# Project 5

# Integrated Management of Maize Pests and Diseases

## Annual Report 1997

International Institute of Tropical Agriculture

## Contents

# Preface

The research agenda of IITA is subdivided into a portfolio of 16 projects (Annex 1). 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. The institute-wide log frame (Annex 2) shows the expected contribution of each project to this overall institute goal.

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).

Highlights from all these projects can be found in Annex 3 which provides an illustrative summary of IITA's research activities and achievements of the year, together with special reports on selected themes.

Annex 4 shows all the agroecological zones of sub-Saharan Africa in which IITA conducts research.

The project organization for implementing IITA's research agenda is relatively new, and continues to evolve from a divisional management structure. In previous years, detailed research outputs and achievements were reported in divisional reports; this is the second year 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.

# Project 5

# Integrated Management of Maize Pests and Diseases

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## 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*, and *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.

Food security and human nutritional status of the target clients of the CGIAR are directly affected 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 preharvest 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), *Sitophilus zeamais* Motschulsky (Col., Curculionidae), and *Sitotroga cerealella* (Olivier) (Lep., Gelechiidae). *P. truncatus* can cause much higher losses where it occurs. Lepidopteran larvae 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. For example, a study of maize stores in Benin Republic revealed that after 3 months of storage, anywhere from 30 to 50% of the stores had aflatoxin levels ranging into 100s of ppbs, and correlation with insect damage was highly significant.

# Outputs

## 5.1. Knowledge of pest and disease systems in pre- and postharvest maize

**Background**

Countrywide 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 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 nobody 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 1996, the disease control campaign appeared to be having an 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. At present *P. truncatus* has been confirmed from a total of 13 African countries. In the affected countries, the larger grain borer has become one of the most important pests of farm-stored maize and cassava, particularly for small-scale farmers. The general approach of the larger grain borer project is to first gather the necessary socioeconomic data through on-farm surveys, identify farmers' practices and possible control options, and then to carry out properly arranged on-farm trials to ensure the immediate relevance of our work to farmers in the region. Rapid loss assessment techniques and standardized sampling plans for insect collection in grain stores are used in the course of the surveys, in order to obtain a maximum of information in a limited amount of time.

## Ongoing and future activities

### 5.1.1. Diagnostics and loss assessment studies

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In 1997, in Cameroon, questionnaires were administered, field maize health assessed, and stored grain sampled with 12 farmers per village, in 6 villages, in each of 2 agroecological zones. Subsamples of the grain will be analyzed for mycotoxins. These data will be analyzed to assess 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 socioeconomic data will be done in 1998.

In Uganda, the countrywide surveys are completed and work will concentrate in benchmark sites set up by socioeconomists based on biotic data obtained from the surveys (see 5.4.5.). First diagnostic work in the benchmark sites was done at the end of 1997/beginning of 1998 with emphasis on GLS, stemborers and their natural enemies [especially *Telenomus* spp. (Hym., Scelionidae), and *Cotesia* spp. (Hym., Braconidae)] of stemborers. At Namulonge, labs for rearing stemborers and natural enemies have been completed. First releases of *Cotesia flavipes*, a larval parasitoid of *C. partellus*, were 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 1996 and 1997, grey leaf spot caused by *Cercospora zea-maydis* had become a very prevalent disease in both Uganda and Cameroon. Preliminary data from farm-level assessments in Uganda are indicating that significant yield losses occur due to this disease. The relationship of the disease severity and yield appears to be nonlinear and confounded with plant size. Thus yield loss assessment needs to be conducted under controlled conditions on station.

In Ghana, the choice of these benchmark areas has 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 savanna; 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 to test hypotheses created via survey data and for R&D of IPM technologies.

Between 1994 and 1997, a new disease appeared in Cameroon, Ghana, and Nigeria and is spreading. The causal organism has been identified as the mushroom fungus (order Agaricales, subdivision Basidiomycotina) *Marasmiellus paspali* (Petch) Singer. At this point, nothing is known about why the disease appeared, how it is moving, or its potential to reduce yield. These aspects will be investigated while continuing to monitor spread.

In surveys in Ghana during 1996 and 1997, a multiple ear phyllody was recorded that in some fields resulted in 100% loss. This abnormality, up to 6 ears forming in the same node, was also seen predominantly on a local variety, Namulonge 1, in Uganda in 1995, and it became prevalent in experimental fields on the IITA campus in Nigeria in 1997. The etiology of the problem is unknown, but the phenomenon appears to be increasing, suggesting

biotic origin. A plant genetic based physiological disorder could spread via outcrossing, or a stem inhabiting pathogen such as *Gibberella fujikori*, the sexual stage of *Fusarium moniliforme* Sheldon, could illicit such a physiological response.

This multiple ear characteristic is definitely undesirable, often resulting in vain cobs. The cause and solution need to be determined.

### 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 West 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 countrywide surveys were carried out between 1991 and 1997 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. Mucuna, a plant recommended as a cover crop, has been found to be an excellent host for maintaining relatively high *Mussidia* populations during parts of the dry 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.

One generation of the borer is generally found on maize whereas several generations were recorded on *Parkia biglobosa* and *Gardenia* spp. Agroecological variation in the availability of wild host-plants coupled with overlapping fruiting periods is responsible for maintaining high population densities especially in the Guinea savanna with only one maize growing season. This corroborates results from light trap catches over a 4-yr period (1994 and 1997) in three agroecologies of Benin which showed that the number of adults caught increased from the south to the north, with a close correlation between catch numbers and abundance of host-plants, and especially *Zea mays, Parkia biglobosa* and *Canavalia enseiformis.* Average maximum temperature and mean minimum RH had a positive effect on the number of adults trapped.

Based on aggregation indices, sampling plans were developed for *M. nigrivenella* on *P. biglobosa, Gardenia* spp., *Adansonia digitata,* etc. The distribution was aggregated when the mean borer density per fruit was > 1.0. Because small fruits harbored low numbers of borers an increase in randomness was observed with the decrease of fruit size of the host-plant species.

So far, no larval or pupal parasitoids, and low egg parasitism (< 0.01%) was found on maize, cotton, *Canavalia,* and *Phaseolus* bean. An indigenous solitary chalcidoid parasitoid, *Antrocephalus crassipes,* was found parasitizing pupae of *M. nigrivenella* on fruits of *Gardenia* spp. during the dry season only. Over a 2-year period, 38% of all trees sampled contained parasitized pupae with an average of 12.4% and a maximum of 90%. By contrast, in Cameroon, *Tetrastichus* sp. was the most common species. In Nigeria, first surveys on wild hosts were done in 1996, but no natural enemies have been recovered so far.

*M. nigrivenella* is only known as a field crop pest from some West African countries, although it was reported from noncultivated hosts in East 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 redistribution approach (See 5.4.1.). Given sufficient funding, exploratory work will be done in East and southern Africa.

### 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*

To study the mode of entry and establishment of *P. sorghi* in the seed via the silk, two maize varieties TZSRW (susceptible) and SUWAN I (resistant) were planted in replicated RCB design. *P. sorghi* inoculum was sprayed on the silk before and after pollination while the controls were only pollinated.

The histological examination showed that the stigma was highly susceptible to conidial infection. Seed was determined to be infected by microscopic examination of microtomed sections. There was no significant difference in the level of seed infection in TZSR when inoculated with *P. sorghi* before (30%) and after pollination (27%). SUWAN I gave higher infection (45%) when inoculated before pollination than after pollination (8%). In the control, internal mycelia were not observed. One important aspect of this work was that seeds collected from inoculated plants looked healthy even though they carried *P. sorghi* mycelia. Hence, we went further to study the effect of inoculation on grain quality viz. grain weight, floating ability, protein, hardiness, etc.

There was no significant difference in the grain weight among the two varieties, but inoculation increased the grain weight by an average of 11.8 g. Neither the treatments nor the varieties affected the protein content of the kernels. There was a trend of increased hardness with inoculation. Kernel hardness is naturally higher in Suwan 1 than TZSR, but with inoculation, kernel hardness TZSR increased while Suwan 1 was unaffected. Another test of grain quality, % floaters, was affected by inoculation, being significantly lower in inoculated ears than the noninoculated control. This may be a function of increased grain weight and hardness when the fungus is inside.

### 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*

A dose-inoculum response trial was developed to monitor levels of "breakthrough" of *P. sorghi* at a range of inoculum levels at various dosages of Apron plus®, applied to seed of both susceptible and moderately resistant maize varieties. On the susceptible Pool 16, % incidence of systemically infected plants increased linearly on the 0-dose control as inoculum concentration was increased from $1x10^4$ to $1x10^7$/ml. A mean of 94% infection was achieved at $1x10^7$ in the 0 dose control. At 50% (commercially recommended) dosage, the inoculum threshold for breakthrough was $1x10^6$/ml, at which there was only 4% infection incidence. At full dosage (10 g/kg seed) no breakthrough was seen at any inoculum level. The DMR variety had half as much infection in the control, but still had up to 2.7% breakthrough and 50% dosage and $1x10^7$/ml inoculum. This information is going to be used with regional DM prevalence data, data on DMR and Apron plus® utilization, and spore levels near and away from infected fields to model the probability of breakdown of Apron plus® over time.

### 5.1.5. Study of seasonal effects on 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, M. Sétamou**

Surveys were carried out in July 1997 to establish a catalogue of endophytic fungi in maize in southern Benin. Species belonging to 12 different genera of fungi were isolated. *Fusarium*

spp. were the most common accounting for 69–84%. Most fungi were more commonly found in stems damaged by stemborers than in healthy stems. On-station trials corroborated these results. In addition, protecting the ear significantly reduced grain infection indicating that infection occurs via the silk. Young plants were efficiently protected from seed transmission of *Fusarium* via a hot-water treatment of the seeds (5 minutes at 60 °C). The same plants, however, became reinfected at a late stage.

Trials are underway to assess the effect of season, environment, and other background flora on the degree of cob infection with *A. flavus and F. moniliforme*; and the prevalence of earborers, beetles, and weevils. In 1996, a study of the association of fungi with borer tunnels in the maize stem began. Borers often move from stem to ear, and tunnels in the stem are often associated with fungi such as *Fusarium moniliforme*, which is known for production of the mycotoxin, fumonisin (among others). The question to be addressed, is whether there is a cause and effect between stem tunneling and the fungi associated with the stem, and subsequent ear infestation and grain contamination with mycotoxic fungi. Preliminary data showed higher numbers of all types of insects in cobs that were infected with *F. moniliforme*. Now it appears that many insect species including the lepidopterans *Mussidia nigrivenella* Ragonot and *Sesamia calamistis* Hampson, and known storage pests such as *Sitophilus zeamais* (Motsch.) and *Carpophilus* spp. are attracted to the fungus. On the other hand, ears that had been inoculated with *A. flavus* had significantly lower numbers of insects of all classes.

Greenhouse and lab experiments showed that on plants with *F. moliniforme, 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. Also, covering the ear significantly reduced *F. moliniforme* incidence.

The second season showed a marked decline in insect infestation and a significant increase in *A. flavus*. *A. flavus* and *F. moniliforme* hypothetically are favored by different climates; *A. flavus* having an advantage in hot, dry conditions and *F. moniliforme* being more fit in humid conditions. The toxin fumonisin, a metabolite of *F. moniliforme*, was significantly more prevalent in the first growing season (the heaviest rainy season) than in the second (and dryer) season of 1996, with mean levels of 5.8 ppm and 4.6 ppm in the first and second season, respectively. In the same trial, aflatoxin, the *A. flavus* metabolite, was significantly higher in inoculated ears in the second season than the first. Mean levels of aflatoxin in inoculated ears rose from 300 to 560 pp. in separate trials from the first to the second growing season.

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

*by C.B., G.G., W.G.M., C.N. - in collaboration with A. Lawson, A. Tchabi**

For a period of one year, the gut contents of beetles collected with pheromone traps at two different sites in Benin, the Lama forest and the IITA station in Abomey-Calavi, were analyzed. Insects originating from the forest habitat had predominantly lignin in their guts, whereas the guts of *P. truncatus* from the IITA station contained mainly starch, indicating that the beetles from the Lama forest had been feeding on woody host-plants and the ones from the IITA station on a starchy substrate (presumably maize or cassava). In olfactometer studies pheromone production of *P. truncatus* on woody hosts could be demonstrated. How-

ever, the results from an analysis of the nutrients in the wood sample were inconclusive. No clear relationship between the amount of reducing sugars and pheromone production of *P. truncatus* could be revealed. Emergence data from larger numbers of Cerambycid girdled *Lanea* spp. branches, sampled in the Lama forest in January and February 1997, could not only for the first time in West Africa demonstrate the close association between *P. truncatus* and Cerambycids, but also between *P. truncatus* and *T. nigrescens* in the forest habitat. In addition, olfactometer trials showed that *P. truncatus* is strongly attracted to odours emitted by Cerambycid girdled *Lanea* spp. branches.

Additional studies have been initiated in the Lama Forest to identify potential host tree species of *P. truncatus* and to characterize the ecological constraints of the pests' distribution and abundance in the natural environment. A vegetation survey has been carried out to outline forest heterogeneity and identify principal explanatory variables for the species composition variation. The species composition of the forest was found to be remarkably heterogeneous and pheromone traps were installed according to the species variation. *P. truncatus* were caught in all weekly catches but there was a considerable variation between trapping sites. The identified tree species on trap sites were tentatively used as explanatory variables for the trap catches, and *P. truncatus* abundance was found associated with certain forest formations. On the basis of the obtained information about the forest heterogeneity and the ecological variables responsible for the forest composition, we have preliminary tools to explain pheromone trap catches and to identify tree species that may sustain *P. truncatus* populations. *T. nigrescens* was present in all but a few pheromone trap catches. Multivariate statistical analyses of trap catches suggest that the correlation between *T. nigrescens* and *P. truncatus* is not straightforward and that other factors than *P. truncatus* abundance in the environment may play a major role in the ecological distribution of the predator. Ongoing experiments try to elucidate whether density dependent factors also play a role in the dispersal behavior of *P. truncatus* on woody host plants. Moreover, the role of potential symbionts in the life strategy of *P. truncatus* will be investigated.

### 5.1.7. Studies of host-finding behavior of *P. truncatus* in relation to both crop and natural host-plants

*by C.B., R.H.M. - in collaboration with H.-M. Poehling, D. Scholz**

In the course of the studies on host finding behavior of *P. truncatus*, an appropriate methodology, using a modified 4-arm olfactometer, to measure short range attraction in *P. truncatus* was developed. Volatiles emitted from shredded maize kernels, whole maize kernels, cassava chips, and shredded cowpea—the latter being a nonhost-plant for *P. truncatus*—proved to be attractive to the beetles, though the response expressed towards whole maize kernels and cowpea was less intense than towards the other odor sources mentioned. Maize cobs and odors released by *S. zeamais* and *T. nigrescens* did not evoke any reaction in *P. truncatus*. These results indicate that at short range *P. truncatus* is attracted to rather general plant volatiles, and that these substances might guide the insect to the food source from a short distance. The strongest attractive response was evoked by artificial and natural pheromone which confirms the crucial function of the pheromone as a long- and short-range attractant. Electroantennogram studies revealed that the threshold of *P. truncatus* and its predator *T. nigrescens* to the two components of the male-produced aggregation pheromone of *P. truncatus* are approximately the same. In a field experiment, carried out on the IITA station, we could demonstrate that for *P. truncatus* the attraction capacity of the T2 component of the pheromone is significantly stronger than the T1 component. However, *T. nigrescens* showed no differences in response to the two components of the *P. truncatus* aggregation pheromone. In another experiment, the responses of male and female *P. truncatus* to the pheromone produced by a single male *P. truncatus* (confined on a maize cob) have been

investigated. We demonstrated that a single male *P. truncatus* can attract large numbers of conspecific males and females. Apparently the males stop pheromone production upon arrival of conspecific females. With these findings we were able to confirm the hypothesis that the *P. truncatus* pheromone is not *sensu stricto* an aggregation pheromone but a male-produced sex pheromone. A density dependent dispersal pattern could be shown in another experiment. However, even from very crowded cultures not more than 30% of the *P. truncatus* was dispersed. Of the emigrants, 60% were female, confirming previous observations from pheromone trap catches. An investigation of seasonal and weather factors on the dispersal behavior of *P. truncatus* revealed that only mean daily temperature had an effect on the emigration of the beetles, confirming the results from a previous study of pheromone trap data from the Mono province. By dissection of large numbers of beetles originating from pheromone traps, the reproductive system of male and female *P. truncatus* was described. Analysis of the reproductive status of the females showed that the great majority of dispersing females were mated, indicating that females might play a more crucial in niche colonization than previously thought. Studies in 1997 will try to determine the actual location where the *P. truncatus* pheromone is produced.

