Project 6

Integrated Management of Cassava Pests and Diseases

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Preface

The research agenda of IITA is subdivided into a portfolio of seventeen 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 17 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.

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 first 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 6
Integrated Management of Cassava Pests and Diseases

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Project rationale

Cassava is increasingly important as a food source for the rapidly expanding rural and urban populations in Africa. Easy to grow, even under harsh agronomic conditions, cassava is the primary source of carbohydrates for more than 200 million people, including the poorest on the continent, and provides food security to most subsistence farmers. However, increasing production demands coupled with finite agricultural resources threaten the sustainability of the cassava agroecosystems. Plants grown on marginal lands are less vigorous and more susceptible to a range of biotic constraints. Pests, diseases and weeds currently reduce potential yield by half. The major arthropod pest is presently the cassava green mite, *Mononychellus tanajoa* (Bondar) (Acari, Tetranychidae), while the whitefly, *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae), is important as a vector of the pervasive African cassava mosaic disease (ACMD) found throughout the cassava belt. The larger grain borer (LGB) is principally a pest of stored maize, but is equally important as a pest of processed and stored cassava. Termites and the variegated grasshopper are being investigated as pests of ecosystems that include cassava, while the importance of the cassava root scale, *Stictococcus vayssierrei* Richards (Homo, Stichoccidae) in Central Africa, is now emerging. The principal diseases are cassava mosaic disease (CMD), which is estimated to decrease potential yields by a third, cassava brown streak virus in East and Southern Africa, cassava bacterial blight (CBB) particularly in the transition forest and moist savanna, cassava anthracnose disease (CAD), and several *Cercospora* leaf diseases and root rots.

The exotic phytoseiid predator of the cassava green mite, *Typhlodromalus aripo*, continued its rapid spread, but the breakthrough in 1996 was evidence of field impact. The predator was found to increase root yield by a third in farmers' fields in southeastern Benin. This translates into about $70 added value per hectare per season. Meanwhile, *T. aripo* was confirmed established in 10 countries and suspected in two more covering an area estimated at ca 400,000 km^2. Cassava green mite populations have dropped significantly everywhere the predator has established. Average pest densities are now below 20 mites per leaf compared to twice that or more in previous years.

On the plant pathology front, a mixed cropping system was developed to control CBB, while the epidemiology and etiology of CAD was elucidated and control methods developed. Sources of resistance were also identified against CBB, CAD and CMD from local clones and breeding lines in Benin and Nigeria. Two fungal diseases on cassava, *Curvularia lunata* (Wakker) Boedijn stem and leaf blight and *Nattrassia mangiferae* (B.& P. Syd) B. Sutton & Dyko root and stem rot, were reported for the first time in Benin, Ghana and Nigeria as part of the multidisciplinary diagnosis of production constraints in ESCaPP countries.

ESCaPP established local networks of farmers, extensions agents and scientists to address the farmers' demands and facilitate the exchange of control practices. The same regional collaboration was used to developed a curriculum reflecting the assessed needs for sustainable cassava plant protection and didactic training materials for farmers' field schools and source books and posters for farmers' field schools. Project scientists also compiled a 10-MB relational database on the protection, production and socioeconomic constraints found in all production zones of four countries.

The project will continue current efforts on cassava green mite, CMD, CBB, and CAD, root rots, and whitefly vectors, while looking at opportunities in postharvest pathogens, cassava root scale, termites and the new fungal diseases. Work on the cassava green mite shifts to impact assessment in the lowland humid tropics of West Africa, while natural enemy releases and monitoring is implemented in the rest of the continent. ACMV and the closely related East African cassava mosaic virus, which cause CMD, continue as the major cassava pathogens in Africa. The epidemiology of CMD is being studied to elucidate the role of the virus vector *B. tabaci* in CMD incidence in diverse agroecozones, investigate contrasts in variety susceptibility, CMD severity and vector population dynamics with the view to provide farm-level crop sanitation management protocols. The distribution and economic importance of cassava brown streak virus are being investigated in East and Southern Africa. CBB caused by *Xanthomonas campestris* (Pammel) Dowson pv. *manihotis* (Arthaud-Berthet) (Xcm), also causes severe cassava yield losses in Africa. Although resistance breeding and cultural measures mitigate CBB damage, unpredictable and severe disease outbreaks have recently been reported in parts of West Africa and will continue to be investigated. Cassava anthracnose disease (CAD) and root and stem rots, major problems in humid lowlands, are being investigated for cultural control possibilities. Several rot pathogens have been identified, their virulence characterized and epidemiology, yield losses and variety evaluations undertaken to develop sustainable control methods, including the use of pathogen antagonists.

Outputs

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

Background

An understanding of a pest's distribution, impact and interactions provides the basis for assessing the importance and generating background information needed to design and execute appropriate intervention technologies. Evaluating farmers' constraints as influenced by biotic, abiotic and socioeconomic factors within agroecosystem in collaboration with the clients assure the relevance and focus of proposed R&D activities.

Regional surveys on incidence and severity help define the extent of pest and disease constraints. Yield loss trials in specific ecozones complement survey data in assessing economic importance. Identification and characterization of insects and pathogens with molecular, genetic, biochemical and physiological methods help quantify their diversity and provide additional information needed to develop control strategies.

Ongoing and future activities

6.1.1. Population diversity of Xcm strains: biochemical and physiological characterization

by K.W. - in collaboration with K. Rudolph, J. Janse, A. Fessehaie

Fatty acid analysis is a tool to identify bacterial strains by comparing their fatty acid profiles to a library of profiles from different species and pathovars. The profiles were used in a cluster analysis and a multiple component analysis to define differences between strains of Xcm. All 174 strains tested were identified as *X. campestris* pv. *manihotis*. An additional 22 strains from Latin American and Asian origin were tested for fatty acid and comparison with the results from 152 Xcm strains originating mainly from Africa. The formation of two major groups, one a homogeneous group containing all the African strains and some Latin American and African strains, the other a heterogeneous group apart from group 1 containing only Latin American and Asian strains, was confirmed.

Two hundred twenty-five Xcm strains were tested for amylase activity by growing on a starch medium, 30 more strains from Latin American and Asian origin were analysed by an enzymatic test for amylase activity using the substrate dye-labeled and partially hydrolyzed polysaccharide CM-Amylose RBB. The African strains appeared homogeneous with a low ability to utilize starch and a low amylase activity. The diversity of strains was high among Latin American and Asian strains while all African strains were low in amylase activity. Amylase was produced constitutively and was detected also on medium with glucose as C-source. The groups correlated to groups formed in the fatty acid analysis.

Cellulase is a pathogenicity factor of plant pathogenic bacteria and can be used to differentiate bacterial strains. Five Xcm strains were tested on a special medium containing CM (carboxymethyl)-cellulose-Ramazole Brillant Blue (CM-Cellulose-RBB) developed by Wolf and Wirth (1992) for the detection of cellulase activity. All the strains were cellulase negative.

6.1.2. Virulence test of Xcm strains from different origin and identification of possible existence of races

by K.W.

Highly virulent strains from different geographic origins are tested on a selected set of varieties to identify the possible existence of races. These experiments are conducted in the glasshouse under containment conditions. The cassava varieties were selected after evaluation and analysis of a field trial with 423 varieties inoculated with Xcm. The inoculation method was stem puncture; in a following experiment, leaf infiltration with different concentrations of inoculum will be used.

6.1.3. Identification of specific protein patterns of Xcm strains and isolation and characterization of lipopolysaccharides of Xcm as pathogenicity factor and specific antigen

by K.W. - in collaboration with K. Rudolph, B. Ahohuendo, M. Kecskes, P. Müller, P. Laux, A. Fessehaie

After protein extraction and quantification of proteins, protein extracts were separated in discontinuous sodium dodecyl sulfate-acrylamide gels (SDS-PAGE) and in native form. Proteins were also analyzed in gradient gels (5-15%). The gels were stained with Coomassie Blue or silver for proteins. In comparison to *X. campestris* pvs. *malacearum, phaseoli,*

campestris and *Erwinia carotovora* spp. *carotovora, E. herbicola* and *Pseudomonas fluorescens* a Xcm-specific protein was detected.

For lipopolysaccharide extraction, bacteria were produced in 20-l fermenters, centrifuged and lipopolysaccharides isolated. After purification, structural analysis was performed: determination of structure of O-chains and core region, determination of contents of phosphates, keto-desoxy-sugars, neutral sugars, fatty acids and hexosamin. By electrophoretic analysis (SDS-PAGE and silver staining), typical lipolysaccharide structures were detected. The analysis is ongoing. Results were compared to lipopolysaccharides obtained from *Pseudomonas syringae* pvs. and *X. campestris* pv. *vignicola*.

6.1.4. Determination of yield loss due to CBB with selected varieties in different ecozones

by K.W., A.G.O.D.

