fertilizer even when the mulch is carried from another field.
- Seven high-yielding and pest-resistant varieties of white yam (*Dioscorea rotundata*) and 10 of water yam (*D. alata*) were cleaned of pathogens and certified for international distribution. About 15 000 minitubers were distributed to NARS collaborators in 5 countries. Over 7098 in vitro plantlets were delivered to collaborators in 6 countries. Water yam was distributed internationally for the first time.
- Eleven hectares of land were planted to local yellow yam (*D. cayenensis*), water yam (*D. alata*), and introduced white yam (*D. rotundata*) varieties using the minisett technique at the Sendusu farm of ESARC and the Namulonge Agricultural and Animal Production Institute (NAARI). Varieties selected for good tuber yield and quality were given to farmers for on-farm evaluation. They confirmed most of the on-station results about taste of the varieties, and additional requests have since come in for white yam varieties.
- 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, Ebonyi, and Rivers States in Nigeria

plants established from hot water-treated seed yams performed better than those established from standard farmers' planting material.

- In a survey of viruses infecting yams in the major yam growing areas of Ghana, yam mosaic potyvirus (YMV) was the most commonly found followed by *D. alata* potyvirus (DAV). YMV was found more often in *D. rotundata* than *D. alata*, which was more susceptible to DAV.
- One new virus has been fully characterized and diagnostics 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's groups, agricultural extension workers, grassroot opinion leaders, and politicians participated in training activities on yam production at IITA/ESARC, Uganda. At training sessions farmers received planting materials of both local and introduced yams for planting.

Project 14

Cassava productivity in lowland and midaltitude agroecologies of sub-Saharan Africa

Goal

To develop, evaluate, and promote improved and adapted cassava germplasm for the lowland and midaltitude agroecological zones of sub-Saharan Africa, and to develop agronomic and other practices to ensure sustainable cassava production and utilization. Interaction with national programs is fostered through long-established links in West and Central Africa, two root crop research networks (EARRNET and SARRNET) covering East and Southern Africa, and cassava research at the Eastern and Southern Africa Regional Center (ESARC) in Uganda.

Highlights

- Landraces from West Africa have provided new sources of resistance to cassava mosaic disease (CMD) and cassava green mite. Their genetic relationships have enabled efficient utilization for maximization of heterosis and hybrid vigor.
- Hybridization between 2 low cyanide cultivars and a *Manihot tristis* accession has provided 6000 true seeds for improvement of cassava for high storage root protein content.
- Improved genotypes incorporating multiple pest and disease resistance, early plant growth vigor, high foliage yield, appropriate plant architecture, early bulking storage roots with high dry matter,

low cyanide, high carotene content, good cooking quality, ease of peeling, and good root shape have been developed for a range of agroecologies including the moist and dry savannas. About 367 improved genotypes including 14 selected African landraces with their seed populations are available for international distribution and testing under specific local conditions.

- An additional 45 improved genotypes were regenerated from meristem culture and cleaned for viruses; 23 have been certified and the Nigeria Plant Quarantine Service is observing 22 for certification.
- About 16800 plantlets from 320 genotypes were distributed to NARS collaborators in 14 countries. In addition, a total of 227650 seeds from 1143 families of broad-based and special trait populations segregating for pest/disease resistance, high yield and dry matter, and culinary quality were distributed to 12 national programs in sub-Saharan Africa.
- In providing germplasm adapted to the midaltitude and lowland agroecologies of East and Southern Africa, a total of 7100 clones were evaluated in various regional trials in Uganda and Kenya. Clones with desirable characteristics (low to medium CNP, 25–45% dry matter, and 25–70 t/ha storage root yield) were identified. The local cultivar Bao and the popularly grown improved cultivar Migyera, used as checks, produced 10% and 20–25 t/ha, respectively.
- Sourcing from the broad-based germplasm of IITA, Tanzanian NARS and SARRNET scientists have identified an early bulking and drought-tolerant cultivar HBL 95/05 producing 39 t/ha storage roots in 12 months, within the highland and semiarid zone of Dodoma (655 mm of rainfall per year).
- Agronomic and nutritive value indices of storage root and foliage have been shown to be important criteria for selection of dual-purpose cassava for smallholder crop–livestock farming systems in collaborative work with ILRI.
- To combat the threat to cassava production in Western Kenya due to the spread of the Uganda variant of CMD, 16.3 acres of IITA-derived CMD-resistant varieties (SS4, Migyera) were established in 4 primary sites in collaboration with NGOs, extension services, and farmers to feed into more secondary and tertiary multiplication sites.
- Cassava rapid multiplication courses were conducted with World Vision International in Angola, Liberia, and Mozambique, and with the Danish International Development Agency in Mozambique, training 116 researchers and technicians.

Project 15

Molecular and cellular biotechnology for crop improvement

Goal

To apply molecular and cellular tools to complement and increase efficiency of conventional breeding and diagnostic techniques in the genetic improvement and dissemination of germplasm. The project makes molecular and cellular tools and new products available to collaborating scientists working on IITA's mandated crops.