### 5.1.8. Modeling of storage pest population dynamics and grain losses

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

A demographic, distributed delay population model of *S. zeamais* in West African grain stores was 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, to which this work is considered complementary, 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. The developmental rates, larval survivorship, age-specific fecundity, and density-dependent emigraton rates were obtained from experiments done at IITA-Calavi or from published data. Field experiments done at IITA-Ibadan and in the Mono Province of Benin provided the validation data. The model was used to evaluate the effects of varietal resistance and interspecific competition on *S. zeamais* population dynamics. The *P. truncatus* model and the *S. zeamais* model have been linked to a "grain store" environment. This environment contains informations such as weather files for driving the respective simulation models as well as the size of the grain store and the damage state of the maize. Results already confirm some field observations, for example, that few mortality factors act on *S. zeamais*, at least early in the season, and that immigration plays a large role relative to beetle fecundity at the beginning of the season. Using this structure, the modeling work will focus on the links between the pest models and between the pests and the predator, *T. nigrescens*. Data on *T. nigrescens* larval survivorship, developmental rates and, currently, temperature effects on age-specific fecundity are being determined in laboratory experiments and will be used to construct a simulation model of *T. nigrescens* population dynamics, linked to the pest models via a functional response model. Data from field experiments investigating varietal effects on pest density will be included to make the grain store model more useful as a 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*. Ten data sets, from Benin, Mexico, and Nigeria, are being used to understand 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 (see below).

Temperature and humidity probes were placed both inside and outside 7 rural maize stores (at least one store in each province) in order to record within-store and ambient weather conditions. This data, combined with data on grain moisture content, will allow workers to evaluate the effect of the store structure on the maize temperature and grain moisture content, which then allows a link between weather conditions observed in stations maintained by governments and institutes, and expected conditions in grain stores. This link will be important in combining geographical information system approaches with simulation models as part of a decision-support tool.

## 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 stemboring 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 possible 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 10 million eggs of the 2 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 lab colonies of *M. nigrivenella* and *Sesamia poephaga* (occurring on sorghum in the northern Guinea savanna). These in-

sects 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*. In 1997, emphasis was given to establish a stable colony of *B. fusca*. So far, three successive generations have been completed this year. Because of cannibalism, only one larva was reared per vial. From the first to the third generation, larval developmental time decreased from 105 to 60 days, while fecundity increased progressively and reached 285.8 eggs per female.

The major constraint in NARES HPR programs is to achieve uniform field infestations. Since rearing of stemborers on an artificial diet is too expensive for the 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 an 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.

### 5.2.2. Improve stemborer-resistant populations and lines

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

In continuation of our effort to upgrade levels of resistance to stemborer attack in our populations, a cycle of improvement was again completed in TZBR Ses 1 to generate the cycle 3 (C3) separated along color lines to form the white and yellow versions. TZBR Ses 1 was originally created as a mixed grain type with both yellow and white germplasm going in to form the population. Research effort was also initiated in 1997 to broaden the base and adaptability of TZBR Eld1 C7 which has a high level of resistance, but is relatively poorly adapted. A first generation of backcrossing was completed using a few adapted populations as donor parents.

A collaborative breeding arrangement with the Institute of Agricultural Research and Training at Moor Plantation in Ibadan, Nigeria has yielded 3 new locally adapted and stemborer-resistant populations of maize. Stemborer infestation is a serious constraint to maize production in southeastern Nigeria. Consequently, a number of genetically diverse populations were grown in a hot spot of the area and desirable individuals from the populations selfed. Levels of resistance of the selfed lines were confirmed under artificial infestation at IITA and selected lines recombined along color lines to form Ama TZBR-W, Ama TZBR-Y, and Ama TZBR-W/Y.

Progress from selection in all stemborer-resistant populations was evaluated in 1997 and revealed that although reduction in levels of damage may be slow, there was evidence of increases in grain yield of newer cycles thus suggesting that increases in levels of tolerance are equally being achieved.

In 1997, S4 lines selected from several stemborer resistant populations were testcrossed to a broad-based converted population (ICZ5-BC2A) having cross resistance to *Chilo partellus* and *Sesamia calamistis*, two geographically isolated early infesting stemborer species with similar feeding behavior. These lines form the first set of parents of hybrids being generated with resistance to stemborer attack.

### 5.2.3. Develop screening and sampling protocols in maize breeding nurseries for resistance to *A. flavus* in Nigeria

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

*A. flavus* is known to infect ears of maize via feeding channels created by earborers or other wounds such as bird damage. Another mechanism for infection, independent of damage by other organisms, is via conidia which come out of the soil, land in newly emerging silk, germinate, and grow into the end of the ear. Inoculation methods which cause injury, such as a jab with an *A. flavus* laden toothpick or nail, are very effective in introducing the organism into the ear, but tend to bypass any mechanism for resistance to primary entry such as incompatibility of the silk for the fungus, pericarp resistance, or long husk cover. In inoculation experiments, ear silks were sprayed at 5 and 10 days after mid-silk with a $1x10^6$ spore suspension. Spray inoculated ears had significantly higher aflatoxin loads (mean 430 ppb) than the noninoculated controls (79 ppb). No difference among varieties was detected, although Pool 16 always had the lowest mean aflatoxin levels, differing by as much as 200 ppb from the most susceptible, Composite 4. *A. flavus* resistant inbred lines from the United States will be converted to tropically adapted materials and tested for resistance under stress conditions and/or inoculation. A breeding strategy for population development with these materials is being developed. At the same time, clean inbred lines from IITA will be sent for bioassay for pericarp resistance in collaboration with the USDA Southern Regional Research Center in New Orleans.

### 5.2.4. 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 N.A. Bosque-Pérez, O. Ayinde, S. Odubiyi*

IITA breeders have been selecting for good husk cover and ear-rot resistance in the process of screening for other characteristics. Good husk cover is considered one of the main mechanisms for exclusion of insects and fungi from the ear. The toxigenic fungi, *Aspergillus flavus* and *Fusarium moniliforme* were introduced onto the silk at 5 and 10, and 10 and 15 days after mid-silk, respectively, of older and newer cycles of selection of four open-pollinated maize lines (TZEComp4 C0 and C2, TZBR Eld 1 C0 and C5, Pool 16 1981 to 1990, and GobgbeXTZSRW C0 and C3). In 1996, there was significant difference between the old vs new cycles of selection for husk cover and a general ear appearance rating, but there was no significant improvement with respect to total fungal infection, total *A. flavus* incidence, total *F. moniliforme* incidence, total grain damage, or total insect damage. The newer cycles of selection had, on average, 200 ppb more aflatoxin than the older cycles, across two seasons in 1996. Thus, it appeared that to achieve progress toward better grain quality and storability, passive selection for improved husk cover would not be adequate. Nevertheless, husk cover has long been considered one of the primary lines of defense against both insect pests and fungi that attack the ear. Therefore, the trials have been repeated in 1997. Analysis is ongoing.

Ear rot rating has also been a selection criterion while improving lines for other characteristics. Of the four varieties in this experiment, Pool 16 and Gbogbe are considered to be the most rustic. The ear rot rating for Pool 16 was consistently highest, indicating more discoloration than the other varieties. On the other hand, Pool 16 was the variety with the lowest % kernel infection and lowest colony forming units/gram of milled material, followed consistently by Gbogbe. In the case of Pool 16, the ear rot rating was not helping to improve the storability and grain quality with respect to these two fungi.

### 5.2.5. Upgrade existing downy mildew resistant (DMR) materials

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

Levels of DMR in maize are routinely upgraded in elite germplasm. In 1997, a cycle of S1 recurrent selection was completed in five (AK9522 DMR-SR F2, AK9528DMR-SR F2, AK95 DMR-ESRW F2, TZL Comp4 DMR F2, and AK 96 DMR-LSRW F2) maize populations. DMR levels in the original and newer cycles of selection of different populations were further compared in trials at Ibadan using the direct seed inoculation technique. Results obtained from the evaluation showed that DM rating for the populations ranged from 2 to 5 with percent incidence of less than 20% in a number of the entries. Rating for the susceptible check (Pool 16SR) was 8. In general, ratings and grain yield potential of the newer cycles were definitely much better than for the older cycles.

A number of lines with resistance to DM infection and obtained from Pop 22, Pop 28 and Pop 31 were evaluated in testcross trials for yield potential and DMR in Ibadan and in two other environments for grain yield and resistance to other foliar diseases in 1997. From these evaluations, inbreds with good combining abilities were identified in crosses having significantly higher grain yield and better DMR than the commercial hybrid (8644-27). These lines are being used to form experimental hybrids for further testing in 1998.

### 5.2.6. Study mechanisms of resistance to *Stenocarpella macrospora (ex Diplodia macrospora)*

*by K.F.C., A.M. - in collaboration with R. Olatinwo*, A. Julian, M. Deadman*

Studies to assess the genetics of resistance to *S. macrospora* and particularly the relationship between expression of leaf symptoms and cob rot have been conducted in 1995 and 1996. A diallelle cross of two resistant and two susceptible inbred varieties was made and selfed to each parent. Inoculation in the shank with *S. macrospora* infested leaf powder resulted in very high levels of cob infection. Generation means on inheritance of six *Stenocarpella macrospora* ear rot characters indicated that dominant gene effects made the major contribution to variation in ear rot. Epistatic effects were also important contributors to variation for ear rot. Additive effects had little importance in the total variation. Leaf infection was not correlated to levels of ear infection, indicating separate mechanisms in the plant. Leaf infection was significantly negatively related to yield.

## 5.3. Biological control and habitat/store management options

**Background**

Biological control and habitat management provide the options of choice, when levels of host-plant resistance are inadequate to protect the crop against pest or disease pressure, since these strategies are usually highly compatible, or even synergistic, with genetic resistance. Indeed, biological control, especially for an introduced pest species like the larger grain borer, can often be implemented much more rapidly than adequate levels of plant resistance can be developed by breeding; thus, in some circumstances, biological control becomes the option of first choice. In the case of maize pests and diseases in Africa, we are faced with organisms of a variety of different origins, including 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 vital to diagnose the source of the pest or disease problem correctly. Especially for biological con-

trol 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. 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*, A. Yayé-Dramé,* O. Youm, 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, *Telenomus 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 enemy complexes are identified by a joint NARO/IITA project funded by IFAD.

*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 West 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) adapted to *S. calamistis* were established at IITA-Benin. They have been provided by the ICIPE/WAU biological control project in Nairobi, Kenya. Suitability tests using seven West African stemborer species showed that *C. sesamiae* is highly specific to *S. calamistis* and also successfully parasitized *Sesamia poephaga* Bowden & Tams and the pyralid millet borer *Coniesta ignefusalis* (Hampson). *C. sesamiae* was released in Benin in 1995 together with two other exotic *Cotesia* species. It is still being recovered at one site in southern Benin and is spreading. Electrophoresis work comparing several strains showed that the field collected parasitoid is identical with the East African strain. Concomi-

tantly, DNA analyses for strain differentiation are being carried out in the biotechnology lab at IITA-Ibadan and at BBA, Germany. Mating experiments using two Nigerian and the East African strains yielded fertile F1 females (although a large part of the Kenyan females did not accept Nigerian males). Reciprocal backcrossing of F1 females with males of the three strains again yielded fertile F2 female indicating that the three strains are not reproductively isolated populations. In Nigeria, first releases of *C. sesamiae* were carried out in late 1997 in collaboration with an entomologist from the Plant Quarantine Service, Moor Plantation, Ibadan.

At the ICRISAT-Sahelian Center, Niamey, Niger, the millet stemborer, *Coniesta ignefusalis* is being tested for suitability to the three *Cotesia* species. The work is part of a PhD project funded by an IITA/Winrock fellowship.

Collaboration with the South African Sugar Experiment Station (SASEX), Durban, continued in 1997 with a one month visit of D. Conlong to West Africa for collections of natural enemies to be used against *E. saccharina* on sugar cane in South Africa. *Sturmiopsis parasitica*, a tachinid pupal parasitoid which does not exist in South Africa, was found parasitizing *E. saccharina* on sugar cane in a small field planted on the IITA campus. A larvae exposure method showed again that *S. parasitica* is much more common in the West African stemborer system than assumed from collections on maize. Peak parasitism of 70% on *S. calamistis* and *E. saccharina* occur during a time when natural borer infestations were close to zero. This indicates gaps in our knowledge about the range of insect and/or plant hosts (see 5. 4. 4.). A colony of *S. parasitica* was established in the SASEX laboratories in 1997. Another possible candidate for redistribution between West and South Africa is a tachinid of the genus *Actia* collected from *E. saccharina* in the forest zone of Cameroon by R. Ndemah, IRA, and D. Conlong.

PHMD/IITA, on the other hand, is interested in a South African strain of *C. sesamiae* which occasionally shows high parasitism on a *B. fusca*. As in 1996, life specimens of borers species collected during surveys in West Africa in 1997 were sent on artificial diet to the quarantine facility in Pretoria, South Africa, for parasitoid emergence, identification, and rearing.

### 5.3.2. Ovipositional behavior and host discrimination in two scelionid egg parasitoids *T. busseolae* and *T. isis*

*by F.S - in collaboration with A. Chabi-Olaye*

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. In a first step, the oviposition behavior (drumming, insertion of ovipositor, marking of eggs) of *T. busseolae* and *T. isis* was studied. Both *Telenomus* species could discern eggs already parasitized by a conspecific female. Respectively, 32% and 65% of *T. isis* and *T. busseolae* oviposited in eggs already parasitized by a conspecific female, but superparasitism per egg mass was between 4 and 10% only. Both species could also discriminate eggs parasitized by the other species. Superparasitism was 20.3 and 15.8% by *T. busseolae* and *T. isis*, respectively, as compared to 82 and 65% of nonparasitized eggs. *T. isis* ovipositing after *T. busseolae*, and *T. busseolae* after *T. isis* yielded, respectively, 100 and 65% of *T. busseolae*.

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*.

### 5.3.3. 'New association' for stemborer control in Africa

*by F.S. - in collaboration with J. Haile-Michael*, J.O. Bukola, W. Overholt, A. Yayé-Dramé*, H. Youm, J.W. Smith, J.H. Smith Jr.*

New associations refers to the introduction of natural enemies from closely related species, rather than the use of coevolved natural enemies. The new association approach was highly successful against stemborers on various crops in the Americas and Pakistan. At IITA, this work is being done in close collaboration with the ICPE/WAU project which provided IITA-Benin with *C. flavipes* from Pakistan and *C. chilonis* from Japan. Suitability studies with seven stemborer species carried out at IITA-Benin, however, showed that both species are not very host specific. They equally attack hosts on which all eggs are incapsulated, and as a result, parasitism on the suitable host *S. calamistis* decreases drastically with increasing proportion of the unsuitable *E. saccharina* in the system. Releases in Benin in both 1995 and 1996, have not yet led to the establishment of either, *C. flavipes* or *C. chilonis*, corroborating results from lab and greenhouse studies. Similar studies are underway at ICRISAT Sahelian Center in collaboration with PHMD-Benin, with the suitable host *C. ignefusalis*.
In 1997, 100 *S. calamistis* pupae parasitized by *Pediobius furvus* were shipped to Brazil to be tested on the sugar cane borer *Diatraea saccharalis*. Earlier tests in Texas showed that *D. saccharalis* is a suitable host but *P. furvus* did not establish for climatic reasons.

### 5.3.4. 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.

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

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

Since maize is not available year-round, biological control by larval and pupal parasitoids takes place in the wild habitat. Thus, in addition to being trap plants during the growing season (see 5.2.4), they are a refuge for natural enemies during the between and the off-season thereby stabilizing the system. Consequently, knowledge of the entire host range of stemborers is of utmost importance for the evaluation of the importance of natural enemy species which may be responsible for the fluctuation in pest densities between countries, ecozones, and seasons. Survey results from Cameroon, Côte d'Ivoire, and Ghana 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 habitats 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 preadult 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 most wild host species act as trap plants. In 1996, on-farm experiments were planted in Cameroon, to look at the effect of border rows with *Pennisetum purpureum* on the population dynamics of both the pest and the egg parasitoids *Telenomus* spp. in maize fields. First results showed that, although receiving a high egg load, *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. Further studies are needed to find out how *P. purpureum* can be managed (kept short) to reduce stemborer densities in maize fields.

In the forest benchmark areas of Cameroon, an attempt was made to correlate type of vegetation with pest variables. Under conditions where grasses increased (mixed with *Chromolaena odorata)*, egg batch size was positively correlated with grass abundance. Where *C. odorata* displaced grasses, percent deadhearts and plants infested with eggs was high. Young forest and other vegetation (very often other maize fields or cassava and plantain fallow) had the opposite effect. Both egg batch size and *B. fusca* numbers were low in mature forests.

### 5.3.6. 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, and 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.

### 5.3.7. Soils characterizations for atoxigenic strains of the soil-inhabiting fungus *A. flavus*

*by K.F.C. - in collaboration with P.J. Cotty, 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 USA 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 USA 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 semicommercial scale in the USA as a potential control for contamination of cotton, groundnut, and maize.

In 1996, approximately 700 isolates of *A. flavus* were characterized from soils across 4 agroecological zones of Benin Republic. In 1997, another 540 isolates were collected tak-

ing into account cropping history of the fields from which the soil samples were taken. Two distinctly different strains were predominant, and strain prevalence shifted from south to north with the most toxigenic strains being found in the north. Several isolates were physiologically and phyllogenetically distinct from all other strains, although conidial morphology placed them in the *A. flavus* group and they produced both B and G toxins. A number of apparently atoxigenic isolates were identified, NIT mutants generated, and characterized as to vegetative compatibility group (VCG). The ultimate goal will be to assess the potential of using atoxigenic strain displacement in smallholder maize (cotton, groundnut) farming systems in Africa.