In field trials in five sites in four different ecozones, data on plant growth, yield loss and epidemiological parameters on CBB development using a resistant and a susceptible variety were regularly collected. The data analysis of the epidemiology and yield loss trials in five sites is still ongoing. (See PHMD Annual Report 1995.) In two sites, trials were repeated for a third season. Starch content of tubers was determined of 12-month-old plants, inoculated and not inoculated with Xcm. Data analysis is ongoing.

Trials with 23 varieties are ongoing in three ecozones - rain forest zone, transition forest zone and dry savanna. The varieties were selected among 423 varieties after the analysis of their symptom development and their susceptibility towards CBB. Resistant and few susceptible varieties were chosen. A detailed symptom evaluation, six weekly in the rainy season and less frequent in the dry season, is conducted and plant growth and root yield data are collected. Epiphytic Xcm populations are screened regularly.

6.1.5. Characterization of the cassava mosaic epidemic in Uganda

by J.P.L. - in collaboration with S. Ogwal, J. Colvin, J. Brown

Appraisal surveys carried out in Uganda in 1995/96 confirmed the continued expansion southwards of an epidemic of severe cassava mosaic disease. Recent evidence has suggested that a novel cassava mosaic geminivirus species is associated with the epidemic and that the most severe symptoms may result from dual infections. It has also been suggested that increased vector (*Bemisia tabaci*) populations also play a role in the epidemic's expansion, and it has been hypothesized that a 'novel' *B. tabaci* biotype may be involved. In order to test each of these assertions, whitefly samples were collected for characterization at the University of Arizona, USA, and a protocol for a trial to compare the population dynamics of *B. tabaci* at a location before and after the arrival of the epidemic was developed. A preliminary assessment of the whitefly samples suggests that there are differences between populations from pre- and postepidemic locations, but further samples will need to be examined before conclusions can be drawn on the significance of these differences. The population dynamics study, conducted at Namulonge (now postepidemic), will be closely comparable to one conducted on three occasions between 1992 and 1994 (then pre-epidemic), and should provide evidence to substantiate or refute suggestion that changes in vector/vector activity are an important component in the dynamics of the Ugandan cassava mosaic epidemic.

6.1.6. Baseline/impact survey of cassava in Uganda

by J.P.L. - in collaboration with scientists of the Root Crops Programme, NARO, Uganda and EARRNET

A protocol developed in 1995 for a joint IITA-IITA-ESARC/EARRNET/NARS diagnostic and impact assessment survey of cassava in Uganda was pretested in 1996 and modifications made to overcome deficiencies encountered. The plant protection protocol, involving a largely field-based assessment in sampled villages of pest and disease constraints, was found to be appropriate. Modifications were made to strengthen the assessment of nematodes and the natural enemies of cassava mealybug (*E. lopezi*) and cassava green mite (*T. aripo*). The full survey began in May 1997, to be completed within a month.

6.1.7. Survey of cassava mosaic viruses in East and Southern Africa

by J.P.L., A. M.-K. - in collaboration with F.M. Quin, F. Ogbe, M. Raya

Distributions of the two viruses (EACMV and ACMV) known to cause cassava mosaic disease in Africa were described in 1994. EACMV appeared to be restricted to coastal East Africa (Kenya, Tanzania), Malawi, Zimbabwe and the Indian Ocean Islands, whereas ACMV was more widely distributed throughout central and western Africa. A key observation was that the distributions of the two viruses did not overlap. These conclusions, however, were based on a relatively small number of samples collected from each country. In order to verify and update the distribution map while at the same time testing the robustness of a newly developed diagnostic technique, IITA, in collaboration with the National Root Crops Research Institute of Nigeria and host NARS, carried out diagnostic surveys of EACMV and ACMV in Kenya, Uganda, Tanzania, Malawi and Zambia in 1996. The surveys were done using a monoclonal antibodies (MAbs) only method of ELISA in which two MAbs, SCR 23 and SCR 33, were used to detect and distinguish between ACMV and EACMV. IITA-ESARC participated directly in the survey in Tanzania, where sampling was done in three main cassava-growing regions: the northern coast, the southern coast and the Lake (Victoria) zone. In all coastal regions, including Amani in the Usambara Mountains, EACMV alone was detected, although some plants with clear mosaic symptoms did not react with either detecting MAb, suggesting the presence of a strain of EACMV. In the Lake Victoria area, both ACMV and EACMV were detected. This complemented previous evidence for the occurrence of EACMV in western Kenya and confirms the overlapping distributions of the two viruses. Observations of field symptoms of sampled plants further suggested that EACMV infected plants were more severely diseased than those infected with ACMV. It was also hypothesized that unusual MAb reactions derived from a small number of severely infected plants could have resulted from mixed ACMV/EACMV infections.

6.1.8. Survey of cassava mosaic geminiviruses in Uganda

by J.P.L.

The new geminivirus species identified in Uganda, referred to as the Uganda Variant (UV), appears to be an ACMV/EACMV recombinant. Co-infection of cassava with ACMV and EACMV must have been a prerequisite for the occurrence of such a recombination event. Conditions for co-infection would seem to occur in areas where the distributions of the two viruses overlap, as recently demonstrated in western Kenya and Tanzania. Unusually, EACMV has yet to be found in Uganda, but in order to reassess this situation, cassava was surveyed in the eastern part of the country bordering Kenya. Samples were collected from more than 100 locations and tested for ACMV/EACMV using the detecting MAbs SCR 23 and SCR 33. All samples reacted with SCR 33 indicating the presence of ACMV or UV. Although the technique used is not able to detect EACMV where it occurs in a mixed infection together with ACMV, EACMV-only infections would be anticipated in locations where the two

viruses occur together, as evidenced by results obtained from western Kenya and western Tanzania. The results do therefore suggest either that EACMV does not occur, or is extremely infrequent, in the areas of eastern Uganda surveyed.

6.1.9. Diagnostic survey of whiteflies and whitefly-borne viruses of cassava and sweetpotato in sub-Saharan Africa

by J.P.L., B.J. - in collaboration with P. Anderson, F. Morales, C. Cardona, L. Calvert, S. Sithanantham, N. Smit, P. Markham

The principal output of the first two-year starter phase of the Inter-Center Whitefly IPM Project will be a diagnostic survey of whiteflies and the viruses they vector. Overall co-ordination of the project is being handled by CIAT, although IITA is responsible for co-ordinating one of four subprojects, which focuses on whiteflies as virus vectors in cassava and sweetpotato in sub-Saharan Africa. Nine major cassava and sweetpotato-producing countries in Africa will participate in this subproject, including: Ghana, Benin, Nigeria, Cameroon, Uganda, Tanzania, Kenya, Malawi and Madagascar. One of the key aims in developing the diagnostic survey protocol was to produce a common methodology, which might allow comparison of problems from continent to continent, country to country and crop to crop. A protocol was developed collaboratively by scientists from each of the CG centers involved (CIAT, IITA, CIP, ICIPE) and key supporting ARIs. Implementation of the survey began in mid-1997.

6.1.10. Seasonal incidence of *N. floridana* in cassava green mite populations in Benin and Nigeria

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

The seasonal incidence of the entomophthoralean pathogen, *Neozygites floridana*, has been monitored in *M. tanajoa* populations in 38 fields from 14 locations representing different ecological zones of Benin. Distribution of *N. floridana* was recorded up to a distance of about 400 km north of the coast. However, the incidence was very low. Observations of population densities of the red mite, *Oligonychus gossypii*, and infections in their populations were also made wherever they were present. A hyphomycetous fungus, *Hirsutella thompsonii*, was found attacking both *M. tanajoa* and *O. gossypii*. *H. thompsonii* may be another potential microbial agent for the control of *M. tanajoa* as it had caused infections as high as 26%.

A total of four on- and off-campus (IITA) cassava fields in Ibadan, Nigeria, were regularly monitored for the abundance of *M. tanajoa* and the incidence of *N. floridana*. None of the samples showed infections. However, *N. floridana* was found in one sample from Edo state.

6.1.11. Cassava faunistic inventory and curation

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

A continent-wide inventory of mites found on cassava and associated crops, selected weeds and native plants was designed and initiated to improve our knowledge of the local mite fauna associated with *M. tanajoa*. A total of 2,926 vials of mite specimens representing 46 collections were received from national programs and IITA during the year for taxonomic determination. Specimens in 2,923 vials were processed during the year generating 5,203 curated slides to be added to the cassava mite database. This database now contains 27,725 records of more than 131,218 specimens (108,073 from cassava and 23,145 from other plants) from 1,643 sites collected during the period 1983 through 1996 from 26 countries in Africa. The curated mite specimens are found on 20,117 slides representing 184 species

and 37 mite families. The largest group of specimens belong to the family Phytoseiidae which is represented by 19 genera accounting for 90 known and ca 30 unknown species from 751 host plant species. The data provide a basis for examining species associations, comparing the structure of new and old world communities, and a decision support system for identifying potential unfilled niches and candidate natural enemies. They are also being used to re-describe the Phytoseiidae of Africa. This database, available on diskette, is updated annually.