Highlights

- Cryopreservation of yam and cassava meristems resulted in 25% and 80% recovery rate, respectively.
- Through manipulation of culture media, daylength, and light intensity, aerial tubers were obtained from in vitro cultures of *Dioscorea rotundata* for the first time.
- Putatively transformed yam shoots were obtained by injecting meristems with agrobacterium carrying herbicide and antibiotic resistance genes.
- Partial clones for 4 plant defense response genes, i.e., thionin, phenylalanine ammonia lyase (PAL), chalcone synthase (CHS), and the soybean disease resistance gene analog (RLG1), were cloned from African yam bean and cowpea.
- For the first time, a molecular genetic linkage map was developed for *D. rotundata*.
- Random amplified polymorphic DNA (RAPD) markers linked to A and B genome sequences in *Musa* were identified.
- Monoclonal antibodies were used to detect East African cassava mosaic virus (EACMV) in Cameroon, Nigeria, South Africa, and Togo.
- Specific primers were designed for the detection of African cassava mosaic virus (ACMV), EACMV, Indian cassava mosaic virus, and the Ugandan Variant. These primers were used to detect mixtures of ACMV and EACMV in Nigeria and Togo. General primers were also designed for the detection of geminiviruses. The complete genomes of cowpea golden mosaic virus and lima bean golden mosaic virus were sequenced and confirmed as new geminiviruses.
- A TAS-ELISA and IC-PCR were developed and monoclonal antibodies were produced for the detection of banana streak virus.
- Genetic diversity and phylogenetic relationship in tropical rhizobia were established using RAPDs.
- Specific RAPD markers were identified to distinguish different strains of brachonid larval parasitoids.

- RAPD analysis of bruchid populations showed that different types were present in Nigeria.
- About 51 isolates of *Collectotrichum*, the causal agent of anthracnose in yams, were analysed and distinguished.
- Technical support in setting up a tissue culture laboratory was provided to NARS in the Democratic Republic of Congo and Nigeria. Attachment training (2–6 weeks) in tissue culture of root and tuber crops was provided to 3 NARS staff. On-site training was provided in Zanzibar.
- IITA contributed to a regional training course in plant cell and tissue culture in collaboration with the United Nations University and University of Legon in Ghana.

Project 16 — Conservation and utilization of plant biodiversity

Goal

To improve the conservation and utilization of plant biodiversity to promote sustainable food production in sub-Saharan Africa. This goal is achieved through enhanced collection, conservation, and characterization of selected African food crops and related species, studies on genetic diversity, development of source germplasm, and exchange of disease-tested planting materials with research partners.

Highlights

- New accessions (245) of cassava germplasm were collected from many different ecologies in Cameroon, using the in vitro culture method. Also 203 yam accessions were successfully transferred to the in vitro genebank, bringing the total number in the in vitro yam collection to about 1900 accessions.
- Genetic diversity of 80 accessions of *Dioscorea bulbilfera* from 6 countries in West and Central Africa was assessed using 50 phenotypic descriptors and 9 random amplified polymorphic DNA (RAPD) markers.
- Amplified fragment length polymorphic (AFLP) markers have been established for the characterization and identification of yam, while genotype-specific restriction fragment length polymorphic (RFLP) markers have been established for use in *Musa* characterization.
- Genetics of resistance to yam mosaic potyvirus (YMV) and resistance to anthracnose disease were studied. The YMV resistance in the *Dioscorea rotundata* landrace TDR 92-2 is controlled by a single recessive locus and the inheritance of resistance to anthracnose in *D. alata* accession Tda 95/00328 is governed by a single dominant gene.

- Over 12000 accessions of cowpea were planted in Mokwa, Nigeria for evaluation for resistance to aphids, flower thrips, *Maruca*, and pod sucking bugs and for incidence of cowpea viruses.
- New maize inbreds, open-pollinated varieties and hybrids of intermediate maturity, have been developed in Côte d'Ivoire. Many of them have resistance/tolerance to *Striga*, drought, and lodging in addition to resistance to major fungal and viral diseases. Seeds of some of these materials have been provided on request to NARS scientists in Burkina Faso, Cameroon, Côte d'Ivoire, and Mali.
- The database management system for documentation and retrieval of germplasm information, GERMSYS, has been migrated to the Windows platform using Foxpro.
- The available elite germplasm and selected landraces of cassava for international distribution have been characterized and catalogued and the data have been computerized.
- A study showed that some yam pollens remained viable after storage for 2 years at -20°C or -80°C. The pollens that had been stored at -80°C for over 1 year could fertilize female flowers with a 70% success rate.
- About 1200 samples of many crop and plant species conserved in IITA's genebank were distributed to NARS researchers in over 20 countries. Large quantities of seeds and genotypes of IITA's breeding lines and selected elite germplasm were sent to many countries throughout the world, particularly in Africa.
- Six new accessions were acquired from the Fundación Hondureña de Investigación Agraria, 2 diploids, 1 triploid and 3 tetraploids.
- Two triploid hybrids were selected from crosses between diploid parents, demonstrating the feasibility of sexual polyploidization (2n gametes) as a viable breeding scheme for genetic enhancement of *Musa* species.

Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa

Goal

To assist smallholder and medium-scale farmers to improve their well-being and alleviate poverty through the use of sustainable production technologies and postharvest systems that increase productivity and food security and minimize natural resource degradation.

Highlights

Research Highlights

- In 1998, benchmark area development continued to be the main focus for EPHTA. Characterization surveys were completed in the forest pockets benchmark area in Ghana and in the derived/coastal savanna benchmark area in Benin.
- The southern Guinea savanna benchmark area was officially launched on 12 March 1998 at Kassere in northern Côte d'Ivoire at a ceremony attended by farmers, stakeholders, and local and regional government officials. This was followed by a workshop on how to conduct characterization surveys coordinated by IITA backstopping scientists.
- The northern Guinea savanna benchmark area was officially launched on 2 December 1998 at Zaria in northern Nigeria during a workshop attended by stakeholders, government officials, and staff of the Institute for Agricultural Research, Ahmadu Bello University, the host institute.
- In February 1998, a Memorandum of Understanding was signed establishing a partnership between CORAF and IITA for the development and implementation of a long-term research strategy.
- The EPHTA Program Management Committee (PMC) held its second meeting at IITA, Ibadan, on 19 and 20 May 1998. In addition to representatives from EPHTA member countries, institutions, and organizations, the meeting was attended by all EPHTA benchmark area and pilot site coordinators.
- From 17 to 20 November the third EPHTA Scientific Workshop was held at IITA Ibadan. The purpose of the workshop was to formulate strategies for supporting farming systems development. Papers based on EPHTA outputs were presented at the workshop by regional scientists. The workshop was also attended by EPHTA benchmark area coordinators and IITA scientists backstopping the benchmark areas.
- A project proposal for funding was developed with the assistance of a regionally recruited consultant after discussions and consultations with the various EPHTA partners. The proposal was reviewed and endorsed at the second EPHTA PMC meeting, and subsequently submitted through CORAF to the European Union.

Systemwide Program on Integrated Pest Management

Goal

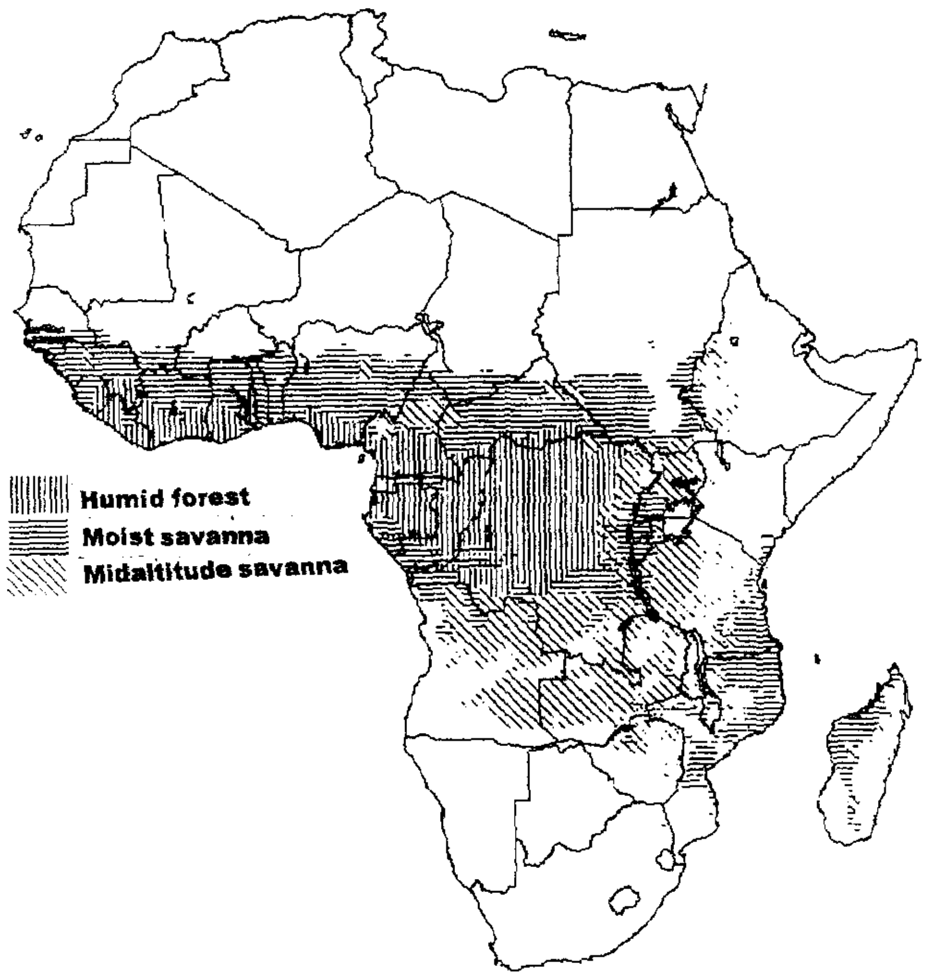
To enhance the effectiveness of integrated pest management

(IPM) 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 Systemwide Program on Integrated Pest Management (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 World Wide Web 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).

Annex 5



Map of agroecological zones