### 5.3.8. Monitoring the spread *of T. nigrescens* in southern Benin

*by C.B.*

Data on the spread of *T. nigrescens* in southwestern Benin, collected between 1992 and 1995, have been analyzed. Surveys carried out during January and February 1997 in the Mono province indicate that *T. nigrescens* is now present also in the northern part of the province. In collaboration with GTZ, ongoing studies concentrate on the distribution of *T. nigrescens* in central and northern Benin.

Data from the pheromone monitoring at the IITA station in Abomey-Calavi was used to investigate the effect of weather on the flight activity of *P. truncatus* and *T. nigrescens*. The comparatively low trap catches on the IITA station between February and April 1997 confirm our hypothesis that the first yearly peak in flight activity is linked to storage practice.

### 5.3.9. 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 5.4.6) show that many farmers treat their stores with highly toxic compounds intended for cotton or cocoa, 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 section 5.1.8) suggest that it may be less effective in drier regions. Laboratory and field experiments are underway to evaluate the potential of the entomopathogenic Deutermycete fungus, *Beauveria bassiana*, as a further biological alternative to chemical insecticides or adjunct to *T. nigrescens*. Critical to the success of *B. bassiana* is its capacity for vertical and horizontal transmission from an initial inoculum to invading individuals and then to subsequent generations following decay of the original inoculum.

In the laboratory, 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 is being evaluated in a 7-month field experiment involving 20 widely 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 include carrier with and without the fungal spores, maize stored with and without the husk, and controls. Stores were inoculated with laboratory reared *P. truncatus* to present a maximum challenge situation for the fungus. Cobs are sampled on a monthly basis, evaluated for insect density (*P. truncatus*, *S. zeamais*, and *T. nigrescens*), grain loss, and grain moisture content. Live insects are held for observation, while cadavers are placed in petri dishes in CTH cabinets to check for fungal sporulation.

### 5.3.10. Studies of behavior and impact of parasitoids in maize stores in Mexico
*by R.H.M. - in collaboration with N. Mills, J. Hirabayashi**

Field and laboratory studies conducted in Mexico with a view to providing a better understanding of the role of insect parasitoids in grain stores were completed during 1996. Analysis of the data continues and full results in the form a doctoral thesis will be available during 1997.

### 5.3.11. Methodologies for assessing the impact of *T. nigrescens*
*by C.B. - in collaboration with H-M. Poehling, A. Bell, H. Schneider**

The spread of *T. nigrescens*, and its impact on storage pest populations and losses, is being monitored in southern Benin. In addition, IITA is providing logistic and technical support for a study of *T. nigrescens* impact funded through a closely linked GTZ project for implementation of IPM against storage pests. The results of these research activities are being used to develop practical protocols for impact assessment to be used in following up biological control interventions, in collaboration with NARES.

### 5.3.12. Logistic support and scientific backstopping for further *T. nigrescens* releases in Africa
*by C.B.*

In collaboration with IITA's and GTZ's TT&TU project, a collaborative prerelease survey was carried out with the National Plant Protection Agency of Guinea-Conakry in the Fouta province of Guinea-Conakry during March 1997. In April 1997, a total of 5000 *T. nigrescens* were released in several locations in the North-Western province of Zambia. A protocol for postrelease studies has been developed and implemented in Zambia. *T. nigrescens* releases continued throughout 1997, concentrating on the heavily *P. truncatus* infested regions in southern Zambia. Four years of survey data on *P. truncatus* spread in Zambia were analyzed. The Plant Protection Agency of Malawi, in collaboration with GTZ, intends to release *T. nigrescens* in Malawi with technical backstopping by IITA. A collaborator from the Malawi national program participated in a training course on *T. nigrescens* mass rearing in April 1997. In addition, a total of 10,000 *T. nigrescens* was shipped to Malawi for mass rearing.

## 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 preharvest pests and diseases, working with soil fertility may be an especially important component of the system. Once diagnostic research has indicated the real nature of the problem and the form of a possible solution, the key to progress towards IPM implementation lies with the empowerment of farmers. Usually, neither farmers nor extensionists understand the underlying ecological principles of pest and disease regulation and it is only when they have acquired some of this knowledge that they may be prepared to undertake the changes, often requiring extra labor, that are involved in the implementation of IPM. Participatory or collaborative approaches may provide a vital entry point to this process.

# 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, D. Onukwu, D. 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 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.

In Ondo, Osun, and Oyo states, not more than 40% of the farmers were aware of the cause of the downy mildew disease in their fields, although DM was present in their fields. More than 50% of the farmers in Osun and Oyo states knew of the disease 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, 44% awareness was recorded at 5 km distance, while at 15 km distance 38.4% knew. 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 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. More women (12%) used DMR than men (8.4%). Statistics on Apron plus plus® utilization are proprietary. Data on which extension mechanism, i.e., radio, TV, poster, ADP field day, was most effective, is being analyzed. Economic analysis of control measures is underway.

### 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*

A deployment strategy to saturate the Ogbomosho area of Oyo State in Nigeria with DMR maize varieties was initiated in 1997 with the support of World Vision International (WVI). To initiate the project, a random sample of five villages was chosen in each of two local government areas earmarked by WVI. Three farmers were again randomly selected from each of the ten villages to obtain a total of 30 participating farmers for the first year. However, only 25 farmers from nine villages joined the project in 1997. All the farmers were assisted to grow DMRESR-W on land areas ranging from 0.3 to 1.2 ha. to give a total of 25 ha. Grain yields obtained ranged from 1.1 t/ha to 4.1 t/ha with an average of 2.2 t/ha. Farmers were also exposed to DM inoculation methods, appropriate plant density, fertilizer application methods,. and concepts of seed production. Seeds for the second year (1998) operations were generated from identified farms and each farmer was equipped to backstop at least four other farmers in 1998 to ensure a total coverage of the area by the end of 1999.

### 5.4.3. IPM 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%. Infected plants are always rogued as soon as detected. The average spore catch in a Burkhard spore trap in the center of IITA campus dropped from a mean maximum of 5 to around 3 spores/mm$^2$/hr from 1994 to 1995. In 1996, the maximum mean spore catch in the year was about 1.2 spore/mm$^2$/hr which indicates a marked decrease in epidemic potential. The highest mean central campus spore trap catch in 1997 was 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.

### 5.4.4. Regional IPM initiative on storage pests

*by C.B. - in collaboration with NARES in Togo and Benin*

In collaboration with local farmers and colleagues from the agricultural extension services, two participatory, long-term, and replicated on-farm storage experiments were carried out in Dogbo, Mono province of southwestern Benin, and near Atakpame, Plateau region of Togo, between September 1996 and April 1997. The trials were a continuation of the collaborative and 'competitive' testing of IPM approaches in postharvest maize protection. Data analysis is still ongoing. However, results to date from the Mono trial in 1996/97 correspond well with the observations of the previous year. Again, in all treatments the level of insect infestation was remarkably low, particularly in the case of *P. truncatus*. Consequently, grain losses, even in the "traditional storage practice" treatment, did not exceed 10%. In the Togo trial, the situation was quite similar until the seventh month of storage, with in general a low level of insect infestation and grain losses less than 10% in all treatments. However, after the eighth month of storage, two of the farmers' treatment suffered from a serious *P. truncatus* infestation, and grain losses rose to approximately 20% of dry weight losses.

### 5.4.5. Database generation on economics of maize as a commodity in Cameroon, Ghana, 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.

The socioeconomic work in 1997 has focused on benchmark site selection in Ghana and Uganda and on the analysis of data and draft reports from the maize IPM socioeconomic surveys in Cameroon. The benchmark sites were selected in Ghana and Uganda by a multidisciplinary team for research on maize IPM according to the criteria of maize production and potential, the diversity of agroecological zones, the gradient of population density and access to road and markets. In Ghana, 3 regions were preselected: (i) The Ashanti Region representing the transitional agroecological zone lying between the forest and the Guinea savanna, with high population density and maize production, and better access to roads and (i) markets. (2) The Eastern Region which is the forest zone with medium population density/access to roads and markets and maize production, and (iii) the Volta Region characterized by a coastal savanna with degraded forest agroecology and low population. A sample of 10 villages and 120 farm households was chosen across the 3 benchmark sites for a multidsciplinary research on maize. In Uganda, three districts were chosen by a multidsciplinary team as the 3 benchmark sites: Iganga, Mbale, and Masindi and the criteria used were population density, maize production, and access to roads and markets. As in Ghana, a sample of 10 villages with 130 farm households were selected for research and testing maize health technologies. The choice of these benchmark sites was backed up by macroeconomic statistics on population, access to roads, maize areas, production, and yields assembled from the University of Ghana and Makerere in Uganda. The socioeconomics surveys on farming systems, maize production, farmers perceptions on maize pests and diseases, and corresponding losses were carried out in the sample households of the benchmark sites in both Uganda and Ghana in 1997.

### 5.4.6. Sampling plan development and economic analysis of stored maize

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

Validation data for enumerative and sequential sampling plans developed last year were collected at more than 60 rural grain stores throughout Benin. Each store was visited at least four times, and 30 to 60 cobs were removed and individually evaluated for pest density, grain loss and visual damage. In addition, data on the variety of maize stored and management practices such as the time of stocking and the use of pesticides were also recorded. These data will be used to examine the usefulness of the sampling plans already developed, and to indicate areas of concern in the construction of simple guidelines for extension agents and farmers to properly assess pest density and to make economically sound decisions. The extensive nature of the sampling will also permit these data to be used to help evaluate simulation model output.

Data on maize prices and quality are being collected every 3 months at several markets across Benin. 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.

# Completed studies

## Journal articles and book chapters

***Asanzi, M.C., N.A. Bosque-Pérez, and L.R. Nault. 1997. Movement of* Cicadulina storeyi *in maize fields and its behavior in relation to maize growth stage. Insect Sci. Applic. 16: 39–44.***

Dispersal of *C. storeyi*, vector of maize streak geminivirus, within maize fields was studied using mark, release and recapture experiments. *C. storeyi*, marked with fluorescent dye, were released at dusk and monitored for 14 days using yellow sticky traps placed at different distances (5–160 m) and directions from the release point. *C. storeyi* catches decreased steadily with distance from the release point and exponentially with time following the release. The mean leafhopper dispersal rate varied between 2.6 and 2.8 m/day for dry season and rainy season tests, respectively. The dispersal rate increased with distance from 1.44 m/day at 5 m to 13.62 m/day at 160 m. Wind was a major factor affecting direction of leafhopper movement with the largest proportion of *C. storeyi* collected downwind. The suitability of maize growth stage for settling by *C. storeyi* was also investigated. *C. storeyi* preferred young (2–6 weeks after planting) over old maize.

***Ayertey, J.N., W.G. Meikle, C. Borgemeister, M. Camara, and 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 a minor role as an alternative prey or in interfering with *T. nigrescens* reproduction.

***Bolaji, O.O. and N.A. Bosque-Pérez. Life history and mass rearing of* Mussidia nigrivenella *Ragonot (Lepidoptera: Pyralidae) on an artificial diet in the laboratory. African Entomology 6(1) (in press).***

Life history of *Mussidia nigrivenella* Ragonot was studied at 26 ± 2 °C, 65 ± 5% R.H. in the laboratory. When reared on an 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 towels were compared for preference by *M. nigrivenella*. In both multiple and no-choice tests, paper towels folded diagonally and 21 x 21 units plastic mesh had significantly more eggs laid on them than other substrates.

***Bonato, O. and Schulthess, F. A simulation model for carbon and nitrogen allocation and acquisition in maize. Ecol. Model. (submitted).***

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) and 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-day 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.

***Borgemeister, C., W.G. Meikle, D. Scholz, C. Adda, P. Degbey, and R.H. Markham. Seasonal and meteorological factors influencing the annual flight cycle of* Prostephanus truncatus *(Coleoptera: Bostrichidae) and its predator* Teretriosoma nigrescens *(Coleoptera: Histeridae) in Benin. Bulletin of Entomological Research (in press).***

Investigations were carried out in southern Benin on the annual flight cycle and the effects of weather variables on the flight activity of *P. truncatus* and its natural enemy, *T. nigrescens*. Two seasonal peaks in flight activity of *P. truncatus* were observed, one between the end of December and the beginning of January and a second one between May and June. *T. nigrescens* showed a single delayed peak in June, approximately 6 weeks after the major peak of *P. truncatus*. Flight activity of *P. truncatus* was only weakly associated with weather characteristics (standardized regression coefficient for mean daily temperature $b = 0.18$, $t = 2.87$, $P < 0.05$), whereas for *T. nigrescens* it was associated with precipitation (standardized regression coefficient for accumulated rainfall during the trapping period $b = 0.38$, $t = 4.76$, $P < 0.05$). The possibility that one of the *P. truncatus* peaks was associated with dispersal from crowded maize stores and the other with the search for natural woody host-plants is discussed.

***Borgemeister, C., G. Goergen, S. Tchabi, A. Awande, R.H. Markham, and D. Scholz. 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 (in press).***

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 enemies, the histerid predator *T. nigrescens*, with twigs girdled by an indigenous cerambycid. We found more *P. truncatus* directly above the girdling site than anywhere else. *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., F. Djossou, C. Adda, H. Schneider, B. Djomamou, K. Azoma, and R.H. Markham. 1997. Establishment, spread and impact of* Teretriosoma nigrescens *Lewis (Coleoptera: Histeridae), an exotic predator of the larger grain borer* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae), in south-western Benin. Environmental Entomology 26: 1405–1415.***

Studies were carried out between 1992 and 1997 in southwestern Benin to investigate the establishment, spread, and impact of *T. nigrescens*, a natural enemy of the larger grain borer, *P. truncatus*. Trap data, using the 2-component synthetic aggregation pheromone of *P. truncatus*, from 5 different surveys, carried out twice yearly over a 3-yr period, showed a rapid establishment and spread of the predator throughout the region. Increasing numbers of *T. nigrescens* in the pheromone traps were associated with decreasing numbers of *P. truncatus*. Pheromone trap data, collected weekly at a small number of sites over the entire study period, revealed a yearly bimodal peak in flight activity of *P. truncatus* in 1992, 1993, and 1994. The 1st peak in flight activity of *P. truncatus* was sharply reduced in 1995, 1996, and 1997, accompanied by increasing numbers of *T. nigrescens* in the pheromone traps. Data from on-farm storage experiments and from surveys in farm-stored maize, *Zea mays* L., showed a considerable reduction of *P. truncatus* infestation, and decreasing losses of maize, coinciding with the increasing presence of *T. nigrescens*.

***Borgemeister, C., C. Adda, M. Sétamou, K. Hell, B. Djomamou, R.H. Markham, and K.F. Cardwell. 1997. Timing of harvest in maize: Effects on postharvest losses due to insects and fungi in Central Benin, with particular reference to* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae). Agriculture, Ecosystems and Environment (in press).***

A storage experiment was conducted in Banté, 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 8 months. The main results were: (1) Leaving the maize in the field for extended periods after physiological maturity resulted in severe grain losses after eight months of storage. (2) Most of the grain losses were attributed to *Prostephanus truncatus*. (3) Early harvested maize had a higher proportion of mouldy grain. (4) Harvest date had no consistent effect on the level of aflatoxin contamination. (5) Based on a participatory evaluation of maize quality by local farmers, the economic value of maize stored for 8 months was highest in maize harvested 3 weeks after physiological maturity.

***Borgemeister, C., A. Tchabi, and D. Scholz. Trees or stores? The origin of migrating* Prostephanus truncatus *collected in different ecological habitats in southern Benin. Entomologia Experimentalis et Applicata (in press).***

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 periurban 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 wood, 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 periurban site. At the forest site, most beetles had lignin in their guts, while the proportion of beetles containing starch was highest in the periurban 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.

***Bosque-Pérez, N.A., S.O. Olojede, and 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. and F. Schulthess. Maize: West and Central Africa. Pages 11–24 in: A. Polaszek (ed.). African Cereal Stemborers. CAB International, England. (In press.)***

***Cardwell, K.F., J. Kling, and C. Bock. 1997. Comparison of field inoculation methods for screening maize against downy mildew (*Peronosclerospora sorghi*). Plant Breeding 116: 221–226.***

Methods of inoculum delivery and timing of test row planting were assessed for efficacy in promoting development of downy mildew (*Peronosclerospora sorghi*) in susceptible maize, and for cost of implementation in terms of personnel and labor. Direct inoculation of pre-germinated seed of spreader rows resulted in consistent and high incidence of downy mildew infected plants and required substantially less labor and inoculum than the spray inoculation of spreader rows. The optimum time to plant test rows was around 15 days after inoculation of spreader rows. Eight breeding lines were screened for resistance to downy mildew using the revised inoculation method. After one cycle of screening with the new method, resistance levels improved by a range of 0 to 44 % over the previous cycle.