6.1.12. Yield loss assessment of *M. tanajoa* in the Zambian mid-altitude environment

by J.S.Y., B.M. - in collaboration with M. Toko, J. Purakal

Yield loss trials planted in Samfya (Luapula province) and Mutanda (North Western province) in 1992 indicated no significant differences in fresh and dry storage root weights between acaricide-treated and control plots in Luapula province. *M. tanajoa* reduces the fresh root weight by 13.9%, 16%, 15.2% and 0.43% at 7, 11, 14 and 17 months after planting (MAP), respectively. The low impact of *M. tanajoa* on fresh and dry storage root weights was attributed to low *M. tanajoa* population densities during the experimental period. In North Western province, significant differences in fresh and dry storage root weights were found between acaricide and control plots at 17 MAP. A new yield loss trial was planted in January 1996 at Lubwe (Luapula province) where *M. tanajoa* populations reach much higher levels compared to Samfya and Mutanda. The first harvest was made 12 MAP. Preliminary observations confirm higher *M. tanajoa* populations in the trial.

6.1.13. Surveys for *C. lunata* in Benin, Ghana, and Nigeria

by W.M.

C. lunata was found causing disease on cassava stems in Ghana. The disease was expressed as grayish brown superficial mycelial mats (stroma) predominantly on the lignified stem portions. Surveys were conducted in Benin (covering 66 fields, randomly selected between lat. 6° 25′ N and 8° 25′ N), Ghana (60 fields between lat. 4° 55′ N and 8° 16′ N), and Nigeria (47 fields between lat. 4° 50′ N and 7° 56′ N). Of the 66 fields of cassava surveyed in Benin, disease was found in six fields (representing 9.1% of total fields surveyed). In Ghana, the disease was found in eight fields (representing 13.3% of total fields surveyed), and in Nigeria, the disease was found in eighteen fields (representing 38.2% of total fields surveyed). The results appear to indicate that there are cassava genotypes that are resistant to the disease, and that there may be conditions in the field that pre-dispose cultivars to the disease. In all the three countries, incidence and severity varied significantly within and among cassava fields. The highest incidence (93%) was found in a field in Nigeria, whereas the highest severity (22 lesions) was recorded in Ghana.

6.1.14. Surveys for *N. mangiferae* in Benin and Nigeria

by W.M.

Surveys for *N. mangiferae* were conducted only in Benin (covering 79 fields between lat. 6° 22′ N, 2° 08′ E and 11° 10′ N, 2° 57′ E), and south west Nigeria (covering 20 fields between lat. 6° 36′ N, 4° 36′ E and 7° 49′ N 3° 50 E). Samples of wilted, and ungerminated cassava plants were collected. All samples showing termite damage were excluded in the sampling. From Benin 169 samples were collected and cultured, and nine types of fungi: *Aspergillus* spp., *Botryodiplodia theobromae, Fusarium* spp., *Macrophomina phaseolina, Nattrassia mangiferae, Penicillium* spp., *Pythium* spp., *Rhizopus* spp., and *Trichoderma* spp. were identified. Of the total fungi isolated, 95 (or 56.2% of total) were positively identified as *N.*

mangiferae, 24 (or 14.2%) as *M. phaseolina*, 20 (or 11.8%) as *Fusarium* spp., 13 (or 7.7%) as *B. theobromae*. Out of the 32 samples collected from Nigeria, four types of fungi were identified as follows: 13 (or 40.6%) as *N. mangiferae*, 9 (or 28.1%) as *B. theobromae*, 6 (or 18.7%) as *M. phaseolina*, and 4 (or 12.5%) as *Fusarium* spp. These results suggests that *N. mangifeae* is much more prevalent than the fungi hitherto known to cause cassava root rot. Interestingly, whereas fungi such as *Fusarium oxysporum, F. solani and F. moniliforme* have already been reported to be primary agents causing cassava root rot, there is a paucity of information regarding *N. mangiferae* as a primary causal agent of cassava root rot.

6.1.15. Pathogenicity of *C. lunata* on cassava

by W. M.

This study was initiated following the discovery of *Curvularia lunata* causing disease of cassava in Benin, Ghana and Nigeria. Studies were set up to elucidate the pathogenicity of *C. lunata* on cassava buds, and leaves. On stems, the study showed that *C. lunata* inhibits bud sprouting and growth of cassava. Inhibition of growth is particularly pronounced when the fungus completely colonizes buds. Under severe infection, fungal colonization extends to the young portion of the stem, suggesting that it may be disrupting other vital processes (such as gaseous exchange) in the plant. Inoculated leaves turned yellow and abscised. Presence of the fungus on the plant also led to abscission of other lower leaves on the plant. Between 10 and 40% more leaves abscised in inoculated plants, depending on the genotype.

6.1.16. Pathogenicity of *N. mangiferae* on cassava

by W.M.

N. mangiferae is one of the new diseases discovered in West Africa. Diagnostic surveys conducted in Benin and Nigeria showed that the disease was much more prevalent on cassava than the commonly recognized root rots such as *Fusarium* spp., and *Botryodiplodia theobromae*. Presence of a fungus on a plant does not necessarily mean that the fungus is pathogenic on the plant. This study was undertaken to elucidate the pathogenicity of *N. mangiferae* on cassava. The results demonstrated that *N. mangiferae* is a primary root rotting pathogen of cassava. The fungus kills cassava by inhibiting root formation as well as killing infected stem tissue. Symptoms (i.e., flaccid roots on which pycnidia-like structures were visible) of the disease resemble those caused by *Botryodiplodia theobromae*. Results also show that there are genotypes (e.g., 'TMS 30572') of cassava that are more tolerant of the fungus than others. Because the fungus rapidly kills its host, has a wide host range including humans, is much more prevalent than other root rots, *N. mangiferae* may be an important emerging disease of cassava.

6.2. Evaluation of multitrophic interactions of key cassava pests

Background

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

Ongoing and future activities

6.2.1. Dynamics of severe and mild forms of cassava mosaic disease over repeated cropping cycles in Uganda

by J.P.L.

A trial was planted in November 1996 with the twin aims of relating severity of mosaic symptoms to yield loss and investigating the phenology of cassava mosaic disease symptomatology over repeated cropping cycles. Severely (mosaic) diseased, mildly-diseased and disease-free stems were collected from two separate locations, and cuttings derived from each 'class' planted out in equal proportions at random in the field at Namulonge. Although cuttings were planted in a random array, the provenance of each plant was known, and records collected could therefore be related to this provenance. Preliminary results indicate that, although a larger proportion of plants derived from mildly-diseased source plants are expressing mild symptoms than those derived from severely-diseased source plants, there is considerable overlap in the distributions of severity scores for plants from the two groups. PCR-based diagnostics should be available before the first season of this trial is complete and should allow symptom histories to be related to the presence of a particular virus or virus combination. Most plants which were initially healthy were infected during the early stages of the trial, a result which was anticipated given the high current inoculum pressure at Namulonge. The trial will be replicated in 1997 at Serere, where inoculum pressure is lower, thereby facilitating the comparison of disease phenology under contrasting conditions.

6.2.2. Detection of specific antigens of Xcm (proteins and lipopolysaccharides), production of a monospecific, polyclonal antiserum and test of a DNA probe for the detection of Xcm in various habitats

by K.W. - in collaboration with V. Verdier, A. Fessehaie

Protein was extracted from Xcm strains and proteins were analysed by electrophoresis on SDS Page gels and native gels. One gel was stained with Coomassie Blue for proteins, and the twin gel was electroblotted on a nitrocellulose membrane, which was subsequently immunologically probed with a polyspecific antiserum against whole cells of Xcm received from BOHER, ORSTOM. A protein band specific for Xcm, but not for other Xanthomonads nor *Erwinia* or *Pseudomonas* was detected. The protein was eluted and injected into rabbits for production of the monospecific, polyclonal antiserum. Lipopolysaccharides were produced in high quantities in fermenters (see 6.1.), purified and injected into rabbits for the production of a monospecific antiserum.

More than hundred Xcm strains were analysed by RFLP (PHMD Annual Report 1994/1995), using chromosomal and several plasmid probes. For the first time, a classification of the African strains in several groups was demonstrated. The best differentiation was achieved with a plasmid probe. The probes shall be tested for their specificity and practicability for the detection of Xcm in field samples, and the optimal probe shall be selected. The primers (PCR) and the probe (dot-blot) shall be tested with the entire Xcm collection. This technology shall be available at IITA and CIAT and be transferred to interested national programs in Africa and Latin America.

6.2.3. Diagnosis: Test of the new semiselective medium with fresh plant, stem and soil material from different ecozones and its use for cutting sanitation

by K.W. - in collaboration with A. Fessehaie

The efficiency and suitability of the newly developed semi-selective medium shall be tested with material from different ecozones (leaves, stems, soil), to find out if the medium can suppress epiphytes and saprophytes from different areas. The medium will be tested by the Seed Health Unit for the seed material from different geographic origin. CIAT will test the medium with plant and soil samples from Latin America.

Epidemiology: Validation of the medium for detection of Xcm in cassava stems. Epidemiological studies were conducted, to identify the sources of inoculum from where an infection starts. The new medium (ingredients see abstract below) was used to detect bacteria in cuttings from 18-month-old cassava plants. Bacteria were located in stems of the susceptible and the resistant variety, but significant differences between the varieties were found in the quantity of bacteria in stems.

6.2.4. Epidemiology: Production of Xcm strains from different ecozones with a resistance towards two antibiotics and their use in epidemiological research on varieties in three ecozones

by K.W.

To study the epidemiology of Xcm on leaves, stems, in plant debris and the soil, antibiotic resistant mutants allow to follow precisely the population dynamics of the bacteria. Spontaneous mutants were selected first for resistance against increasing quantities of rifampicin. In a second step these strains were subjected to high quantities of streptomycin, until a strain, resistant against 100 ppm of rifampicin and 100 ppm of streptomycin was received. In order to elucidate the mechanisms of resistance of cassava varieties to CBB, the quantification and fluctuation of the epiphytic Xcm population during the growing season could give insights into different suitability of cassava leaves as habitat for the bacteria. The antibiotic resistant strains of Xcm were produced to screen and quantify the survival and the population build up in the dry season and the rainy season. Young and old leaves were screened for their epiphytic Xcm population. Twenty-three varieties were planted in three ecozones and spray inoculated with a highly virulent strain of Xcm isolated from the same area. The strain was produced for the epidemiological studies with a resistance towards two antibiotics. Preliminary analysis of the still ongoing experiments show differences between the varieties in the quantity and dynamics of epiphytic populations of Xcm on young and old leaves: Xcm population increases on two susceptible varieties while it decreases on a resistant variety (experiment is ongoing); the survival and multiplication on young leaves is less than on old leaves.

Additionally, symptom development and influence of the symptoms on growth parameters were investigated in field experiments with 23 varieties in three ecozones, using spray inoculation with a highly virulent strain of Xcm from the same area. The varieties were selected from 423 varieties tested and analysed for their reaction towards CBB in 1995. The disease development after inoculation was variable in the various agroecological zones, revealing a strong influence of agroecological conditions on the epidemiology. The influencing factors will be analyzed at the end of the experiment, the data analysis is ongoing.

6.2.5. Survival of Xcm in soil and plant debris and as epiphytes on weeds
by K.W.

Antibiotic resistant strains were used for these studies. The survival in plant debris and in plant debris in soil was screened under different soil moisture regimes. Dry conditions: Xcm survived less than three months.

Wet conditions: Xcm in plant debris in soil survived less than one month, Xcm in plant debris without soil survived less than two months.

Weeds: To identify the role of weeds in the survival and spread of Xcm, a cassava field was not weeded and weeds were spray-inoculated with an antibiotic resistant strain of Xcm. The epiphytic population on the leaves of the weeds was screened during the growing period of the weeds with three weekly quantifications of bacteria. Xcm survived about one month after spraying on *Solanum nigrum, Talinum triangulare, Mariscus alternifolius, Pupalia lappacea, Brachiaria deflexa, Dactyloctenium aegyptium*; about one week after spraying Xcm was additionally found on *Euphorbia heterophylla* (Euphorbiaceae), *Cyatula prostrata* (Amaranthaceae) and *Digitaria horizontalis* (Poaceae). Seven weeks after spraying, none of these weeds Xcm was detected. This experiment conducted under natural conditions shall be repeated under controlled conditions with spray-inoculated and spray-infiltrated leaves in the glasshouse. Additionally, other plants from the Euphorbiaceae family will be tested.

6.2.6. Movement and multiplication of bacteria in the plant and disease spread by vectors
by K.W.

The reasons for the development of healthy and infected plants from infected cuttings shall be elucidated. The conditions for the survival and the activation of the bacteria after a latent phase in the cutting and the mechanisms of translocation of Xcm from the infected cutting into the sprout will be investigated. The multiplication of the bacteria in plants deriving from infected seeds will be quantified.

Experiments are planned on the importance of vectors for the distribution of CBB on short and long distances, and the mechanisms of spread by the vectors. Experiments will be conducted with the antibiotic-resistant strains. Bacteria shall be isolated from the exosceleton, the alimentary tract and the feces. The active inoculation of plants be feeding insects has never been demonstrated. At present, it is still unclear whether bacterial lesions on the leaves originate from insect distribution and if insects prefer to feed on diseased tissue. The efficiency of insects for long-distance contamination shall be tested.

6.2.7. Virulence of the Brazilian and Beninese isolates of *N. floridana* to the cassava green mite
by S.K.D., C.J.L., J.S.Y.

Virulence of one isolate each from Brazil (Alto Alegre) and Benin (Cotonou) of *N. floridana* was compared against the male and female *M. tanajoa* in laboratory bioassays. In two out of three tests, both isolates of the fungus were equally virulent to males and females of *M. tanajoa*. In one test, the exotic isolate was significantly more virulent than the indigenous isolate to males of *M. tanajoa*.

6.2.8. Multitrophic interactions between cassava, *M. tanajoa*, and *T. aripo*

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

Several complex ecological questions concerning the interactions between cassava, *M. tanajoa* and *T. aripo* will be developed through a simulation model. This includes identifying and mapping ecologically homologous regions of Africa and the Neotropics based on dynamic climatic and agrometeorological criteria, incorporating phytoseiid predation in the cassava green mite element of a systems model, and evaluating the prospects of cassava green mite control using exotic phytoseiid natural enemies. A cassava systems model developed by IITA, the University of California, Berkeley, and ETH, Zurich, provides a basis for this work.

6.3. Development, testing, and integration of IPM components

Background

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

Ongoing and future activities

6.3.1. Exotic phytoseiid life table and feeding studies

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

T. aripo developed at all temperatures tested including 18, 22, 25, 28, 31 and 33 °C. The development period ranged from 4.86 to 5.75 days between 25 and 33 °C. As temperature approached the lower threshold, development of *T. aripo* slowed dramatically. A developmental threshold of 13.75 °C was calculated using a polynomial function. Oogenesis was completed at all temperatures tested. A daily fecundity of 1.64 eggs at 25 °C was the highest observed. At 33 °C, oogenesis was severely inhibited; a single female laid a total of 2 eggs. The intrinsic rate of increase, r_m, and the net reproductive rate, R_o, were also highest at 25 °C. Mean generation time was 22.3 days at 18 °C and decreased continuously to 10.23 days at 31°C. Doubling time similarly dropped from 11.39 days at 18 °C to 4.93 days at 28 °C. The female:male sex ratio was greater than unity at all temperatures, but lowest at 25 °C.

6.3.2. Exotic phytoseiid predation and competition

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

An evaluation of the predation by and competition between the exotic phytoseiids, *T. manihoti* and *T. aripo*, is needed to understand the relative contribution and importance of each in the field. Thus, a screenhouse trial was implemented to measure the relative impact of each species and to monitor interactions between species. Potted plants similarly infested with *M. tanajoa* in a screenhouse were manipulated with the following treatments: *T. manihoti* only (TM), *T. aripo* only (TA), *T. manihoti* and *T. aripo* (TM&TA), and a control without phytoseiids, then monitored weekly for five weeks - ca five phytoseiid generations. The effect of *T. manihoti* on *M. tanajoa* was evident in both the TM and TM&TA treatments in the

first generation. By the second generation, *T. manihoti* had completely suppressed *M. tanajoa*. Most of the impact was attributed to functional response, since relatively few *T. manihoti* eggs and actives were produced during the entire five generations of the experiment. *T. aripo* on the other hand, had little effect on *M. tanajoa* in the first generation, but showed significant impact by the second generation before completely suppressing the pest by the third. Direct competition between predators was limited since *T. manihoti*, an actively hunting predator, was found mostly on developed leaves, and *T. aripo*, a lie and wait ambush predator, was largely confined to the apex and young leaves, and also because the period of interaction was only two generations before *M. tanajoa* was controlled.