***Cardwell, K., F. Schulthess, R. Ndemah, and Z. Ngoko. 1997. A systems approach to assess crop health and maize yield losses due to pests and diseases in Cameroon Ecosyst. Agric. Environm. 65: 33–47.***

Three surveys of maize fields were undertaken in 1993 in Cameroon, ranging from low to high altitudes, and from the forest in the south with bimodal rainfall (two cropping seasons) to northern savanna agroecologies with monomodal rainfall distribution (one cropping season). Field conditions, insects and diseases, plant growth, and yield variables were assessed in 164 fields. Increased soil fertility (expressed as plant vigor) favored *Bipolaris maydis*, *Physoderma maydis*, and *Busseola fusca*. There was a positive relationship of soil organic matter with *B. fusca*, *E. saccharina*, and *B. maydis*. As organic matter decreased, percent leaf area lost to pathogens, particularly *Puccinia sorghi*, increased. There was an inverse relationship between wild grasses around a field and stemborers in the field. Increased weediness within the field was positively correlated with *Exserohilum turcicum* and stem lesions. Stem diameter, cob fill and weight increased with altitude reflecting the change in germplasm from early maturing lowland varieties to very late maturing mid- to high-altitude

varieties. Across ecological zones and surveys, *B. fusca* accounted for 95% of all the species found on maize, followed by *Eldana saccharina*. In the first cropping season, mean percent borer infestation was similar in lowlands and highlands with a mean of 43%. Borer incidence was highest during the second cropping season. In both low and midaltitude fields, 52–56% of the plants were infested resulting in cob weight loss calculated at 9 g per plant. At that time, the average plant loss due to dead hearts across zones was 11%. *B. maydis, Puccinia polysora,* and *Physoderma maydis* were predominant in the lowlands, while *E. turcicum, P. sorghi,* and *Phaeosphaeria maydis* were mainly mid- to high-altitude pathogens. Maize streak virus, *B. maydis, Rhizoctonia solani,* and *Puccinia sorghi* had a significant negative impact on cob weight. The etiology of stem lesions was not determined, but they significantly affected cob weight in the humid lowlands. Average reduction in cob weight due to foliar and stem diseases in the different ecological zones and seasons ranged between 10 and 12 g per plant.

***Cardwell, K.F., and T. Wehrly. 1997. A nonparametric significance test for combating crop disease. Biometrics 53: 207–218.***

Many species of plant pathogens vary genetically in ability to cause disease on a given hostplant. Conversely, plant populations often have variability with respect to a gene or series of genes that provide resistance to a given pathogen. In many cases, crop plants were bred for homogeneous, highlevels of genetic resistance to a disease and then lost the resistance, often catastrophically. This has led plant protectionists to seek ways to develop stable resistance to plant pathogens that are variable by nature. A nonparametric procedure that tests for variation among populations of a specific pathogen at different locations is described. Critical values and *P*-values are developed via simulation and tested. The same procedure can be used to determine the reaction of a specific crop variety to a pathogen under different environmental conditions or a different locations, and to look for stability across environments. A set of differential varieties that is stable across environments is used to characterize pathogen populations across environments.

***Chabi Olaye, A., F. Schulthess, T.G. Shanower, and N.A. Bosque-Pérez. 1997. Factors influencing the bionomics of* Telenomus busseolae *(Gahan) (Hym.: Scelionidae) an egg parasitoid of* Sesamia calamistis *Hampson (Lep.: Noctuidae) Biological Control, 8: 15–21.***

The effect of seven constant temperatures on the development of *Telenomus busseolae* was determined, using *Sesamia calamistis* eggs as the host. The developmental threshold calculated was 13.7 °C, the optimum temperature was 31 °C, and the maximum temperature at which no parasitoid emergence occurred was 34 °C. Female *T. busseolae* began ovipositing immediately after emergence. They produced more offspring during the first 24 hours of adult life than during any subsequent , At 20 °C, adult females lived twice as long as those at 30 °C (21.7 and 11.0 days, respectively). Total progeny of *T. busseolae* was significantly higher at 27 °C than any subsequent temperature. Mean fecundity ranged from 61 to 182 offspring per female. The effect of host age and host deprivation on the host parasitization rate, egg viability and of sex ratio of *T. busseolae* was also investigated. Only parasitism and emergence rates were affected by host age. The numbers of total progeny were the same between 0 and 10 days of host deprivation, whereas longevity tended to increase from 12.8 to 23.4 days from 0 to 14 days of withholding hosts. Percent parasitoid emergence and sex ratio was not affected by withholding hosts. *T. busseolae* is adapted to an ecosystem with strong environmental fluctuations that cause temporary scarcity of hosts and food.

***Gudrups, I., S. Floyd, and 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 (OPs) varieties, the local varieties were generally more susceptible. This may be related to kernel size, as all improved OPs 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.*

***Hailemichael, Y., F. Schulthess, J.W. Smith, jr., and W.A. Overholt. 1997. Suitability of West African gramineous stemborers for the development of* Cotesia *species (Hymenoptera: Braconidae). Insect Sci. Appl. 17: 89–95.***

The gregarious, endoparasitic paleotropical braconids, *Cotesia sesamiae, Cotesia flavipes,* and *Cotesia chilonis,* were recently imported into Benin as candidates for biological control of stem and cobborers of maize. Host acceptability and host suitability of six gramineous borers occurring in western Africa (the noctuids *Sesamia calamistis, Sesamia poephaga, Busseola fusca,* and the pyralids *Coniesta ignefusalis, Eldana saccharina,* and *Mussidia nigrivenella*) to these candidate parasitoids was evaluated to gain insight into the physiological suitability of these natural and factitious hosts. All hosts were accepted by all *Cotesia* spp., except *M. nigrivenella* which was not attacked by *C. chilonis.* Parasitoid progeny development was successful in *S. calamistis, S. poephaga,* and *C. ignefusalis. S. calamistis* was the most suitable host for *Cotesia* spp. development, in terms of duration of developmental time, brood size, and mortality of parasitoid progeny.

***Meikle, W.G., C. Adda, K. Azoma, C. Borgemeister, P. Degbey, B. Djomamou, and 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(1): 4–59.***

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, D. Scholz, and 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 that of field data well, 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, and N. Holst. Distribution and sampling of* Prostephanus truncatus *(Horn) (Coleoptera: Bostrichidae) and* Sitophilus zeamais *Motschulsky (Coleoptera: Curculionidae) in maize stores in Benin. Journal of Economic Entomology (submitted).***

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.

***Oussou, R.D., W.G. Meikle, and R.H. Markham. Factors affecting the survivorship and development rate of larvae of* Teretriosoma nigrescens *Lewis (Coleoptera: Histeridae). Insect Science and its Application (submitted).***

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 adulthood, 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, R.H. Markham, and H.-M. Poehling. 1997. Flight initiation in* Prostephanus truncatus*: influence of population density and aggregation pheromone. Entomologia Experimentalis et Applicata (in press).***

The influence of population density and aggregation pheromone were investigated as possible flight initiating factors for *Prostephanus truncatus* (Horn) (Col.: Bostrichidae). Flight initiation of the progeny was observed over a period of 4 weeks using four initial insect densities (20, 50, 150, and 300 beetles on 175 g maize grains) and the synthetic aggregation pheromone of *P. truncatus*. The number of beetles dispersing increased with increasing initial and progeny densities. For progeny densities of up to 400 per jar, the dispersal rate (% of total progeny dispersing) rose steadily with increasing densities. However, for progeny densities greater than 400, no further increase could be observed. Within this high progeny level, the dispersal rate averaged 32%. The addition of the artificial pheromone had no influence, either on the number of beetles flying off or on the dispersal rate. Of the beetles dispersing, 74% left the cultures between 18.00 and 20.00 hours. Surviving progeny per female decreased with increasing initial density. The sex ratio in the initial cultures and in the F1 was ca. 1:1, whereas a higher proportion of females (67%) was found among the dispersing beetles.

***Scholz, D., C. Borgemeister, W.G. Meikle, R.H. Markham, and H.-M. Poehling. 1997. Infestation of maize by* Prostephanus truncatus *initiated by male-produced pheromone. Entomologia Experimentalis et Applicata 83: 53–61.***

Delta traps baited with maize cobs, which were infested each with one male *Prostephanus truncatus* (Horn) (Col.: Bostrichidae), were distributed in southern Benin and collected 1, 2, 3, and 4 weeks. The numbers of *P. truncatus* caught during the different trapping periods were not significantly different. Of the trapped *P. truncatus*, 64% were females. Females attracted during the 1 week trapping period produced a mean of 6.9 progeny during the 7 days. The sex ratio of the progeny was 1:1. Trap catches with the infested cobs were on average 13 times lower than catches with 2 mg of the artificial pheromone. Estimation of *P. truncatus* densities in a maize store at the beginning of the storage period (based on laboratory data) revealed that very small initial numbers of *P. truncatus*, possibly attracted by a single male, sufficed to initiate high infestation rates later in the storage season.

***Scholz, D., A. Tchabi, C. Borgemeister, R.H. Markham, H.-M. Poehling, and A. Lawson. Host finding behavior of* Prostephanus truncatus*: primary attraction or random attack? Journal of Applied Entomology (in press).***

Host-finding behavior of *Prostephanus truncatus* was evaluated in a four-choice olfactometer for reactions to odors of maize, cassava chips, wheat, cowpea (a nonhost plant), and woody plant species in which reproduction has been observed, and of organisms associated with maize stores. *P. truncatus* reacted in general to odors from starchy commodities and to some of the woody plants. Beetles did not respond to volatiles from cowpea or organisms associated with maize stores, but did react to the aggregation pheromone produced by single male *P.* truncatus (secondary attraction). *P. truncatus* raised on cassava and emigrants from maize responded as strongly to maize odors as beetles raised on maize, whereas *P. truncatus* trapped with pheromone traps showed reduced or no reactions. Stored commodities seem to elicit short-range arrestment, but not primary attraction at long range. However, stored products might only be attacked facultatively by *P. truncatus*, coevolved primary attraction could possibly exist to the native host-plant complex.

***Schulthess, F., N.A. Bosque-Pérez, A. Chabi-Olaye, S. Gounou, R. Ndemah and G. Goergen. 1997. Exchanging natural enemies species of lepidopterous cereal stemborers between African regions. Insect Sci. Appl. 17: 97–108.***

The difficulties in identifying candidates of natural enemies of cereal stemborers for "redistribution" in Africa are discussed. Establishing a catalog of natural enemies and mapping their geographic distribution is only the first step. Tritrophic level studies in wild and cultivated habitats of borers and beneficials at selected sites are needed to judge the impact of a natural enemy species in the cropping system. For selection of such sites, areas with low-pest pressure but climatically favorable for pest development, have to be identified.

Based on the results of various countrywide surveys to map the relative importance of *Sesamia, calamistis, Eldana saccharina* and *Busseola fusca* in western Africa, recommendations are given for sites for tritrophic level studies.

It is hypothesized that because of the short presence of maize in the field and its high susceptibility to stem damage biological or naturally occurring control has to take place in the wild habitat of borers. This emphasizes the importance of the knowledge of the wild host-plant range. Survey results complemented with oviposition and life-table studies in the lab showed that most wild grass species act as trap plants causing mortalities of 100% rather than being reservoirs for pests responsible for outbreaks on crops. A comparison of light trap catches with pupae found on wild hosts and the scarcity of known wild hosts in areas with high pest pressure suggests gaps in our knowledge of the range of host-plant species.

Based on a comparison of known natural enemy complexes in East and West Africa, the scelionid egg parasitoid *Telenomus isis* and an East African strain of the braconid larval parasitoid *Cotesia sesamiae* are proposed for redistribution against *B. fusca* and *S. calamistis*, respectively. The former has never been reported from East Africa whereas the latter is common in East and Southern Africa but exceedingly scarce in western Africa suggesting that it is probably not adapted to *S. calamistis* and *B. fusca* in this region.

***Sétamou M., K.F. Cardwell, F. Schulthess, and K. Hell. 1997. Effect of insect damage to maize ears, with special reference to the earborer* Mussidia nigrivenella, *on* Aspergillus flavus *infection and aflatoxin production in preharvest maize in the Republic of Benin. J. of Econ. Entomology (in press).***

Preharvest maize infection by *Aspergillus flavus* and subsequent aflatoxin contamination as affected by insect pest damage to maize ears was studied via surveys in farmers' fields and in an 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 earborer 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.

***Sétamou M., K.F. Cardwell, F. Schulthess, and K. Hell. 1997.* Aspergillus flavus *infection and aflatoxin contamination of preharvest maize in the Republic of Benin. Plant Disease 81: 1323–1327.***

Eighty and sixty maize fields were sampled in 1994 and 1995, respectively, to monitor *Aspergillus* infection and aflatoxin contamination of preharvest maize in Benin. Three *Aspergillus* species were isolated from different agroecological zones with *A. flavus* being the most prevalent. The countrywide mean percentage of kernel infection was about 20% in both years. Aflatoxin was extracted from maize in at least 30% of the fields sampled. Toxin concentrations exhibited a distinct zonal variation with relatively high levels in the Guinea savanna. There was a trend towards higher rate of aflatoxin accumulation per percentage *A. flavus* infection from the south to the north. Damage by the earborer, *Mussidia nigrivenella,* increased toxin accumulation in maize. Hence, the geographic pattern observed in the occurrence of *A. flavus* and aflatoxin may be related to the incidence of *M. nigrivenella.*

***Scholz, D., C. Borgemeister, and H.-M. Poehling. Electrophysiological, and behavioral responses of the larger grain borer,* Prostephanus truncatus, *and its predator,* Teretriosoma nigrescens, *to the borer-produced aggregation pheromone. Physiological Entomology (in press).***

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 behaviorally differentiate between the pheromone components.

***Scholz, D., C. Borgemeister, R.H. Markham, and H.-M. Poehling. Physiological age-grading and ovarian physiology in* Prostephanus truncatus. *Physiological Entomology (in press).***

The reproductive systems of male and female *Prostephanus truncatus* were described for beetles between emergence and 30 days old, and an age-grading method was developed for females based on yellow body development. Females migrating under semifield conditions and caught with pheromone traps were of varying physiological age and mated, and their ovarian development was suspended. The applicability of migration theories on *P. truncatus* and adaptive interreproductive dispersal as part of its life history strategy are discussed, and the role of females as additional colonizers suggested.

## Conference papers, workshop proceedings, abstracts, newsletters

***Adenle, V.O. and K.F. Cardwell. 1997. The seed-borne nature of* Peronosclerospora sorghi, *downy mildew disease of maize. Pages 317-321* in *(Badu-Apraku et al., eds.) Contributing to food self-sufficiency: Maize Research and Development in West and Central Africa. Proceedings of a Regional Maize Workshop 29 May–2 June 1995, IITA, Cotonou, Benin. 404 pp.***

The downy mildew (DM) disease of maize, incited by *Peronosclerospora sorghi,* is one of the most damaging crop diseases in Nigeria. The maize strain of the pathogen is thought to survive the dry season on maize plants in hydromorphic valleys in southwest Nigeria. Kernels harvested from a heavily infected farmer's field were subjected to histological studies which clearly revealed the presence of mycelium in the endosperm, scutellum, and embryo of the maize kernels. Two susceptible maize varieties and cultivar of sweet corn have been observed for further evidence of internally seedborne *P. sorghi* viz: (1) Pool-16, (2) Funtua-88TZSR-W, and (3) Sweet corn. *P. sorghi* mycelia were observed in the kernels of all three.

Most Nigerian small-scale farmers buy grain for seed from the local market or used their saved seed. Mycelium may remain viable on improperly dried seed and could be a source of primary infection. Inoculum within seeds is an important means by which many pathogens reach areas hitherto free from disease. Seed borne mycelium could be one mode of survival of this pathogen and could account for its recent sporadic spread now under study.

***Adenle, V.O. and K.F. Cardwell. 1997. Downy mildew diseases of maize in Nigeria. Pages 241:244* in *(Ransom, Palmer, Zambeze, Mduruma, Waddington, Pixley, and Jewell, eds.) Maize Productivity Gains Through Research and Technology Dissemination: Proceedings of the fifth Eastern and Southern Africa Regional Maize Conference. Arusha, Tanzania, 3–7 June 1996. Addis Ababa, Ethiopia: CIMMYT.***

***Adenle, V.O. and K.F. Cardwell. First report of oospores of* Peronosclerospora sorghi *in maize in Nigeria and the significance in seed transmission. To appear in proceedings of the 1997 WECAMAN Workshop, IITA-COTONOU, May 1997 (in press).***

Maize seed from systemically downy-mildew infected plants from southern Nigeria (maize pathotype) were subjected to histological studies to detect oospores. Also some leaf symptoms viz: narrow leaf, half leaf, and crazy top symptoms were examined for oospores. Oospores of *P. sorghi* (maize pathotype) were found in 3 of 120 seeds and were detected in the leafy proliferations of the crazy top symptom, but not in the leaves. This was the first report of finding oospores in the plant from the maize strain, and it is very significant from the epidemiological point of view. The downy mildew species that produce oospores in maize present the greatest threat of long distance dispersal and provide an off-season survival mechanism in the area to which they are introduced. This is the first report of oospores in maize pathotypes since three decades of active research on downy mildew in Nigeria.

***Bigirwa, G., E. Adipala, P. Esele, and K.F. Cardwell. 1997. Disease progress of* Peronosclerospora sorghi *on some Ugandan maize genotypes. Pages 229–232* in *(Ransom, Palmer, Zambeze, Mduruma, Waddington, Pixley and Jewell, eds.) Maize Productivity Gains Through Research and Technology Dissemination: Proceedings of the fifth Eastern and Southern Africa Regional Maize Conference. Arusha, Tanzania, 3–7 June 1996. CIMMYT: Ethiopia.***

The type and level of disease reaction of Ugandan maize genotypes to *Peronosclerospora sorghi* was characterized using several variables during the second season of 1994 at two locations, Nagaretti in Mpigi district and Ikulwe in Iganga district. Maize genotypes differed significantly ($P < 0.05$) in susceptibility as determined by the rate of disease increase, area under disease progress curve, and disease incidence. The Gompertz model was the most appropriate to describe the epidemics. Analysis of the parameters of the fitted models and other variables indicated that hybrid NZ1, Farida, and Pool 16 were the most susceptible while Longe 1 and 102 were moderately resistant. At Nazaretti there were significant differences in the epidemic onset.