6.3.3. Foreign exploration and natural enemy selection

by J.S.Y., B.M. - in collaboration with G. J. de Moraes, L. Smith

Foreign exploration in 1996 included semiarid and high altitude ecozones in Colombia and Brazil. Collaboration continued with the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) in Brazil and the Centro Internacional de Agricultura Tropical (CIAT). Several natural enemy populations selected in Brazil and Colombia were shipped to Africa for mother-stock establishment and subsequent mass rearing for experimental release trials (Table 1). In addition, a number of field and laboratory studies were done to identify and measure the efficacy of potential *M. tanajoa* natural enemies. Foreign exploration for natural enemies adapted to the mid-altitude conditions found in the southern African cassava belt continues in 1997.

Table 1. Predatory mites received by IITA in 1996

Species	Origin[1]	Date received	Number[2] sent	Number[2] received	Overall mortality (%)	Number alive
T. limonicus	E/MG	14/5/96	258	257	19.5	207
	E/S. Catar.	14/5/96	156	156	26.9	114
T. aripo	E/Brasi.-FD	5/11/96	29	25	24.1	22
T. manihoti	B/Djèrègbé	18/1/96	177	177	-	177
	C/Barbosa	14/5/96	47	39	61.5	15
	C/Barbosa	28/5/96	305	295	13.6	255
	C/Cajibio	14/5/96	31	31	19.3	25
	C/Q. Arm.	24/12/96	64	61	26.2	45
	C/S.R.d.Cab.	24/12/96	18	17	11.1	16
	C/L. Colora.	24/12/96	75	76	6.6	71
	C/Cal. Chin.	24/12/96	18	23	52.2	11
	C/Bijagual	24/12/96	28	28	7.1	26

[1] E = EMBRAPA (Brazil); C = CIAT; B = Benin; MG = Minas Gerais; S. Catar. = Santa Catarina; Brasi.-FD = Brasilia-Federal District; Q. Arm. = Quindio Armenia; S.R.d.Cab. = Santa Rosa de Cabal; L. Colora. = Los Colorados; Cal. Chin. = Caldas Chinchina; [2] adult females

6.3.4. Quarantine and culture of exotic phytoseiids

by J.S.Y., B.M. - in collaboration with F. Bakker, G. J. de Moraes, L. Smith

The University of Amsterdam continued to provide quarantine for *M. tanajoa* natural enemies shipped to IITA. The exotic phytoseiids received by IITA in 1996 (Table 2), included *Typhlodromalus limonicus* (Garman & McGregor) from Santa Catarina and Minas Gerais, Brazil (1 shipment each); *T. aripo* from Brasilia-Federal District, Brazil (1 shipment); *T. manihoti* from Barbosa, Colombia (2 shipments), from Cajibio, Quindio Armenia, Santa Rosa de Cabal, Los Colorados, Caldas Chinchina and Bijagual, Colombia (1 shipment each), and from

Djèrègbé, Bénin (1 shipment). The pathogenic fungus *N. floridana* was received from Saõ Gabriel de Goias, Brazil (1 shipment).

The maintenance of mother cultures continued at an acceptable level of production for the number of colonies present. The exotic species still in culture included *N. anonymus* (represented by one Colombian population), *N. idaeus* (one Colombian and four Brazilian populations, including one from a release field in Benin), *T. aripo* (four Brazilian populations), *T. limonicus* (five Brazilian populations) and *T. manihoti* (nine Colombian and four Brazilian populations including two from release fields in Benin). The pathogenic fungus *N. floridana* from Brazil is also being maintained in culture. New populations of cassava green mites natural enemies from Brazil or Colombia well adapted to mid-altitude and semiarid conditions are expected in 1997.

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

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

Inoculum of three Brazilian isolates of *N. floridana* (from Alto Alegre, Colas Almas, and Adanai Lambari) will be multiplied in vivo and released along with the Beninese isolate (Cotonou) and released on experimental basis in different fields in transition forest and moist savanna zones of Benin. Collaborative arrangements will be made for conducting similar experiments in two regions in Kenya and in one region in Ghana. A local isolate of *H. thompsonii* (from Adjohoun, Benin) will be cultured in vitro and applied along with *N. floridana* in Benin to compare its potential as a microbial control agent. The performance of the released isolates of the pathogens will be monitored regularly.

6.3.6. Development of screening methodologies for identification of resistant varieties and their resistance mechanisms to CBB in the greenhouse and the field, and greenhouse screening of selected varieties for resistance to CBB

by K.W., A.G.O.D.

Natural infection of plants from healthy cuttings occurs primarily through leaf infection. To identify resistance mechanisms and to evaluate the resistance against bacterial blight, repeated spray inoculations and symptom evaluations considering the first occurrence, the percentage and the duration of the different types of symptoms and their impact on the yield parameters (leaf number, leaf weight, stem weight, root weight) are recommended. Stem puncture inoculation can be used additionally, but not as only screening method. In the greenhouse, varieties are tested by leaf infiltration of Xcm. Additionally, the number and distribution of stomata, the main entrance for the bacteria, on the abaxial and adaxial leaf surface shall be screened for different varieties. Also the leaf wax quantity in different varieties will be determined.

Xcm strains from various regions showed a high virulence when inoculated in cassava plants of a susceptible variety in the greenhouse. The virulence of the isolates may be one reason for heavy infections which were observed in various regions. The regions where isolates with high virulence have been identified and where symptoms and epidemics develop very quickly should be preferable used for screening of varieties for resistance against CBB. Varieties identified as tolerant or resistant after the field screening are inoculated with highly virulent strains from various geographic regions in greenhouse experiments. Different inoculation methods are used to identify a method which shows best correlation to the field results. The existence of pathogenic races will be tested.

6.3.7. Test of resistant and susceptible cassava varieties for their suitability to support epiphytic Xcm populations in different ecozones
by K.W.

Twenty-three varieties were planted in three ecozones and spray inoculated with a highly virulent strain of Xcm isolated from the same area. The strain was produced for the epidemiological studies with a resistance towards two antibiotics. Preliminary analysis of the still ongoing experiments show differences between the population density on leaves of different age and different varieties, thereby revealing differences in the suitability of cassava leaves as habitat for the bacteria. Since disease outbreaks are, among others, a function of the population build up and density on the leaf surface under favorable conditions, these data are useful to support the identification of resistance mechanisms. A difference in the population build up on the varieties was observed. On the susceptible varieties Ben 86025 and Antiota the multiplication of Xcm was high, while there was no multiplication on TMS 30572. The experiment and the analysis of the data from 20 other varieties in ongoing.

6.3.8. Improvement of cultural practices to control CBB infection
by K.W., A.G.O.D.

Yield loss experiments revealed the effect of different levels of CBB infection at different stages of plant growth on tuber and leaf yield. Control measures are developed for areas with high infection pressure. Field trials evaluating CBB infection and the impact on yield loss by planting at different dates were conducted in one site (Ibadan). Another trial concerned the infection date: influence of early and late infection on the growth parameters and the yield. Data analysis is ongoing.

Experiments on the influence of cropping systems on the incidence and severity of CBB were conducted in Ibadan: cassava and maize, and cassava and cowpea were intercropped in two arrangements for each combination, both species in the same row and in alternative rows. The cassava border plants were spray inoculated with an Xcm strain. CBB infection was significantly less in both cassava maize arrangements than in the cassava cowpea combination. The epiphytic population on cassava and maize was screened, the data analysis is ongoing.

6.3.9. Development of a quarantine procedure for CBB: Sanitation experiments on bacterial blight infection in the field and quantification of bacteria in cuttings using the new semi-selective medium
by K.W.

A sanitation experiment was conducted with cuttings from CBB infected plants, being infected with CBB already in the second generation. The percentage of infected plants deriving from cuttings from different parts of the stem was established. Surprisingly, the number of infected plants was very low. This trial was a repetition of a trial in 1995, which showed a similar result.

Analyzing cuttings from infected plants showing dieback symptoms, Xcm bacteria were more frequently detected in cuttings from the susceptible than from the resistant variety. Nevertheless, bacteria were also able to invade the stem of the 'resistant' variety TMS 30572. The bacteria are not evenly distributed in the plant and also not concentrated in a specific part of the plant. The experiments are repeated with cuttings derived from different ecozones. From infected cuttings, healthy plants may sprout, but sometimes plants develop blight symptoms, originating from cutting infections after the bacterium has gone through a latent phase

in the cutting. The conditions for the survival and the activation of the bacteria and the mechanisms of translocation of Xcm from the infected cutting into the sprout shall be investigated.

6.3.10. Screening of varieties for resistance to bacterial blight, mosaic disease, anthracnose, and identification of sources of resistance

by K.W., A.G.O.D.

In various ecozones, varieties which have been regarded as resistant developed serious symptoms to CBB. Breeding for resistance is, besides sanitation measures, the most suitable and promising means of control of CBB. The disease cannot be controlled by chemicals, and thus breeding receives special importance. Cassava mosaic disease was prevalent with high incidences in all ecozones. The surveys also revealed high incidences and severities of anthracnose disease in the humid ecozones and especially the rainforest areas. Clones with a multiple resistance to several diseases shall be identified.

CBB, CAD and CMD symptoms were evaluated in field trials with 1625 clones in two sites (Cotonou, Ibadan) with detailed protocols to identify mechanisms and sources of resistance. This also includes the resistance to the vector *Pseudotheraptus devastans*, which enables the infection by *Colletotrichum gloeosporioides*, causal agent of CAD. From the 1,625 clones tested for resistance against CBB, mosaic disease and anthracnose, promising varieties have been identified for further breeding and selection. Preliminary results from Cotonou reveal, that only few clones possess a multiple resistance to several diseases. In general, the susceptibility to CMD and CBB was high, but many varieties had a tolerance for anthracnose disease. Data analysis of the 1,200 varieties tested in Ibadan is ongoing.

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

by K.W.

Several methods for the quick evaluation of symptom development of fungal isolates were tested. An optimal method was identified and will be used for the screening of varieties for their resistance against root rot pathogens: the inoculation of cuttings and symptom evaluation after five days was selected for further experiments to inoculate varieties with rot pathogens of high virulence and from different locations.

6.3.12. Characterization and mass production of antagonists against root rot pathogens and greenhouse and field experiments on the efficacy of antagonists against root rot pathogens

by K.W.

Strains of the fungal antagonists *Trichoderma harzianum* and *T. koningii* from Benin, Nigeria and Cameroon were tested as agents for biological control of root rot fungi. In vitro antagonistic tests showed variable pathogen x antagonist interactions. Most *Trichoderma* sp. strains were highly effective against the pathogens with an inhibition coefficient higher than 85%. Promising *Trichoderma* spp. strains were used for further investigations in greenhouse experiments. These results indicate that indigenous *Trichoderma* spp. present in the cassava root rhizosphere have antagonistic properties to root rot fungi of cassava. The antagonistic effects of *T.* spp. seem to vary from isolate to isolate. Promising results have been obtained in vitro and in pot experiments. The investigations are ongoing.

Economically feasible techniques for the mass production and management of *Trichoderma* as biological control agent, as part of an IPM package for root rots, were elaborated. Several methods for mass production were tested, a suitable method of mass production of antagonists on a local and cheap substrate was selected.

In greenhouse experiments, different hosts (cassava, cowpea, tomato) were inoculated with *Sclerotium rolfsii, Botryodiplodia theobromae* and *Fusarium oxysporum*. To test the efficacy of the antagonistic *Trichoderma* strains in suppressing the pathogens, *Trichoderma* spores from mass productions were inoculated into the soil, and in parallel experiments seeds of cowpea were pelleted with a suspension of *Trichoderma* spores embedded in a polysaccharide carrier. A significant effect was achieved by inoculating cowpea seeds and soil of cowpea and tomato pots with *Trichoderma*: symptom development by the pathogens was suppressed. In a control, *Trichoderma* showed a growth promoting effect. Field experiments to optimize the concentration of the antagonist in the inoculum, the application method and measures to augment the competitivity in the soil will be tested in Benin and Cameroon.

6.3.13. Influence of ratooning on severity of cassava anthracnose disease

by W.M.

The objective of this experiment was to elucidate the effect of seasonal ratooning on the incidence and severity of CAD. Stems for three genotypes of cassava ('Ben 86002', 'Ben 86052', and 'MCN 89124') were artificially inoculated prior to planting. Treatments comprised plots where stems were not ratooned (control), and plots ratooned at the beginning, or end of the rainy season. Plants were assessed for incidence (number of plants infected) and severity (number of cankers per plant) of CAD, and fresh root yield per plant. Incidence and severity of CAD, as well as fresh root yield per plant varied significantly. For cultivars 'Ben 86002', and 'MCN 89124' disease incidence was significantly lower when stems were ratooned at the beginning of the rainy season, than at the end of the season or when stems were not ratooned at all. For these two cultivars, disease severity followed a trend similar to disease incidence. For 'Ben 86052', disease incidence was significantly lower in plants not ratooned, whereas ratooning at the start or end of the rainy season significantly increased the severity of CAD. Ratooning at the start or end of season also increased fresh root yield per plant for 'Ben 86002' and 'Ben 86052', but decreased the fresh root yield for 'MCN 89124'. Incidence represents plant to plant disease spread, and in all cultivars disease incidence was highest in control plants and plants ratooned at the end of the rainy season, suggesting that the longer the plants remain in the field, the more the disease spreads to health plants.

6.3.14. Effect of type of intercrop on severity of cassava anthracnose disease

by W.M. - in collaboration with J.T. Ambe, F.F. Tengoua

Stems of four genotypes of cassava ('Bitutu', 'Ekobele', 'Zebomedjeu', and 'Agric') were inoculated with an isolate of CAD locally collected, and planted on a farmer's field in the rainy forest in Cameroon. Treatment comprised above mentioned cultivars in monocrop or intercropped with maize, or cowpeas. Plants were assessed for incidence (number of plants infected per plot) and severity (number of cankers per plant) of CAD. Both the incidence and severity of CAD varied significantly by genotype and the interaction of genotype and type of intercrop. For all cultivars, the highest incidence and severity of CAD were in plots where cassava was planted in monocrop. In monocrop, disease severity for cultivar 'Ekobele' was significantly the highest while the differences among 'Agric', 'Bitutu', and 'Zebomedjeu' were insignificant. For all cultivars, the lowest disease incidence and severity were in plots

where cassava was intercropped with maize. When cassava was intercropped with cowpeas, both the incidence and severity was generally lower than in plots where cassava was grown in monocrop, though higher than in plots intercropped with maize. This study demonstrated that intercropping cassava may reduce the incidence and severity of CAD. The reduction is dependent on the choice of intercrop used. Maize was a more effective intercrop than cowpeas in reducing both the plant to plant spread (incidence) and severity of CAD. The trial is in its final season.

6.3.15. Rapid screening of cassava for resistance to cassava anthracnose disease (CAD) and its correlation with the conventional methods

by W.M. - in collaboration with N.A. Amusa

Cassava anthracnose disease (CAD) is among the most serious disease affecting cassava. Field-based screening and selection for resistance is complicated by the need for the insect vector *Pseudotheraptus devastans* [Dist. [Hom. Coreidae]) which creates wounds and the need for adequate moisture for disease and symptom development. An experiment was undertaken to screen and select for CAD using toxic metabolites of *Colletotrichum gloesporioides* f. sp. *manihotis,* and to compare with the conventional screening methods. One hundred and eighteen cultivars and clones were screened in the field and in the laboratory. There were significant differences in reaction of cassava genotypes to CAD. In both the conventional screening and toxic metabolite methods, eight clones were resistant to the disease. Results suggest that using toxic metabolites is as effective as the conventional methods for screening for resistance to CAD.

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

Background

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

6.4.1. Decision support systems

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

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

6.4.2. Interactive information media
by J.S.Y., B.J., W.M.

A cassava plant protection information CD-ROM developed by ESCaPP with the University of Florida will be improved, updated and placed in a Web site. The information resource will consist of a cassava plant protection directory of personnel, projects and institutions, full text of important cassava management documents, photographic quality color images of major production constraints and natural enemies, bibliographies, the entire series of CIAT/IITA cassava newsletters, training modules, an expert system as a decision support tool, and a series of databases including cassava mites of Africa, ESCaPP protection, production and socioeconomic diagnosis, collaborative study of cassava in Africa, and long-term African meteorological data. Additionally, IITA staff will continue to be trained to prepare documents for conversion into an interactive format. The ultimate aim of the training would be to develop an independent capacity to create interactive cassava information resources.

6.4.3. Development, standardization, and field testing of scoring procedures and sampling protocols for cassava pathogens
by K.W.

Disease-scoring protocols, collected from NARS from various countries and from literature sources, were harmonized and the sampling procedures tested during surveys in several countries and improved during 1994 and 1995. The results, including photos for disease classification, are part of the 'Training Manual on Cassava Pathology', a brochure on 'Pest and disease survey protocols' and the source book for extensionists, 'Plant protection constraints in cassava production'. A CD ROM version of the booklet 'Common African Pests and Diseases of Cassava, Yam, Sweetpotato and Cocoyam' was finalized in 1995. A new version of the booklet has been reviewed by several pathologists and is being edited.

6.4.4. Development of training papers for cassava quarantine procedures, course papers for cassava breeders, and a training course on biological control of pathogens
by K.W.