***Borgemeister, C., C. Adda, R.H. Markham, R. Oussou, D. Scholz, H. Schneider, W.G. Meikle, and 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: Benin, Kenya, Ghana, and Togo. The establishment and rapid spread of the predator across Benin has been monitored using pheromone traps. Despite earlier concerns regarding host specificity, biochemical analysis indicates that the great majority of prey consumed are of the target pest, while laboratory life-table studies have confirmed that the predator has appropriate biotic characteristics to act as a successful control agent. Analysis of the effect of meteorological factors on the flight activity of the predator revealed, that both in the Neotropics and in West Africa weather data alone can not sufficiently explain the flight cycle of the beetle. Follow-up studies are now being carried out to evaluate the actual impact of the predator on pest populations and damage in stores.

***Bosque-Pérez, N.A., J.G. Kling, and S.I. Odubiyi. 1997. Recent advances in the development of sources of resistance to pink stalk borer and African sugarcane borer. Pages 234–240. In: J.A. Mihm (ed.). Insect Resistant Maize: Recent Advances and Utilization; Proceedings of an International Symposium held at the International Wheat and Maize Improvement Center (CIMMYT), Mexico, D.F.: CIMMYT.***

The lepidopterous stemborers *Sesamia calamistis* Hampson and *Eldana saccharina* (Walker), are among the most important insect pests of maize in West Africa. Efforts to breed for resistance to these two borer species are an integral part of a project to develop control practices for maize pests at IITA. Since 1985, a wide diversity of maize germplasm has been screened for reaction to infestation by either *S. calamistis* or *E. saccharina*. Three populations with moderate resistance to *E. saccharina* (TZBR Eldana 1, 2, and 3) and 2 with moderate resistance to *S. calamistis* (TZBR Sesamia 1 and 3) were formed in the late 1980s, and are being improved for adaptation and resistance levels primarily through $S_1$ family testing. The populations are intended as sources of resistance to be used by African national breeding programs as well as by colleagues in other parts of the world.

TZBR Eldana 3 was developed from elite, adapted populations and has performed well in multilocational yield trials in Nigeria and Côte d'Ivoire. TZBR Eldana 1 is derived from exotic germplasm and is less adapted to the lowland humid tropics. A selection index which combines agronomic characteristics and *E. saccharina* resistance, is used to improve the TZBR Eldana populations. Cycles of selection trials with these populations have shown continual progress in selecting for resistance to *E. saccharina*.

Of the two *Sesamia* populations, TZBR Sesamia 3 appears to have higher levels of resistance than TZBR Sesamia 1. Future selection will be based on improved agronomic characteristics and disease resistance levels, concurrent with higher levels of resistance to *S. calamistis*.

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

Studies have been conducted in Nigeria on the biology of *Cicadulina* leafhopper vectors of maize streak virus (MSV), on the role of indigenous grasses as reservoirs of virus and vectors, and on incidence and severity of MSV in relation to maize varietal susceptibility/resistance levels. *Cicadulina* populations peak before the rains end in the savanna and after the rains in the forest zone. The proportion of viruliferous leafhoppers increases as the season progresses. *C. mbila* is the predominant vector species; four other species are less common. *C. arachidis* transmits MSV inefficiently and is believed not to be of importance in disease epidemics.

Off-season survival of MSV and vectors occurs mostly in riverine areas in grasses and in areas with hydromorphic soils where maize is grown during the dry season. However, streak found in many grasses in Nigeria is not readily transmissible to susceptible field maize. The weeds most likely to be involved in perpetuating an epidemiologically competent MSV maize strain are *Axonopus compressus* (an introduced perennial), *Brachiaria lata,* and *Setaria barbata* (indigenous annuals). MSV epidemics occur only in years with favorable weather conditions which allow vector survival and build-up, and where maize-competent strains are present in grass hosts. MSV disease reduces maize yield, but varieties differ in amount of loss, disease severity and incidence. Resistant varieties exhibit tolerance—good yield performance when diseased—and lower disease incidence or tolremicity. Low disease incidence is partly due to insect resistance and the potential for disease spread is lower on varieties exhibiting this character.

***Cardwell, K.F., V. Adenle, J.G. Kling and S.O. Ajala. A maize downy mildew eradication campaign in Nigeria - What Works and What Doesn't. Phytopathology (in press).***

A national campaign to control maize downy mildew (*Peronosclerospora sorghi*) began in 1993 in Nigeria. The campaign consists of: technology development, extension, distribution of control inputs, and economic and policy components. IPM recommendations are deployed with the objective of lowering ambient inoculum enough to break the yearly epidemic cycle. WHAT WORKS: Downy mildew resistant (DMR) varieties are available, and new inoculation methods are improving resistance. Apron+® seed dressing chemical is available and 100% effective when used at the commercially recommended dose. Extension messages are creating farmer demand for DMR seed and seed dressing chemicals, and recognition of the disease and of the importance of early planting and rouging of infected plants. WHAT DOESN'T WORK: Due to unfavorable economic factors, Apron+® has not been widely distributed. Due to unfavorable policies, production and distribution of DMR seed has been a severe bottleneck. OUTLOOK: the obstacles to deployment of seed dressing and resistant seed are being addressed. In spite of logistic difficulties, spore trap data show declining ambient conidial deposit/mm$^2$ since 1994, although in 1996 the disease continued to spread. Eradication is unlikely as seed transmission of the disease has been demonstrated in 1996.

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

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, 27–73% of the stores were contaminated with an average of 37 ppb aflatoxin during the 2-year period. Maize in all zones was found to have risk of contamination, but the degree of risk by zone was not consistent between countries, indicating that farming practices had as much influence as climate. The Humid Forest zone had significant risk only in Nigeria when farmers stored maize on the floor of a room. The southern Guinea savanna had high risk in both countries, with 25–30% of the stores contaminated early in the storage period. Factors significantly related to high toxin levels in that zone were insect damage, crop system, prolonged field drying, and sorting practices. Maize stores in the northern Guinea savanna of Nigeria had the lowest incidence and the least toxin contamination, while in Benin the highest incidence, 73%, occurred in this zone in 1994. Crop rotation, use of insecticide and fertilizer, field drying, and storage system were significant factors related to contamination. The Sudan savanna, bordering the Sahel, had the most consistent risk of high aflatoxin contamination, averaging 305 ppb across years. In

summary, maize is a primary staple for human consumption in Benin and Nigeria, and many people are being exposed to aflatoxin levels well above accepted standards. Little is known about the year to year variability of contamination in West Africa so it is unclear if the contamination levels during this sampling period were typical.

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

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 elongated 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.

***Djaman, K. 1997. Le Role des maladies des insect dans l'ecosystem des foreurs de tige a mineurs d'épi du maïs. Mémoires Ing. Agr. Univ. du Benin, Togo.***

L'objectif de la présente étude est de faire l'inventaire des entomopathogènes associés aux foreurs de tige et mineurs d'épi du maïs dans différents agroécosytèmes et de les tester sur des larves saines au laboratoire afin de faire ressortir leur efficacité contre ces ravageurs. Pour l'inventaire, la méthode était triple:

1. Echantillonnage d'une station surveillée : infestation artificielle du mais avec les œufs de *E. saccharina et S. calamistis* sur la parcelle d'expérimentation de l'IITA pour la collecte dans le temps des larves mortes et vivantes pouvant être en incubation.
2. Prospections par transect et maillage : Bénin, Caméroun, Ghana et Nigéria
3. Exposition des larves de *E. saccharina* et de *S. calamistis* sur le sable des forêts de Djougou, Pénéssoulou, Tchaourou, de champs d'Agbogbohonou et station IITA.

Les bactéries *Bacillus thuringiensis, Serratia marcescens* et des cocci, les champignons *Beauveria* sp., *M. anisopliae*, des protozoaires *Nosema* sp. et des grégarines, du NPV et des nématodes de la famille des Mermithidae sont les entomopasthogènes isolés et identifiés sur des larves de *A. ignefusalis, B. fusca, E. saccharina, M. nigrivenella, S. calamistis* et du sol. L'activité pathogène sur trois espèces de foreurs *E. saccharina, M. nigrivenella, S.calamistis* a été démontrée avec les isolats 93 de Bt, 82 de *Beauveria* sp. et 178 de *M. anisopliae.* Quatre doses sont choisies: 0, 10^4, 10^5 et 10^6 spores/larve pour Bt contre 0, 10^5, 10^6 et 10^7spores/larve pour *Beauveria* sp. *M. anisopliae.* De ces tests il ressort que *E. saccharina, M. nigrivenella, S. calamistis* sont tous susceptibles aux isolats de Bt, *Beauveria* sp et *M. anisopliae* utilisés mais l'aptitude à infecter et à causer la mort varie suivant les espèces de pathogènes. Ainsi *M. anisopliae* provoque une mortalité plus élevée (88 à 100%) dans des délais très courts avec TL50 entre 1.61 et 5.81 jours contre 4.2- 15.5 jours pour *Beauveria* sp et 1.14 - 13.5 jours pour le Bt. Le temps d'incubation des maladies parait plus longue chez les larves de S. calamistis (TL50 entre 21 et 4.24 jours) que chez saccharina (TL50 entre 15.5 et 1.35 jours) et *M. nigrivenella* (TL50 entre 13.5 et 1.14 jours). *S. calamistis* s'est montré un peu résistante au Bt (DL50 > 10^6) et aux Hyphomycètes *Beauveria* sp. et *M. anisopliae* par une mélanisation sur sa cuticule autour des hyphes pénétrantes.Outre l'effet léthal, le Bt a induit une réduction de la nutrition, une malformation des chrysalides (6%) de *S. calamistis* et des imagos (13%) de *E. saccharina* et *S. calamistis* et une baisse de la fécondité des mêmes espèces.

***Hell, K. 1997. Distribution and incidence of* Aspergillus spp. *in maize in Benin and resultant contamination of maize grains by aflatoxin compounds in relation with agroecological zones. PhD Dissertation, University of Hannover. December 1997.***

Carcinogenicity of aflatoxin is well documented. Information on aflatoxin related carcinomas in Nigeria, showed significantly higher incidence rates than in Europe and USA. Despite the important consequences for human health and nutrition, fungal infections of maize and aflatoxin contamination have not been adequately analyzed in Benin. In this study, aflatoxin contamination in farmers' stores, were analyzed over a 2-year period. Questions concerning management practices were asked at each of the collection sites to find out about the farmers' maize production, harvest, and storage practices. Regression analyses were used to assess which farming practices were associated with high risk of aflatoxin contamination. On-station trials evaluated some of the possible causes of increased or decreased risk of aflatoxin contamination. These field trials tested the influence of maize variety, husk cover, storage form, harvest timing, insect infestation, and influence of plants on the reduction of aflatoxins.

***Lega, K.B., 1997. Influence de la densité larvaire de* Sesamia calamistis *(Lep: Noctuidae) Hamps et* Eldana saccharina *WLK (Lep: Pyralidae) sur l'efficacité de trois parasitoides larvaires:* Cotesia sesamiae *Cameron,* C. flavipes *Cameron, et* C. chilonis *Matsumura (Hym: Braconidae). Mémoires Ing. Agr. Univ. du Benin, Togo.***

L'objectif du présent travail est de donner un aperçu sur le comportement parasitaire de trois espèces de *Cotesia* spp. sur le complexe d'espèces hôtes *S. calamistis* et *E. saccharina* en conditions de laboratoire et au champ.

Au laboratoire, quatre densités de larves de *S. calamistis* et de *E. saccharina* ont été composées dans deux essais différents. Pour le premier essai, la densité des deux foreurs a varié simultanément; à savoir d(8;0), d(6;2), d(4;4) et d(2;6). Et pour le second essai, la densité de *S. calamistis* est maintenue fixe: d(4;0), d(4;2), d(4;4) et d(4;6). Pour chaque essai, les tiges de mais infestées avec les différentes densités sont introduites dans des cages et cinq femelles de chaque espèce de *Cotesia* spp. sont lâchées pour un test de choix multiple. Les larves et les parasites y sont maintenus pendant 48 heures. Les résultats ont montré que le pourcentage de larves de *S. calamistis* parasitées par *Cotesia* spp. diminuait avec les densités croissantes de *E. saccharina*. Cette baisse du pourcentage de larves parasitées est beaucoup plus remarquable chez *C. flavipes* et *C. chilonis*.

Au champ, trois densités de larves de *S. calamistis* sont utilisées pour infester individuellement des tiges de mais, à savoir 1,2, et 4 larves. Après l'infestation, cent femelles de *C. sesamiae* sont lâchées dans le champ. Les résultats ont montré que l'ampleur du parasitisme par *C. sesamiae* augmente avec la densité de larves de *S. calamistis* par tige.

***Meikle, W.G., N. Holst, C. Nansen, J.N. Ayertey, B. Boateng and R.H. Markham. Developing decision-support tools for postharvest 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 postharvest 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 a 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.

***Oussou, R.D., P. Degbey, W.G. Meikle, B.A. Boateng and R.H. Markham. Submitted. 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 socioeconomic 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.

***Scholz, D. 1997. Dispersal and host finding behaviour of* Prostephanus truncatus *(Horn) (Col.: Bostrichidae). PhD thesis, University of Hannover, Germany. 146 p.***

***Schulthess, F. and 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 broadbased 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 the 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 midaltitudes and highlands. The ecosystem analysis yielded several control options such as forms of biological control [new associations (i.e., the use of noncoevolved 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.

***Sémeglo, A.K. 1997. Etude comparative de la bioecologie de trois Noctuidae foreuses de tige de céréales (*Sesamia calamistis *Hampson,* S. poephaga *Tams and Bowden and* Busseola fusca *Fuller) sur* Zea mays *et quelques Poacae sauvages. Mémoires Ing. Agr. Univ. du Benin, Togo.***

La présente étude vise à mieux gérer l'habitat des foreurs de tiges et mineurs d'épis dans un programme de lutte biologique contre ces ravageurs à l'IITA-Bénin. Deux expériences ont été conduites à cet effet au laboratoire.

Dans la première expérience, des larves de *Sesamia calamistis* Hampson, *Sesamia poephaga* Tams et Bowden et de *Busseola fusca* Fuller ont été élevées à la température de 25 °C sur des fragments de tiges de *Zea mays* L. et de six plantes hôtes sauvages toutes indigènes d'Afrique: *Andropogon gayanus* Kunth, *Panicum maximum* Jacq., *Pennisetum pedicellatum* L., *Pennisetum polystachion* (Linn) Schult., *Pennisetum purpureum L.* et *Sorghum arundinaceum* (Desv) Stapf.. Les différents paramètres $R_O$ (le taux net de production), $r_m$ (le taux intrinsèque d'accroissement naturel), G (la durée de génération) qui affectent la dynamique de la population ont été enregistrés chez les différents insectes élevés sur diverses plantes hôtes et dont les femelles obtenues ont donné des œufs féconds.

Sur toutes les plantes hôtes sauvages à l'exception de *S. arundinaceum*, le taux de mortalité est de 100% pour toutes les larves des trois foreurs. Cependant sur *S. arundinaceum*, seuls *S. calamistis* et *S. poephaga* ont donné un taux de survie qui était respectivement de 2% et de 10%. L'élevage de *S. calamistis* sur le maïs a donné un taux de survie de 30,22% pendant que *B. fusca* enregistre 15,02% et *S. poephaga* 10%. La durée de développement larvaire était plus courte sur *Z. mays* que sur *S. arundinaceum* pour toutes les larves. Pour *S. calamistis*, elle était de 32,9 jours sur *Z. mays* et de 50,60 jours sur *S. arundinaceum*. Alors que pour *S. poephaga* elle était de 37,4 jours sur *Z. mays* et 41,75 jours sur *S. arundinaceum*. La durée de développement est plus longue chez *B. fusca* et est en moyenne de 50,77 jours sur *Z. mays* contre plus de 88 jours sur *S. arundinaceum*, à la mort de la dernière larve diapausante. Les durées de développement des chrysalides sont identiques pour chaque espèce élevée sur différents milieux. Toutefois, cette durée varie d'une espèce à une autre. Elle est en moyenne de 11 jours pour *S. calamistis* et avoisine deux semaines pour *S. poephaga* et *B. fusca*. Le nombre d'œufs pondus par femelle varie d'un insecte à l'autre et est influencé par la source d'alimentation.

Le second essai a consisté à étudier la préférence pour l'oviposition de *S. calamistis* en présence des plantes hôtes déjà signalées. Les résultats ont montré que pour les différents âges (préfloraison, floraison et post floraison) de chaque espèce de plantes hôtes testées, seul le stade de préfloraison apparaissait plus attractif pour la ponte. Ce stade pour toutes les plantes hôtes testées a montré que la femelle de *S. calamistis* préfère pondre sur les poacées sauvages que sur le maïs. Un total de 92,6% des œufs ont été déposés sur l'ensemble des poacées sauvages. Toutefois *Pennisetum polystachion* se révèle de loin l'espèce la plus attractive avec 50,8% des œufs collectés sur elle seule.

L'étude de la dynamique de population par le piège lumineux a montré une variation saisonnière des activités de vol des foreurs étudiés. Cette variation était affectée par certains facteurs dont le cycle lunaire.

## Postgraduate training

### MSc/MPhil, completed in 1997

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| Lega, Kouassi | Togo | 96/97 | self/IITA | Schulthess |
| Mateo, Rafael | Honduras | 95/97 | IITA/BMZ | Markham |
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### MSc/MPhil, in progress

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| Baba-Moussa, A. A. | Benin | 97/98 | self | Cardwell/Schulthess |
| Gounou, Saka | Benin | 96/97 | IITA/IFAD | Schulthess |
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[1] DAAD: Deutscher Akademischer Austauschdienst, Germany; DBF: Daimler-Benz Foundation, Germany; DFPV: Département de Formation en Protection des Végétaux, Niger; FF: Ford Foundation, USA; IIBC: International Institute of Biological Control, UK; OAU: Organization of African Unity, Ethiopia; RF: Rockefeller Foundation, USA; UNB: Université Nationale du Bénin, Benin; Winrock: Winrock International, USA; acronyms of other sponsors are given in the donors' list.
[2] most MSc, all ARPPIS students and some externally sponsored PhD students do not have a direct IITA supervisor
[3] Through the African Regional Postgraduate Program for Insect Science (ARPPIS)

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## Donors

The continued support of the following major donors is gratefully acknowledged:

- Agency for International Development (USAID), United States of America
- Bundeskanzleramt, Austria
- Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung (BMZ), Germany
- Canadian International Development Agency (CIDA), Canada
- Danish International Development Agency (DANIDA), Denmark
- Department of International Development (DFID), United Kingdom
- Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Germany
- Food and Agriculture Organisation of the United Nations (FAO)
- International Development Research Center (IDRC), Canada
- International Fund for Agricultural Development (IFAD)
- Swiss Agency for Development and Cooperation (SDC), Switzerland
- The Rockefeller Fundation (RF)
- United Nations Development Program (UNDP)

# Annex 1

# Research Projects

1. Short Fallow Systems
2. Agroecosystem Development Strategies
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 Control of *Striga* and other Parasitic Plants
9. Improving Postharvest Systems
10. Farming Systems Diversification
11. Cowpea-Cereal Systems Improvement in the Dry Savannas
12. Improvement of Maize-Grain Legume Systems in the Moist Savanna of West and Central Africa
13. Improvement of Yam-based Systems
14. Cassava Productivity in Lowland and Mid-altitude Agroecologies of Sub-Saharan Africa
15. Molecular and Cellular Biotechnology for Crop Improvement
16. Conservation and Genetic Enhancement of Plant Biodiversity

## CGIAR Systemwide and Ecoregional Projects

Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA)
Systemwide Project on Integrated Pest Management (SP-IPM)

# Annex 2

# Institute-wide logframe

| Narrative summary | Indicators by the year 2000 | Means of verification | Assumptions |
|---|---|---|---|
| **Overall Goal:**<br>Increase the well-being of poor people in SSA | • Higher level of food production<br>• Better income and nutritional status of poor people<br>• Reduced drudgery for women | • National and regional statistics and other data | • Political conditions and macroeconomic environment remain stable |
| **Purpose:**<br>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<br>• NARS delivery of technologies increased<br>• Better access to food<br>• Increased gender equity<br>• Increased and sustainable production demonstrated | • NARS and IARC reports<br>• Agricultural and anthropometric statistics<br>• Impact studies | • Financial support to agricultural research and development maintained or increased<br>• Favorable government policies and services<br>• Enabling infrastructures |
| **Outputs:**<br>Plant Biodiversity<br>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%<br>• Adoption of new breeding techniques and diagnostic tools for germplasm movement in at least 3 countries<br>• Coordination of systematic plant collection and management in at least 5 countries<br>• More breeding populations evaluated and disseminated by NARS | • NARS and IARC reports<br>• Seed-sector reports<br>• Workshop proceedings<br>• NARS cultivar releases | • Countries' willingness to share plant genetic resources |
| Agroecosystem Development Strategies<br>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.<br>• Holistic, participatory research programs operational<br>• 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<br>Integrated production technology developed and tested for plantain/banana-based production systems | • Feasibility of IPM strategies demonstrated in benchmark sites<br>• Improved cultivars tested and released by NARS<br>• Sustainable resource and crop management practices adopted in benchmark sites and by NARS | • Project and NARS reports and publications<br>• Feedback from collaborators<br>• Benchmark site survey reports | • Materials meet quarantine standards<br>• Minimum NARS capacity |
| Maize-Grain Legume Systems<br>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<br>• 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<br>• Market can absorb increased production of grain legume crops |
| Cassava Productivity<br>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<br>• 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<br>• Links with NGOs developed and strengthened |
| Yam-based Systems<br>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<br>• 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<br>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<br>• Soil nutritional status improved in selected farmer sites | • NARS and IARC reports<br>• Adoption and impact studies | • Market can absorb increased cowpea grain and fodder |
| IPM Maize<br>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<br>• 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<br>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<br>• 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*<br>Sustainable integrated parasitic plant management measures and components evaluated and disseminated | • NARS testing rotation-based integrated *Striga* spp. management in 15 SSA countries<br>• 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<br>• Market can absorb increased production of and adequate demand for nonhost crops |

| | | | |
|---|---|---|---|
| IPM Cassava<br>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.<br>• 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<br>• Good links with NGOs |
| Biological control<br>Biological control of pests and weeds in farming systems | • At least 1 pest species under biological control<br>• Environmental quality safeguarded | • Socioeconomic and faunistic surveys and impact studies<br>• Pesticide use statistics | • Efficient biological control agents continue to be identified |
| Improving Postharvest Systems<br>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<br>• Increased range of technologies in use in collaborating countries<br>• Improved NARS capacity for food systems research | • NARS and IITA reports<br>• Monitoring tours and surveys | • Socioeconomic environment conducive to small business development |
| Short Fallow Systems<br>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<br>• Farmers in the same 30 communities recognize improved soil conditions | • IARC and NARS reports,<br>• Benchmark and pilot site surveys | • Farmers are receptive to longer-term land management interventions |
| Farming Systems Diversification<br>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<br>• Benchmark site surveys | • Sustained market for enterprise outputs |
| Biotechnology<br>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<br>• Training documentation | • Increased support of governments in the region to the use of molecular and cellular tools for improvement of crop plants |

# Annex 3

# Research Highlights

*IITA's work is organized around 16 multidisciplinary research projects and one project for the dissemination of results to national research systems. 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 1997. 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 Stabilization

### Goal

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

### Highlights

- Herbaceous legume evaluation trials (single and mixed legume species) were established on low P soils with and without P application. The legumes included 12 accessions of *Mucuna pruriens*, 21 accessions of *Lablab purpureus*, 25 accessions of *Aeschynomene histrix*, and 54 accessions of *Centrosema pascuorum*. Preliminary results indicate large variation between species accessions for their adaptability to low P soils.
- The herbaceous legume seed collections of ILRI and IITA have been collated into a comprehensive list of some 388 seedlots. During 1997, 171 seedlots, totaling over 100 kg, were distributed to NARS and IARC scientists, mainly in West Africa.
- The center for cover crop seed and information exchange was established in Cotonou (with IDRC/IITA funding) to support cover

crop seed and information exchange in West Africa. As a first task, several tonnes of *Mucuna* seed were produced for distribution to collaborators.

- Research was undertaken at Ibadan to measure benefits of 13 herbaceous legumes for subsequent maize. On average, subsequent maize grain yield was increased by 70%, compared to the natural grass fallow.
- Field studies were conducted to investigate the influence of three *Mucuna* varieties and two levels of fertilizer on the control of *I. cylindrica* during the year of cover crop planting and one year later. After one growing season, *M. pruriens* var *utilis*, *M. cochinchinensis*, and *M. pruriens* var IRZ reduced *I. cylindrica* shoot density by 50, 76, and 68%, and shoot dry matter by 72, 92, and 79%, respectively. Maize grown one year after *Mucuna* required 50% less weeding than plots without *Mucuna*. Maize grain yield was higher in plots previously seeded to *Mucuna* than in plots without *Mucuna*.
- *Calliandra calothyrsus* hedgerow fallows and well-established *Pueraria phaseoloides* fallows can significantly suppress the growth of *Chromolaena odorata* and associated natural fallow species. At the end of 2 years of fallow, there was an 80% reduction in ground cover and a 90-95% reduction in biomass of these naturally occurring species compared to unplanted fallows.
- A legume-based system close to the farmers' practices was evaluated over a period of 2 years. Maize and legumes were intercropped in the first year, and cassava/maize intercrop was rotated in the second year. Results from the first year data showed that the legume-based systems are economically attractive.
- In 1997, farmers designed trials to integrate *Mucuna* into their maize-based systems in the northern Guinea savanna zone. A pre-maize *Mucuna* system was preferred, although many are also in favor of a maize/*Mucuna* relay system. Farmers recognized *Mucuna*'s ability to improve the soil, and to reduce weeds (including *Striga*).
- Using georeferenced databases on the importance of maize in the cropping systems and suitability of soils to support sustainable maize production, target domains for short-fallow systems were proposed. They show that cereal-based short-fallow systems are likely to have high, medium, and low impact on 386, 256, and 527 million hectares, respectively, in SSA. Potential adoption domains were also mapped. These will assist in selection of sites within the benchmark area for technology development and identify potential pilot sites for technology targeting.

# Project 2

## Agroecosystem Development Strategies

### Goal

*To guide ecoregional research and policies for poverty alleviation and sustainable development of agroecosystems in the subhumid and humid zones. Activities feed directly into the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA).*

### Highlights

- Security over land tenure had a positive impact in Benin Republic on the adoption of *Mucuna*, though the technology is an annual crop, probably because farmers perceived its positive long-run effects on the improvement of natural resources.

About 70% of the total labor input required in cassava farming is on postharvest activities, most of which is contributed by rural women and children. Significant factors that positively influence adoption of improved cassava-processing technologies are the proportion of cassava processed, type of products, mechanization of land preparation, and the number of women with city life experience.

A farmers' survey on the use and availability of organic and inorganic fertilizers was conducted in 5 villages in the derived savanna ecoregional benchmark and 2 villages in the NGS ecoregional benchmark area. The results showed that inorganic fertilizers are used by most farmers in both benchmark areas, but that application rates vary widely between farmers, fields, and crops. Organic amendments are less commonly used, and only on specific fields.

A rapid appraisal of 2009 community-based organizations (CBOs) was completed in 475 villages. The survey shows that traditional credit-solidarity groups tontines (43%) and religious organizations (44%) form the overwhelming majority (87%) of village-based organizations in southern Cameroon. The study shows a strong association between the presence of NGOs and the emergence of both farmers' federations and common initiatives groups at the local level. The information gathered from the surveys is now being used in the development of broad-based partnerships with farmers' organizations and communities in the forest margin benchmark area of southern Cameroon.

Representative farm models have been built for that area. Each model will be used to evaluate potential financial and economic benefits of the new crop and natural management technologies being developed and tested in the benchmark area.

A household characterization survey was conducted in 15 villages among 225 households of the forest margins ecoregional benchmark area of southern Cameroon. Results show that, in general, households in areas with high land pressures have intensified their production systems to a much greater degree than in areas with low land-use pressure.

## 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 preservation of biodiversity.*

### Highlights

A large-scale aerial application of *Metarhizium flavoviride* against the Senegalese grasshopper was carried out, in collaboration with the Niger Plant Protection Service. Farmers preferred the mycopesticide to the chemical pesticide.

Collaborative trials with a Malian NGO demonstrated good control of Sahelian grasshoppers with mycopesticides applied by village brigades.

Ecotoxicological studies demonstrated the low negative environmental impact of the mycopesticide. The registration process for it has been initiated.

# Research Highlights

*IITA's work is organized around 16 multidisciplinary research projects and one project for the dissemination of results to national research systems. 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 1997. 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 Stabilization

### Goal

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

### Highlights

- Herbaceous legume evaluation trials (single and mixed legume species) were established on low P soils with and without P application. The legumes included 12 accessions of *Mucuna pruriens*, 21 accessions of *Lablab purpureus*, 25 accessions of *Aeschynomene histrix*, and 54 accessions of *Centrosema pascuorum*. Preliminary results indicate large variation between species accessions for their adaptability to low P soils.
- The herbaceous legume seed collections of ILRI and IITA have been collated into a comprehensive list of some 388 seedlots. During 1997, 171 seedlots, totaling over 100 kg, were distributed to NARS and IARC scientists, mainly in West Africa.
- The center for cover crop seed and information exchange was established in Cotonou (with IDRC/IITA funding) to support cover

crop seed and information exchange in West Africa. As a first task, several tonnes of *Mucuna* seed were produced for distribution to collaborators.

- Research was undertaken at Ibadan to measure benefits of 13 herbaceous legumes for subsequent maize. On average, subsequent maize grain yield was increased by 70%, compared to the natural grass fallow.
- Field studies were conducted to investigate the influence of three *Mucuna* varieties and two levels of fertilizer on the control of *I. cylindrica* during the year of cover crop planting and one year later. After one growing season, *M. pruriens* var *utilis*, *M. cochinchinensis*, and *M. pruriens* var IRZ reduced *I. cylindrica* shoot density by 50, 76, and 68%, and shoot dry matter by 72, 92, and 79%, respectively. Maize grown one year after *Mucuna* required 50% less weeding than plots without *Mucuna*. Maize grain yield was higher in plots previously seeded to *Mucuna* than in plots without *Mucuna*.
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- The mass production unit was run at full capacity, demonstrating the technical feasibility of the developed production process. Negotiations with commercial companies are well under way, and commercial production is scheduled to start in 1998.
- Participatory field trials in southern Benin demonstrated control of the variegated grasshopper at very low doses in individual fields. Reduced crop loss is estimated to be higher than the cost of biocontrol, making individual purchase and application of the biopesticide attractive.
- Biosystematic capabilities were consistently enhanced, reflected in the extent of the identification service offered, the accumulation of voucher insect specimens, and the availability of collection databases, complemented by a large reference bibliography.
- In 1997 it was documented in southern Benin that the two serendipitously introduced parasitoids, *Encassia haitiensis* and *E. guadeloupae*, had brought under control the spiralling whitefly *Aleurodicus dispersus*, a new exotic pest of cassava and ornamentals.

# Project 4

## Integrated Management of Legume Pests and Diseases

### Goal

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

### Highlights

- Higher levels of resistance identified for flower thrips (initial progeny testing from crosses conducted under intense natural population) and PSBs in cultivated cowpea.
- Multiple pest resistance confirmed in elite cowpea breeding lines, and resistant varieties to CoBB identified.
- Preliminary results from feeding bioasssays on transgenic cowpea plants using MPB neonates indicated some level of successful transformation with *Bt* protoxin *Cry*IA genes.
- Resistance to MPB confirmed in new gene products and secondary metabolites from African yam bean obtained locally.
- A drastic disruption of the utilization of fat in the process of oogenesis in MPB in *Vigna oblongifolia* (e.g., TVNu 42) explains biochemical basis of resistance.
- MPB resistance of TVNu 72 (*Vigna vexillata*) mainly biophysical (trichomes and/other podwall characteristics). *C. tomentosicollis* resistance due both to biophysical (trichomes) and biochemical factors.
- Survey data from over 200 cowpea fields in Benin indicate very low population levels for the local strain of the thrips parasitoid *Ceranisus menes* (Hym, Eulophidae).
- Overall mortality of *M. vitrata* larvae due to pathogens 13%, higher percentages on plants with prostrate growth habit.
- Semiselective medium and polyclonal antibodies for detection of CoBB bacteria developed and tested.

- Pathogen diversity of *Xanthomonas campestris* pv. *vignicola* determined pathologically, biochemically, and genetically; host × pathogen interactions studied, no races identified.
- Genetic diversity of *M. phaseolina* strains from various origins characterized.
- Existence of symptomless virus infection demonstrated; consequences for breeding programs and virus indexing assessed.
- Over 120 cowpea lines screened for resistance to viruses including cowpea aphid-borne mosaic, blackeye cowpea mosaic, cowpea mottle, cucumber mosaic, and southern bean mosaic viruses, and the results sent to the breeder for pyramiding of resistance.
- Heat treatment disinfects contaminated seeds (CoBB and *M. phaseolina*).
- The combined use of solar drying and improved storage for cowpea demonstrated at PEDUNE pilot sites.
- PEDUNE countries have conducted trials with different formulations of neem for both field and storage applications.