Quarantine procedures for the production and safe movement of cassava planting material and cassava seeds were elaborated and embedded in training papers on general quarantine procedures, the importance of exotic diseases for cassava in Africa, etc. Training papers for NARS scientists on biological control were developed and used in a two weeks course held in Benin. The principles of biological control of pathogens, successful examples worldwide, the technologies and laboratory methods involved and the use of biological control in tropical agriculture, demonstrated in examples in the greenhouse. Course papers for cassava breeders on cassava pathology, breeding for resistance and the principles of integrated pest management were developed and used in a course for breeders from 18 African countries.

6.4.5. Extension/farmer training materials
by B.J., J.S.Y., W.M. - in collaboration with J.A. Tumanteh, N.G. Maroya, A.R. Cudjoe, J. Kwarteng, T.N.C. Echendu

A set of new cassava IPM extension/training materials were developed and field tested by the project's cassava farmer field school participants in Benin, Cameroon, Ghana and Nigeria and by the National Biological Control Program in Sierra Leone. The set of extension/training materials include seven extension posters (on the selection of healthy stem planting

material, control of cassava green mite, cassava mosaic disease, cassava bacterial blight, variegated grasshopper and control of weeds for better yield), four cassava IPM extension guides and a source book for cassava IPM training. Four of the posters were finalized for printing and distribution through collaborating NARS and NGOs and participants of cassava farmers field schools.

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

Background

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

Ongoing and future activities

6.5.1. Experimental releases and follow-ups

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

A total of 5,807, 600, 4,345 eggs and actives of *T. aripo, N. idaeus, T. manihoti,* respectively, were shipped from IITA for laboratory rearing in Cameroon and the Netherlands and for experimental releases only in Zambia in 1996 (Table 2). All were successfully reared and released by national programs in Ghana, Nigeria, Cameroon, Uganda and Kenya.

Table 2. Releases of predatory mites shipped from the IITA insectary in Cotonou in 1996

Species (populations[1])	Country (ecological)	Number of mites shipped[2]	Number of shipments	Number of release fields	Zone[3]
N. idaeus (E/MGS)	Zambia	600b	1	1	LR
T. aripo (E/Jaguaricena)	Zambia	1230b	1	1	S
T. aripo (E/Itumbiara)	Zambia	3377b	1	1	S
T. aripo (B/established)	Netherlands	1200b	1	1	LR
T. manihoti (C/Cajibio)	Zambia	3445b	2	2	S
T. manihoti (B/Djèrègbé)	Cameroon	360b	1	1	LR
	Netherlands	240b	1	1	LR
T. manihoti (Gh./Mank.)	Netherlands	300b	1	1	LR

[1] Abbreviations refer to locations where populations were collected; [2] a = actives+ eggs; b = actives only; [3] S = savanna; LR = laboratory rearing

In Benin, *T. aripo* was recovered in all previous release fields, including Djougou at the edge of the dry savanna zone, and dispersed an estimated 400 km since 1994. The predator now covers an estimated 50,000 km^2 in the country. This predator continues to persist and spread in Guinea-Conakry, Ghana, Nigeria, Cameroon, Uganda, Kenya, Togo and Burundi. The

status of *T. aripo* in Sierra Leone could not be assessed in 1996. *T. aripo* was recovered for two to six months in 11 of the 21 fields monitored in Zambia during the year, but disappeared from all the release sites by July after the harsh conditions of the cool dry season in this subtropical mid-altitude region. The predator spreads at a rate of more than 15 km per year, and develops on a range of spider mite prey, pollen, honeydew and plant exudates, but required *M. tanajoa* or maize pollen to oviposit. It reduces *M. tanajoa* population by two thirds where established. *T. aripo* currently covers an area of ca 400,000 km^2. Early results from a cassava production trial indicate significant yield increases when *T. aripo* is present. *T. manihoti* continued to be found in Ghana more than six years after release in May 1990 near Mankessim. It spread more than 14, 15, and 27 km east, west, and north respectively from its original release field (the ocean is to the south), and covers an area greater than 800 km^2. While no recoveries of *T. manihoti* were made in other release sites prior to 1995 in Ghana, it was recovered in six of nine release sites in 1995 and in four of five release sites in 1996. *M. tanajoa* densities where *T. manihoti* was established were ca 60% lower compared to fields where the exotic predator was absent. *T. manihoti* comprised a season-long average of 30% of the phytoseiid fauna when present. *T. manihoti* is still present in the three locations in Benin where it was discovered during a distribution survey for *T. aripo*. One location was near a 1990 release site (Djèrègbé), while the other two were near 1991 (Sè) and 1994 (Allada) release sites. This predator has also been recovered in two locations in Nigeria and one location in Burundi.

The establishment, dispersal and population dynamics of *T. manihoti* and *T. aripo* will continue to be monitored this season as the predators spread in Africa. Promising phytoseiids, especially *T. aripo* and new species adapted to periodic frost, will be released in a range of ecozones from selected countries in the cassava belt of Africa. Experimental releases will continue with *T. manihoti* in transition and rain forests of West and Central Africa. The first releases of the pathogenic fungus, *N. floridana*, will be made in 1997. The success with *T. aripo* in the West African cassava belt will shift our effort in the region from multiplication and distribution to dispersal and impact assessment.

6.5.2. Impact assessment of exotic predatory mites

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

The impact of the exotic phytoseiids *T. manihoti* and *T. aripo* on the population dynamics of *M. tanajoa*, local phytoseiids and the production of storage-root dry matter in cassava are being evaluated in Benin, Ghana and Nigeria. Two types of trials have been established to measure the impact of *T. aripo* on cassava yield and the interaction between *T. aripo* and *T. manihoti*, respectively. The first type is an on-farm trial in farmers' fields managed by the respective farmers, while the other is a standard replicated field plot trial on farm managed by the researchers. *M. tanajoa* and phytoseiids are being monitored monthly in each site, while plant samples are being taken and evaluated for dry matter content at the time of harvest. As anticipated, initial results show higher phytoseiid and lower *M. tanajoa* densities, and increased plant production values in the plots/fields with *T. aripo* compared to plots without *T. aripo*. These trials continue in 1997.

6.5.3. Relationship between cassava mosaic disease severity and yield loss

by J.P.L.

The trial described above will also be used to quantify relationships between symptom severity and yield loss. Severity of cassava mosaic symptoms is being assessed using four distinct methods in an attempt to identify which method or combination of methods can be used to estimate yield loss based on symptom severity scores alone.

6.5.4. Support to national programs

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

The project's support to NARES continues implicitly in many of our research activities and explicitly in a number of training activities. Support activities were carried out in Benin, Burundi, Cameroon, Ghana, Guinea, Kenya, Mozambique, Nigeria, Uganda and Zambia. Seven trainees from two national programs visited the cassava green mite group in Cotonou for an average of two weeks of personalized bench training each during the year. A specialized training course on multiplying, distributing and evaluating *T. aripo* was given to a selected group of 10 national scientists who had previous *M. tanajoa* training and who work on the mite in their countries.

The laboratory at IITA Cotonou serves as an identification laboratory for phytopathological problems and quarantine questions for NARS. Courses on diagnosis, IPM of cassava diseases and phytopathological methods and on the biological control of pathogens were conducted with scientists from NARS and research assistants from IITA/Cotonou and Ibadan at the phytopathological laboratory in Cotonou. Field evaluation techniques are taught at Cotonou and IITA, Ibadan. Two training courses were held for breeders from 18 countries in Ibadan in 1994, 1995 and 1996 and courses at NARS in Nigeria and Cameroon in the following subjects: symptom recognition, selection and transportation of specimens, identification of bacteria, fungi and viruses, control of diseases. A course on the principles of plant quarantine and the production of healthy planting material was held in Ghana in April 1996.

6.5.5. Organize training courses on cassava IPM/control strategies

by B.J., J.S.Y., W.M., K.W. - in collaboration with A. Tumanteh, B. Bakia, N.G. Maroya, K. Ahiou, A.R. Cudjoe, D. Annang, T.N.C. Echendu, R. Salawu, C.C. Asiabaka

Short-term group and individual training have been provided to project and NARES participants to increase the effectiveness of researchers and technicians in various need areas. The areas include overseas (CTPM, Brisbane, Australia) training in "IPM tools for implementation" for community consultation techniques/skills and participatory learning/research; in-country training in "certification of cassava stem planting material" in response to Ghana's need to include vegetative planting materials into its seed certification program and to increase the ability of Seed Inspectors to identify pests and diseases transported via stem cuttings, detect cassava viruses/virus strains in sources of planting materials and estimate primary CMD incidence; a PHMD-based group course on "arthropod collection/curation" to assist NARES to establish reference arthropod pest and natural enemy collections; and ICD based training workshop on "preparation of didactic extension and training materials" in which a set of seven cassava IPM posters were drafted.