## Project 5

## Integrated Management of Maize Pests and Diseases

### Goal

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

### Highlights

- First discovery of oospores of the maize strain of *Peronosclerospora sorghi*, indicating that removal of crazy top at the early stage of development will preclude oospore development.
- A deployment strategy to saturate an area with DM-resistant maize variety was initiated in 9 villages across 2 local government areas of Ogbomoso in Oyo State, Nigeria. About 25 ha of land was planted and 6 tonnes of seeds generated from selected farms.
- Following establishment of an east African strain of the larval parasitoid *Cotesia sesamiae* on *Sesamia calamistis* in southern Benin, first releases have been made in eastern Nigeria.
- New candidates for redistribution BC against *E. saccharina* and *B. fusca* were identified in West and South Africa, respectively.
- Data from the trapping network has confirmed the biological control of *P. truncatus* by *T. nigrescens* in southern Benin and has revealed serious *P. truncatus* infestations in northern Benin.
- Weather-driven population models for *P. truncatus* and *S. zeamais* have been completed, and these will be linked via grain damage rates to a grain loss model for stored maize.
- A toxinic isolates of *Aspergillus flavus* were identified from each of four agroecologies of the Benin Republic, and characterized as to

their vegetative compatibility. Initial trials indicated good biocompetitive fitness of two of the isolates against toxic strains of *Aspergillus* spp.

- The causal agent of a maize disease new to the region was identified as the basidiomycete, *Marasimiellus* spp. The symptom of the disease, a horizontal banded leaf blight, was seen in Ghana, Nigeria, and Cameroon, and was reproduced in Koch's postulates by spraying a mycelial suspension on 12-day old maize plants.

# Project 6

## Integrated Management of Cassava Pests and Diseases

### Goal

*Increase cassava productivity in sub-Saharan Africa.*

### Highlights

- Exotic predatory mites, released for the biological control of the cassava green mite (CGM), showed excellent establishment and spread in West Africa. In field trials, the predators reduced CGM populations by an average of two-thirds and increased cassava yields by a third, resulting in farmer benefit estimated at US$70 per ha. Based on these results, an Africa-wide biological control of the pest was initiated. The virulence of exotic isolates of the pathogenic fungus, *Neozygites floridana*, was evaluated and the indigenous pathogenic fungus, *Hirsutella thompsonii*, isolated for experimental releases.
- Cassava root yield losses to the cassava mosaic disease (CMD) pandemic in western Kenya were estimated at 42%. Characterization of epidemiology and diagnoses of the whitefly vector were initiated in diverse agroecologies in West and Central Africa (Benin, Cameroon Ghana, Nigeria), EARRNET countries (Kenya, Rwanda, and Uganda) and SARRNET countries (Malawi, Mozambique, Tanzania, and Zambia), largely within the framework of the system-wide IPM initiative.
- Yield loss of 20-30% due to cassava bacterial blight (CBB) was recorded in resistant TMS 30572 and susceptible varieties comparing 2 infection levels. CBB epidemiology trial results stressed the importance of soils and weeds as inoculum sources of the bacteria and of variegated grasshopper in the transmission of the disease.
- Yield loss of 30% was recorded for cassava brown streak disease in Tanzania and Malawi, with the variety TMS 30040 and five locally selected clones showing resistance to the disease.
- Two new diseases of cassava, *Curvularia* leaf and stem blight on field and stored cassava stems and *Nattrassia* root and stem rot, were reported and their prevalence determined in Benin and Nigeria.
- ELISA-based CMD diagnostic technology was decentralized to NARS, and PCR-based technology was established to detect new cassava mosaic virus variants.
- Twelve women scientists from West and Central Africa completed postgraduate training in cassava IPM and extension methods. Eleven NARS technicians from 5 SADC countries were

trained in cassava IPM, and farmer field school training was conducted at 25 sites in West and Central Africa.

- Cassava information resources were produced. These included geo-referenced distribution maps of plant protection constraints in Ghana, Benin, Nigeria, and Cameroon; GIS maps of the distribution and characteristics of CMD in Uganda and the wider Lake Victoria basin; cassava IPM extension materials; and directories of personnel, institutions, cassava projects, databases of gray literature, bibliographies, and cassava references.

## Project 7

## Improving Plantain- and Banana-based Systems

### Goal

*Development and dissemination of improved technologies for sustainable* Musa *production in different ecologies of sub-Saharan Africa.*

### Highlights

- Geo-referenced databases. A diagnostic survey of pests and diseases in Uganda has been completed
- Knowledge of pests and diseases enhanced. Identification of banana streak virus in Benin, Ghana, Kenya, Malawi, Nigeria, Tanzania,0 and Uganda confirmed its widespread occurrence. Also, a new virus, tentatively named banana die-back virus, was identified in Nigeria.
- Distribution patterns for nematode species were determined in Ghana, Nigeria, Rwanda, and Uganda.
- Yield losses from pests and diseases determined. Yield loss in plantain (AAB) from nematodes and weevils in Ghana was established. More than 75% of plants infested with both nematode and weevil failed to reach maturity, and there was an overall yield loss of 85% from both pests.
- Yield losses in East African highland bananas (EAHB) (AAA) from weevil increased with crop cycle, reaching 50% in the 4th year, while lesion nematodes caused a 30–40% yield loss in EAHB, but no detectable yield loss in cooking/beer banana (ABB).
- IPM strategies available. Pseudostem traps reduced weevil numbers in on-farm trials in Uganda, and endophytic fungi isolated from banana corms caused egg mortality under laboratory conditions and reduced weevil damage in nursery trials.
- Utilization of germplasm enhanced. Breeding capability was fully established in East Africa, following transfer of breeding technology from IITA-Onne. A first diploid hybrid, derived from highland banana and with black sigatoka resistance, was selected for use in EAHB breeding.
- Characterization of host plant tolerance and resistance to nematodes, including the identification of 4 resistant and tolerant hybrids, was achieved.
- Improved genotypes and populations available. Eight new triploid and tetraploid plantain and banana hybrids were selected, based on high bunch weight, large number of hands per bunch and

large fruits, black sigatoka resistance, and good growth habit. Selection for BSV resistance / tolerance has identified 4 promising banana and plantain hybrids.

- Virus indexing techniques were developed to ensure that IITA's plantain and banana hybrids can again be distributed to other African countries.
- NARS capability enhanced. Twenty-eight national scientists were trained in *Musa* breeding, nematology and / or entomology, and the use of BSV diagnostics.

# 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

- A very positive external review recommended that a world center for parasitic plant research be developed at IITA.
- Demonstration of an integrated crop and land management program for *Striga hermonthica* control was conducted in the moist savanna of Nigeria. Crops planted in this season included cultivars of soybean, cowpea, and cotton selected for their ability to stimulate *S. hermonthica* seed germination. Improved tillage and weed control practices were also implemented. A successful field day was conducted for farmers, NARES, and NGOs to observe the demonstration and learn about integrated *Striga hermonthica* control.
- Significant *Striga hermonthica* seedbank reduction was again demonstrated in farmers fields, using rotations with selected soybean cultivars.
- Incorporation of acetolactate synthase (ALS) inhibitor resistance into open-pollinated IITA maize lines and inbreds was completed.
- Ethylene-producing bacteria were identified and successfully tested for their ability to stimulate *S. aspera*, *S. gesnerioides*, and *S. hermonthica* seed germination. Results showed that 2 isolates of *Pseudomonas* sp. were more effective than the definitive synthetic germination stimulant (GR24) in stimulating parasite seed germination.
- Over 1600 progeny from 5 maize populations were screened under artificial infestation with *Striga hermonthica* in replicated trials. Partially inbred lines from TZL Comp. 1 C3 with very low *S. hermonthica* emergence in the field were selected. Six STR populations were multiplied for on-farm trials, with funding from the Korean government, to be organized by PASCON in 1998. A tolerant early maturing cultivar, EVDT 97STR, as well as EV-IWDSTR, and a resistant inbred (1102), will be available for regional testing in 1998.

- Seventy-five S2 lines were extracted from a backcross population derived from *Zea diploperennis* and initial crosses were made for molecular mapping of resistance in a Rockefeller-funded project in collaboration with CIMMYT and KARI. These lines were also sent to CIMMYT and KARI, Kenya for evaluation under natural *S. hermonthica* infestation.
- A survey on farmers harvest practices related to *S. hermonthica* seed contamination of crop seeds was completed on about 80 farmers fields cropped to cereals. A large proportion of cereal seed samples was found contaminated before and after harvesting. The results confirm the role of the farmer's harvesting method in the contamination of crop seeds and the spread of *S. hermonthica* with crop seeds.
- A total of 25 improved cowpea breeding lines were developed with resistance to *Striga gesnerioides*. A project on cowpea resistance to *S. gesnerioides* has been funded in collaboration with the University of Virginia, USA.
- Hybridization and cytological studies with *S. hermonthica* and *S. asperа* showed that the 2 species differ by only one haploid chromosome, they hybridize readily, and that hybrids can be found in fields where the 2 species are sympatric.

## Project 9

## Improving Postharvest Systems

### Goal

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

### Highlights

- Results from monitoring surveys in the third year of the Soybean Utilization Project in Nigeria, Ghana, and Côte d'Ivoire showed increasing interest in the use of soybean at the household level.
- A socioeconomic analysis of improved postharvest processing showed that the majority of equipment significantly improved income generation. The most remunerative equipment had the capacity for multi-crop applications.
- Adoption of the high-quality cassava flour technology is increasing in Nigeria, and there is evidence that similar activities have started in Tanzania. Developed at IITA, the technology is being disseminated through NGOs, extension agents, and from farmer/processor to farmer/processor.
- Surveys in Nigeria revealed that cassava is being used as the raw material for several commercial-scale processed products, including biscuit manufacturing, starch extraction, noodle production, and industrial distillation into alcohol.
- Results from a study on yam chips processing was completed in Benin, Nigeria, and Togo. This investigation showed that yam processing was highly profitable when developed with specific varieties and in association with short fallow systems.
- Tests on the efficiency of cassava-processing equipment, in Uganda and Kenya, led to the development of a number of modified designs in processing equipment for root crops.

- Cassava processing plants were established in three districts of Uganda. The projects were designed to develop stronger linkages between IARCs, national programs, NGOs, and community based organization (CBOs), and this approach proved to be highly effective, with an internal rate of return of 30% in the first year.
- Four training courses were held on manufacturing and servicing of improved agro-processing equipment for 32 technicians in Benin, Ethiopia, Ghana, Guinea, and Togo.
- A workshop was organized in Nigeria, which brought together industrialists, cassava producers, NGOs, extension agents, extension services, and government agencies for product quality.

# Project 10
# Farming Systems Diversificaton

## Goal

*NARES and international system scientists develop, with farmers, new, diversified, and complementary income-generating enterprises in West and Central Africa.*

## Highlights

- **Multistrata systems.** Focused group interviews with 79 villages in the forest margins benchmark area and the East Province of Cameroon were conducted to examine the reaction of cocoa farmers to recent relative price declines in the cocoa market. Farmers were observed to have diversified their holdings in three ways: diversification from tree crop cultivation into food crops (most common), diversification within the plantation through an increased inclusion of fruit trees, and diversification into other tree crops.
- **Speciality crop systems.** A survey of over 500 market women in the humid forest zone of Cameroon indicated that average daily earnings selling indigenous vegetables were significantly lower than those for exotic vegetables, such as tomatoes and cabbage. However, indigenous vegetables offer a particularly important employment option for the lower economic rungs of urban and rural women in Cameroon.
- Cassava leaves are an important leafy green vegetable in Central Africa. Six cassava clones with different plant architectures were selected to investigate the possibility of increasing edible leaf production. Preliminary results indicate big differences in the production of edible leaves. Although pruning facilitates leaf harvest by women, monthly harvests can lead to a significant drop in leaf yield. Pruning also decreases subsequent tuber yields.
- **Inland valley systems.** Cowpea variety IT90K-284-2 was shown to be a good crop for diversification of crop production in inland valleys of the northern Guinea savanna benchmark area in Nigeria. Over 2 years of testing on farmers' fields during the dry season, it produced more than 1 t/ha of grain, even without insecticide application, and a net revenue of approximately US$500/ha.
- **Mixed farming systems.** The incipient market for crop residues is expanding in the Guinea savannas of West Africa. An

economic analysis showed that the future of the market for crop residues is constrained by the transportation cost, which was found to represent 47–58% of their total cost.

A survey was conducted with 150 farmers in northern Nigeria to assess the impact of a cattle fattening program on the socioeconomic well-being of the participating farmers. It showed a net benefit of US$113 per cattle fattened or about US$450 per farmer per year. The findings suggest that income generation could be increased if the cost of feeding could be reduced and the supply of both veterinary services and medication could be improved through a credit facility program in favor of cattle fatteners.

Reciprocal benefits from crops and livestock in a mixed farming system were investigated from a survey of 150 agropastoralists in two areas at different gradients of resource-use intensification in the northern Guinea savanna of Nigeria. The productivity of the system was threefold higher in a market-driven area than in a population-driven area. Crop and livestock enterprises yielded the highest returns to land at higher cultivation intensity, while the returns to labor were the highest at low cultivation intensity for areas with poor and good market opportunities. In areas where land becomes scarce and labor abundant, increased intensification in resource use is driving farming systems towards greater crop-livestock integration and productivity.

## Project 11

## Cowpea-Cereals Systems Improvement in the Dry Savanna

### Goal

*To develop adoptable crop varieties and agronomic practices for the Sudan savanna and Sahel, which will increase the total productivity of the 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

**Constraints analysis.** Survey of cowpea fields in the Sudan-Sahelian region in 1996 and 1997 indicated a decreasing gradient of *Maruca* pod borer pressure from high rainfall areas to low rainfall areas, but an increasing pressure of aphid, thrips, *Striga gesnerioides*, and drought.

**Improvement of local landraces.** From 150 local landraces of cowpea screened in 1996, 9 were crossed with donor parents for incorporation of genes for resistance to aphid, thrips, bruchid, *Striga*, *Alectra*, and viruses by the backcrossing method.

**Improved grain-type cowpea varieties.** A total of 746 new cowpea breeding lines were evaluated for grain and fodder yields in different cropping systems. A number of lines showed considerable resistance to several biotic constraints and yielded between 1.5 and 2 t/ha.

**Improved cowpea varieties for intercropping.** Several new improved breeding lines yielded 50 to 200% higher than local varieties under intercropping with millet and sorghum, without insecticide spray.

**Screening method for drought tolerance.** A simple method (using a shallow box for seedling screening) has been developed, which discriminates between drought tolerant and susceptible lines of cowpea. Using this method, 2 types of drought tolerant lines have been identified and their genetics studied.

**Early maize and soybean varieties.** The variety trials in 1996 and 1997 have shown that improved extra-early maturing maize varieties can yield over 3 t/ha in areas with about 600 mm rainfall, and early maturing soybean varieties produce 1.5-2.0 t/ha grain yield without insecticide, rhizobia inoculum, or fertilizer.

**Farmer-to-farmer diffusion of improved cowpea seeds.** Preliminary results of IITA/GTZ farmers participatory seed multiplication and diffusion program have shown great promise for rapid distribution of improved cowpea seeds. Three kg seed of one improved cowpea variety was given on credit to each of 36 selected farmers in June '97. By Dec '97, a total of 6672 kg seed had been produced by these farmers. Similarly, farmer to farmer diffusion of an improved cowpea variety has increased cowpea cultivation in the dry season from 1 farmer in 1993 to over 2000 farmers in 1997 in northern Nigeria. Socioeconomic studies revealed that the main driving forces of dry-season cowpea were membership to farmers' association; high grain yield; farm size; and contact with extension workers.

# 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 in the moist savanna by improving crop varieties and the management of cropping systems.*

### Highlights

The maize breeding team of scientists based in Côte d'Ivoire and Nigeria made significant advances in the development of both open pollinated varieties and hybrids with higher levels of N-use efficiency (NUE) and drought tolerance. The 10 best families selected from the low N tolerant pool had 60% higher grain yield under N stress and 19% higher yield under high N than the commercial hybrid. These results confirmed the progress that was reported for this trait in 1996.

The improvement of maize for NUE is expected to have a major impact on both the productivity and sustainability of maize-grain legume systems in the moist savanna, with the majority of producers not able to obtain adequate quantities of N fertilizers.

About 200 soybean breeding lines were evaluated for total nitrogen produced through fixation (from the atmosphere). This has enabled selection of breeding lines that produce high grain yield and also contribute nitrogen to the production systems even when the grain is harvested. Several breeding lines have been identified with grain yield equal to the best check and producing 50% to 75% higher fodder yields. These new breeding lines have the potential to considerably improve the productivity and sustainability of the farming system.

Strip cropping maize with improved varieties of cowpea gave encouraging results for both maize and cowpea grain yields with no insecticide spray. Both maize and cowpea were planted at the beginning of the rainy season, as this helps the cowpea to escape the time when the most damaging insects are present in high numbers.

Response of key maize and soybean genotypes could be predicted with simulation models in diverse cropping systems in on-station studies. Using models, we can suggest ways for maximizing nutrient-use efficiency in various agroecologies. Initial on-farm experimentation and modeling suggest weaknesses in current understanding of physiological processes as well as interactions among N and P nutrients. Regional analysis, combining simulation and geographic information system (GIS), shows large areas of potential impact for soybean-maize rotational systems in West Africa. Models and GIS tools are being combined to develop a decision-support system that can be used by NARS to help identify the appropriate maize-grain legume systems for testing and dissemination.

## 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

Gender implications for the development of resource management technologies for yam production were investigated in a survey of more than 600 yam growers in the southern Guinea savanna of Nigeria. Women were observed to be heavily involved in yam production, contrary to conventional belief. For both sexes, yam was mainly grown in newly cleared land from long fallow and for a continuous period of less than 3 years. The major constraints in yam production for both sexes were pests and diseases in the field and during storage. Other constraints were weeds, declining soil fertility, lack of staking materials, and labor. It was concluded that the practice of growing yam first on newly cleared land and avoiding continuous yam cultivation may have more to do with the control of pest and pathogen buildup than with declining soil fertility.

In studies at IITA, Ibadan, *Scutellonema bradys* (yam nematode) caused 60% loss of marketable tubers under low nematode pressure, and 100% loss under high pressure. Both situations led to complete loss of planting material.

A survey of yam viruses in Nigeria revealed the presence of yam mosaic potyvirus (previously reported from Nigeria); *Dioscorea alata* potyvirus and cucumber mosaic cucumovirus (previously reported in yams in West Africa); *Dioscorea alata* badnavirus and *Dioscorea dumetorum* potyvirus (not previously reported from Africa). Three new viruses, tentatively named *Dioscorea* mottle, *Dioscorea* mild chlorotic, and *Dioscorea* necrosis viruses, have been isolated from their natural *Dioscorea* spp. hosts. Diagnostic techniques have been developed for all yam viruses found to date in Nigeria.

- A protocol to ensure the safe international movement of *D. alata* germplasm was developed. Consequently, two genotypes of *D. alata* were certified for international distribution for the first time. Eleven new genotypes of *D. rotundata* were also certified for international distribution.
- Over 6,300 virus-tested plantlets, representing 22 genotypes of *D. rotundata*, were delivered to NARS in 7 countries while 6,767 minitubers, produced from virus-tested plantlets of the same species, were distributed to NARS in 8 countries.
- The development of yams in Uganda got a major boost during the year. More than 140 farmers (including 104 women) from 3 districts were trained in techniques for rapid field/nursery multiplication of yam planting materials. Twenty-six varieties of introduced *D. rotundata* and 7 local varieties of *D. alata* and one of *D. cayenensis* are under rapid field multiplication. Over 84% of 3,000 virus-tested plantlets of *D. rotundata* were successfully established, following a fresh introduction of 22 genotypes from IITA headquarters.
- Prerelease varietal trials in Nigeria, conducted in partnership with the National Root Crops Research Institute, confirmed the superiority of 3 IITA-derived hybrid clones of *D. rotundata* over popular local varieties used as checks.

# Project 14

## Cassava productivity in Lowland and Mid-Altitude Agroecologies of Sub-Saharan Africa

### Goal

*To develop, evaluate, and promote improved and adapted cassava germplasm for the lowland and mid-altitude 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 East and Southern Africa Regional Center (ESARC) in Uganda.*

### Highlights

- Efforts to broaden the genetic base of cassava in SSA continued, with the distribution of 497,000 seeds of broad-based improved populations (2,764 families) with multiple pest resistance and special traits to national programs in 21 countries. IITA also received 30,000 seeds derived from landraces of 8 SSA countries and 70,000 seeds from CIAT with adaptation to the semiarid, mid-altitude, and subtropical ecologies, respectively.
- Improved genotypes incorporating resistant genes from African landraces, combining acceptable agronomic and end-user characteristics with very high levels of multiple resistance to cassava mosaic disease (CMD), bacterial blight (CBB), anthracnose (CAD), and green mite (CGM) have been developed. Forty-one of these genotypes were virus tested and certified, and a total of 344 genotypes are now available at IITA for international distribution. Of these materials, IITA distributed 21,040 in vitro plantlets to 9 collaborating countries. In addition, the production and delivery was completed of 18,090 certified cassava in vitro plantlets to the

Angola Seed of Freedom Project, through World Vision International.

- Sourcing seeds from broad-based germplasm at IITA, Ibadan, the EARRNET/ESARC regional germplasm program in Serere, Uganda distributed a total of 1,222 promising clones to the national programs of Rwanda (593 clones), Kenya (555 clones), and Uganda (74 clones) for further evaluation under local conditions.
- Collaborative work with the International Livestock Research Institute for smallholder crop-livestock farming systems showed large variations in root and foliage yields and nutritive value.
- Early-bulking varieties continue to be identified from IITA germplasm. In Nigeria, genotypes adapted to dry-season cropping in the inland valley ecosystem could give average yields of 25 tonnes/ha and dry-matter percentage of 36% in a 6-month period.
- Nineteen participants were trained on rapid multiplication of cassava and sweetpotato in Rwanda, in an effort to resuscitate research and development of these commodities.

## Project 15

# Molecular and Cellular Biotechnology for Crop Improvement

### Goal

*To advance the efficacy of genetic improvement and germplasm dissemination beyond the norms associated with the application of conventional breeding and diagnostic techniques. The project makes new molecular and cellular tools and products available to collaborating scientists working on IITA's mandated crops.*

### Highlights

- Roots and plantlets were obtained from 3-week and 7-week-old immature seeds, respectively, in *D. alata*.
- Transgenic cowpea lines were produced with constructs containing *Gus* reporter genes, *Bacillus thuringiensis* genes coding for the *Cry* IAb and *Cry* IAc insecticidal crystal endotoxin. The transgenics are being characterized and evaluated for insect resistance.
- Putative genomic and cDNA fragments corresponding to lectins, thionin, phenylalanine ammonia lyase (PAL), and chalcone synthase (CHS) genes associated with pest resistance have been isolated from African yam bean, wild cowpea, and/or cultivated cowpea. Most of the fragments correspond to the predicted size.
- Affinity chromatographic procedures have been used to purify lectins from African yam bean and *V. vexillata*.
- Six mapping populations from controlled hybridizations between selected yam genotypes of *D. rotundata* and *D. alata* were developed for use in developing linkage maps. The parental lines used for generating the mapping populations were selected for their contrasting phenotypic expressions for virus and nematodes resistance in *D. rotundata*, and for anthracnose in *D. alata*.
- Recombinant inbred (RI) lines developed for the genome mapping of cowpea are now available. Some DNA markers have been generated and placed on the map which presently spans 665 cM,

indicating an average map distance of 7.2 cM. Additional DNA markers are being generated for placement on the map.

- Some markers associated with quantitative trait loci (QTL) in cowpea, such as days to flowering, 100-seed weight, and days to pod maturity were identified, among others.
- Candidate microsatellite markers for parthenocarpy, earliness, and regulated suckering in plantain have been identified and will be tested further.
- IITA, in collaboration with John Innes Centre and Horticulture Research Institute (UK), developed reliable detection systems for *Dioscorea alata* badnavirus, facilitating safe movement of improved *D. alata* germplasm.
- Immunocapture reverse-transcriptase polymerase chain reaction (IC-RT-PCR), a very sensitive protocol, was developed to detect yam mosaic potyvirus.
- Scottish Crops Research Institute (Dundee, UK) donated to IITA six hybridoma cell lines raised against cassava mosaic geminiviruses. Ascetic and culture fluids were produced at IITA and distributed to 10 laboratories in Africa, thereby enhancing the capability of national programs to diagnose geminiviruses in cassava.

# Project 16

## Conservation and Genetic Enhancement of Plant Biodiversity

### Goal

*To improve the conservation and utilization of plant biodiversity to promote sustainable food production in sub-Saharan Africa.*

### Highlights

- Field collections were made of 330 local cassava accessions from Togo, 97 local yam cultivars from Côte d'Ivoire, and 11 wild yam and 25 wild *Vigna* spp. from Nigeria. A total of 331 accessions of yam and 44 accessions of cassava was transferred from the field genebank to in vitro cultures. A large number of indigenous yam cultivars (557) was collected in Benin Republic. A total of 388 seedlots of herbaceous legumes were identified and cataloged, by combining former ILRI and IITA collections, 171 seedlots were distributed for experiments in IITA/ILRI (42) and to NARS (74) and NGOs (55.
- User friendly database management systems for over 37,000 germplasm accessions of cowpea, wild *Vigna* spp., Bambara groundnut, soybean, rice, yams, and cassava were developed. Genetic diversity and heterotic groups in Guinea yams (*D. rotundata and D. cayenensis*) and their wild relative *D. praehensilis* were assessed, using amplified fragment length polymorphisms (AFLPs). Molecular markers were used for the first time to characterize landrace collections of plantains.
- Many improved breeding lines (431) and African landraces (561) of cassava are being evaluated and characterized for agrobotanical traits, and resistance to cassava mosaic disease (ACMD), cassava bacterial blight (CBB), and cassava anthracnose disease (CAD).

- From a study of combining ability of *Musa* hybrids, 18 promising diploid and 6 triploid banana hybrids were identified with large bunch size, large number of hands and fruits, big fruit size, improved ratooning, earliness, and resistance to black sigatoka. A promising diploid hybrid with resistance to nematodes was identified.
- Maize varieties were extracted from TZL COMP4 and TZE COMP3 and were higher yielding than varieties extracted from previous cycles of selection. Two reciprocal populations formed for the mid-altitudes were screened for resistance to maize streak virus, *Exserohilum turcicum*, and ear rot.
- Four maize lines from TZPB-SR prol. C1 had over 90% prolific (2-eared) plants as well as high yield and disease resistance in the forest zone of Nigeria. Across the forest zone and savanna sites, the best line had an average yield of 6.5 t/ha, with 70% prolific plants. $S_2$ and $S_4$ testcrosses from two white maize populations (IWD and IWF) and their STR versions produced over 50% higher yield than the commercial hybrid Oba Super 1.
- Some inbred lines were identified (e.g., 1102, 1309) with levels of resistance to *S. hermonthica* comparable or better than that of inbred 1368. Hybrids generated from these lines were high yielding and resistant to abiotic stresses.
- Some 25-30 $S_1$ families derived from early-maturing maize populations (DR-W Pool and DR-Y Pool) with drought tolerance and resistance to maize streak virus were selected for recombination.

# Ecoregional Program for the Humid and Subhumid Tropics of 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 posthavest systems that increase productivity and food security and minimize natural resources degradation.*

### Highlights

- The 1997 EPHTA work plan, which focused on benchmark area development and pilot studies, was endorsed by the Program Committee (PC) at its first meeting held at IITA, Ibadan, 24-26 Feb 1997.
- Benchmark area development. All 5 countries hosting the 6 benchmark areas appointed Benchmark Area Coordinators. Several meetings were held in all benchmark areas to sensitize stakeholders and potential EPHTA partners.
- Characterization surveys. Surveys have been completed in the forest margins benchmark area in Cameroon, and in the northern Guinea savanna and the degraded forest benchmark areas in Nigeria.
- The forest margins benchmark area in Cameroon was officially launched on 26 May 1997 in Yaoundé, as was the degraded forest benchmark area in southeastern Nigeria on 6 Oct 1997 at Owerri.

Nominations have been received from countries for membership of the 7 working groups indicated in the program document. The working groups will be formed and become operational in 1998.

From 12 to 16 May 1997, a workshop on ecoregional research methodology was held in Cameroon. It was attended by 3 participants from each of the 6 benchmark areas, including the Benchmark Area Coordinators and each of the Pilot Site Coordinators. The workshop was also attended by a 5-man delegation from CIRAD and representatives from ILRI, WARDA, and IITA, the organizing center.

From 15 to 19 Sep 1997, EPHTA, in collaboration with the Systemwide Programs for Integrated Pest Management (SP-IPM) and Alternatives to Slash-and-Burn (ASB), sponsored the Integrated Weed Management Workshop, which was held in Yaoundé, Cameroon. It was attended by participants from EPHTA member countries, representatives from WARDA, CIRAD, NRI, and IIBC (Britain), and IITA.

# Systemwide Program on Integrated Pest Management

## Goal

*To ensure, by encouraging better communication, coordination, and the adoption of more effective approaches, that CG research on integrated pest management (IPM) is more responsive to the needs of IPM practitioners, gains wider recognition, and thereby contributes fully to sustainable agricultural development.*

## Highlights

Researchers from many national programs and several international centers participating in the intercenter project on whiteflies and geminiviruses, have begun field work at numerous sites in Africa and Latin America, with close support from specialist laboratories in Europe and North America. This technically and organizationally complex project is the first to be launched under the auspices of the Systemwide Program on IPM. Its successful establishment, under the leadership of CIAT, will serve as a model for future project development.

In this first, diagnostic phase of the project, researchers in the different regions will use a common set of methodologies to assess the importance of losses associated with different combinations of crops, viruses, and their whitefly vectors. The knowledge gained will provide a sound basis for prioritizing future research efforts.

In Africa, recognizing the urgency of the situation resulting from a highly destructive outbreak of African cassava mosaic disease, researchers involved in the project are moving rapidly to carry out analytical research and implement appropriate counter-measures. In this regard, the network of collaborators and sound knowledge base already established by ESCaPP and IITA's other root crop research and development efforts have been an important factor in facilitating the timely launch of project activities.

A workshop on management of weeds in the farming system, convened at IITA's Humid Forest Station in September, pioneered a new mode of collaboration between the Institute and various inter-

institutional initiatives. The workshop cosponsored by the SP-IPM, EPHTA (both of which are led by IITA), and ASB (the inter-center initiative on Alternatives to Slash-and-Burn, led by ICRAF) was co-convened by IITA and WARDA. Weed scientists from national programs across West and Central Africa came together with disciplinary specialists from the involved centers and from various institutions in Europe to analyze weed problems encountered in the region, examine options for tackling them, and outline plans to carry out the necessary research. Several detailed research proposals are now being prepared within the framework of EPHTA, with plans for pilot studies at various benchmark sites in the different agroecological zones.

Other meetings of intercenter task forces were held, focusing on specific topics. When available CGIAR information is brought together into an authoritative document during 1998, it will provide a more reliable basis for researching and implementing sustainable pest management solutions.

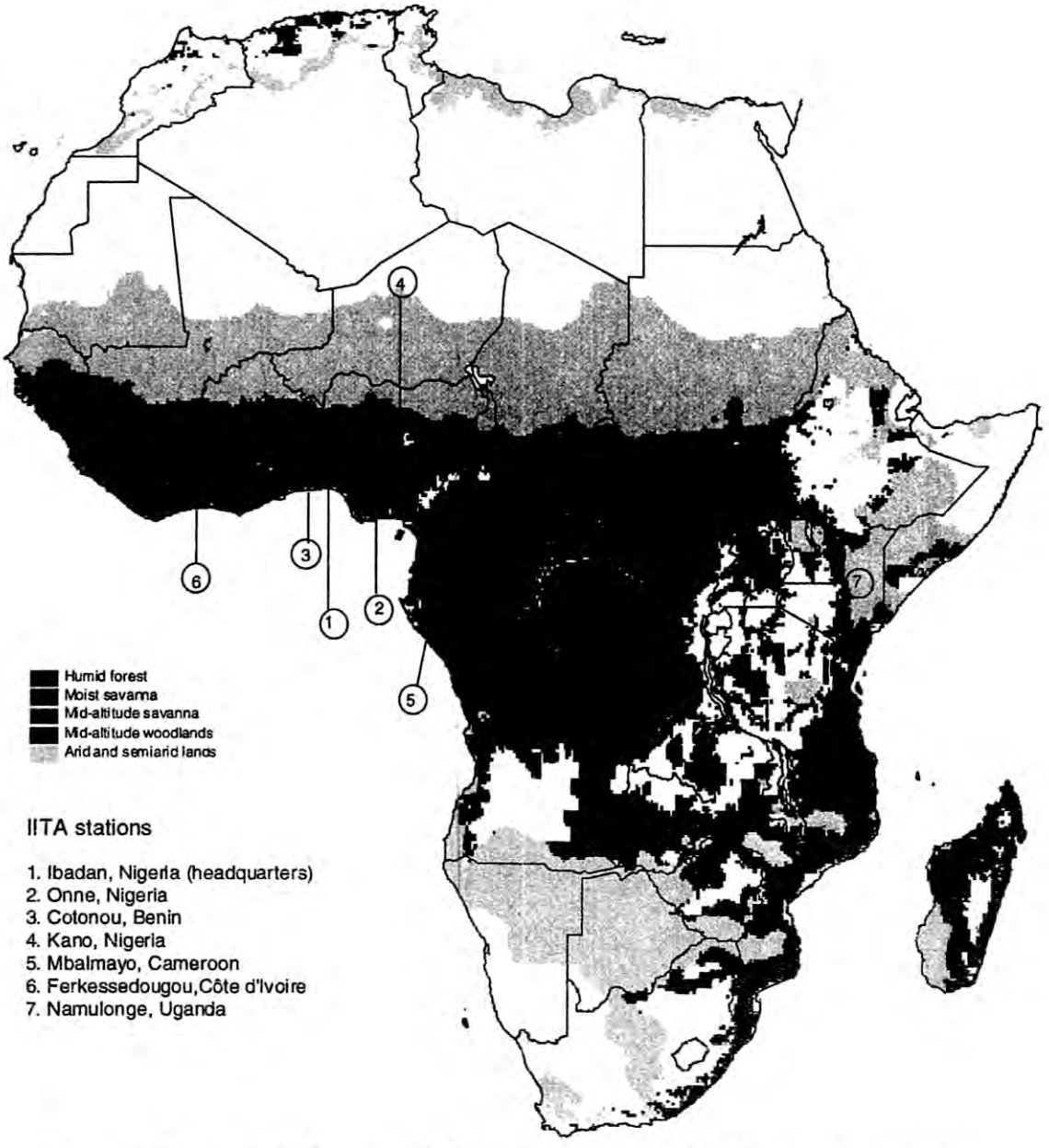


**Figure 1. Agroecological zones and IITA stations in tropical humid and subhumid Africa.**