6.5.6 Organize cassava farmer field school training

by B.J. - in collaboration with A. Tumanteh, B. Bakia, N.G. Maroya, K. Ahiou, A.R. Cudjoe, D. Annang, T.N.C. Echendu, R. Salawu, C.C. Asiabaka, K. Anamoa

Action learning and participatory research were initiated to increase the effectiveness of extension workers and farmers in cassava IPM. Twenty-five cassava Farmer Field Schools (FFS) were established within national extension systems and collaborating NGOs in Benin, Cameroon, Ghana and Nigeria. Two FFS sites were within IITA benchmark zones in Cameroon to encourage interdisciplinary research, integrate research with farm-level training and encourage wider farm-level validation of research recommendations. FFS farmers conducted experiments to test technologies, generate new information for cassava plant health man-

agement, coin local names for pests, diseases and weeds and participated in CGM biological control activities in their proximity. At nine FFS sites in Nigeria and Ghana farmers generated new information that could lead to the reduction of primary CMD incidence through the choice of cuttings from specific cassava stem branches. Another FFS experiment in Benin could generate new information to extend the shelf life of fresh cassava roots. All other FFS experiments were designed to test/adapt recommended technologies, e.g., planting mode, frequency of weeding and use of cover crops in soil/fallow management and weed control. Farmers sampling chores in FFS experiments have enabled them to better understand cassava IPM problems. Didactic cassava IPM extension/training materials were also field tested at FFS sites.

6.5.7. Organize postgraduate training

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

Approximately 50% of the women scientists and extension workers provided with postgraduate training fellowships (in collaboration with Winrock International) successfully completed the courses and returned to their respective national agricultural programs in Benin, Cameroon, Ghana and Nigeria. Other postgraduate fellows continue training to strengthen NARES resource base in the fields of plant pathology, entomology, crop science, biotechnology and weed science.

6.5.8. Collaborative research program

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

The program was initiated in 1995 to foster collaboration with a wide range of individuals from government ministries, nongovernmental organizations (NGO) and universities in the four countries (Benin, Cameroon, Ghana, and Nigeria). Twenty-seven projects were initiated by August 1995 and by December 1996 two projects were completed and final reports were submitted. One of the completed study screened 118 cultivars and clones of cassava for resistance to cassava anthracnose disease (CAD). The study identified eight cultivars and clones resistant to the disease. The second study looked at farmer resource allocation to cassava in 31 sites located in the rainforest, transition forest, dry and humid savanna. The study showed that cassava production is essentially by family labor, that fertilizer was not used, and production was hampered by insufficient credit.

Completed studies

Journal articles and book chapters

Msikita, W., P.E. Nelson, J.S. Yaninek, M. Ahounou & R. Fagbemissi. 1996. First report of* Fusarium moniliforme *causing cassava root, stem, and storage rot. Plant Disease 80:823.

Storage roots of cassava are left in the field as unharvested plants, or are harvested, peeled, and dried in the sun to form a product referred to as "cassava chips". Fifty-five samples comprising rotted cassava crowns and roots (storage and feeder, derived from wilted and/or lodged plants), and discolored chips were collected from various parts of Bénin and Cameroon. Affected pieces of the stems, roots and chips were cut out, surface sterilized, and cultured on water agar amended with 4% (vol/vol) lactic acid. Pieces were incubated for 1 week. For the purposes of identification, mycelia were subcultured on carnation leaf agar medium. More than 36% of the total fungi isolated from the samples were *Fusarium* spp. Fifty-five percent of the *Fusarium* were isolated from rotted roots and crowns of both young and old plants, and 45% from chips. More than 44% of the *Fusarium* isolates

obtained from the chips, and 19% of isolates from the rotted crowns and roots were *F. moniliforme* (Sheldon). To complete Koch's postulates, stem pieces of four cassava cultivars ("Agriculture", "Tchukunochi", "TMS 30572", and "Ben 86052"), were disinfested in hot water (52 °C, 5 min.), transplanted in sterilized sand, and maintained in a greenhouse (natural light, 28 - 30 °C). Two weeks after transplanting, stems were wound inoculated (epidermal scalpel slice) just below the soil line. A 0.5 ml aliquot of mycelial suspension of *F. moniliforme* was applied onto each wound, and the sand covered back on the stem. For each cultivar, control plants were similarly wounded but treated with sterile distilled water. Six to ten days after inoculation, all plants inoculated with *F. moniliforme* showed variable degrees of wilting (0-80% of foliage) and necrosis (2.9 to 6.2-cm-long lesions) of the stem base. Control plants remained symptom free. Necrotic stem and root pieces from artificially inoculated plants were plated on potato dextrose agar, and consistently yielded *F. moniliforme*. This is the first report of *F. moniliforme* pathogenic on cassava.

Msikita, W., J.S. Yaninek, M. Ahounou, H. Baïmey & C.O. Fagbemissi. 1996. Development of an in vitro system to assess for cassava anthracnose disease. Plant Disease (submitted).
Cassava anthracnose disease (CAD) is one of the most serious diseases of cassava. Because field assessment of CAD is influenced by environmental factors such as free moisture and the insect vector *Pseudotheraptus devastans* (Dist. [Hom. Coreidae]) which creates wounds, results from field assessment can be inconsistent and inaccurate. Additionally, because breeding programs often involve large-scale screening of germplasm, the methodologies for field screening are not only inefficient but also cumbersome. A study was undertaken to (a) evaluate several explants for their suitability for in vitro screening and selection for resistance to CAD; (b) identify parameters for an effective in vitro-based screening and selection for resistance to CAD; and (c) test the effectiveness of the in vitro-based system in comparison with the field-based screening and selection method. Response of cultivars to CAD varied significantly both in vitro and in vivo. Of the parameters used to assess for disease severity in vitro, the spread of mycelia, and length of lesions for petiole and shoot pieces were inconsistent and/or inconspicuous. The number of acervuli produced on petiole and shoot pieces best estimated disease severity. The study demonstrated the feasibility of an in vitro-based system to screen and select for resistance to CAD. The method is rapid and permits repeated assays of a large number of plants in a short time under uniform and controlled conditions.

Oduor, G.I., J.S. Yaninek, G.J. de Moraes & L.P.S. van der Geest, 1997. The effect of pathogen inoculum size and host development stage on the pathogenicity of* Neozygites *cf.* floridana *(Zygomycetes: Entomophthorales) to* Mononychellus tanajoa *(Bondar) (Acari: Tetranychidae). Exp. App. Acarol. (in press).
How the pathogen inoculum size and the host developmental stage influence the pathogenicity of *Neozygites* cf. *floridana* (Weiser and Muma) to *Mononychellus tanajoa* (Bondar) was studied at 28°C, 12L:12D photoperiod and 90-100% RH. All inoculum sizes tested (1, 2, 4, 6 and 8 capilliconidia per mite) were lethal. Dead mites started to appear 48 hr after exposure to the conidia. Inoculum size significantly affected time to mortality. All mites exposed to 6 or 8 capilliconidia died of mycosis 57.1 and 62.9 hr, respectively, after infection. At lower doses, infection was lower, dead mites started appearing later and time to mortality was significantly longer (between 68.7 and 89.4 hr). This fungus successfully infected and killed all active immature stages of *M. tanajoa*. Both percent mortality and time to death due to the fungus were significantly affected by the mite developmental stage. Mummification of mites infected as larvae (75.8%, protonymphs (72.9%) and deutonymphs (87.2%) was significantly lower than those infected as adult females (96.9%) and adult males (98.2%). Death of infected mites during the moulting process was significantly higher among deutonymphs (9.6%) than among larvae (2.0%) and protonymphs (1.1%). Periods between exposure to the fungus and mortality of larvae and protonymphs (76.3 and 77.2 hr,

respectively) were significantly longer compared to adult females and males (66.9 and 58.7 hr, respectively). Most mites, irrespective of stage, died within the first 6 hr of the dark phases of the photoperiod. The development of infected larvae and protonymphs, but not deutonymphs, to successive developmental stages was significantly delayed by mycosis.

Oduor, G.I., G.J. de Moraes, L.P.S. van der Geest & J.S. Yaninek, 1997. Production of primary conidia of* Neozygites *cf.* floridana *(Zygomycetes: Entomophthorales) under constant temperatures, humidities and photoperiods. J. Invert. Path. (in press).

The production, germination and viability of primary conidia of *Neozygites* cf. *floridana* as affected by temperature between 13 and 23 °C with a mean of 35.5 and 55.4 conidia, respectively, liberated from each mummified mite cadaver. No conidia were produced at 28 or 33 °C. Conidial production dropped significantly from 96.1/mummy in a moisture saturated environment (Saturated deficit [SD] 0) to 33.9/mummy at SD 0.2. Very few conidia were produced at SD 0.7 (0.6/mummy) and none at SD 1.2. Significantly fewer conidia were produced under continuous light (11.2/mummy) than under continuous darkness (40.1/mummy) or 12L:12D (46.7/mummy) photoperiods. Between 82 and 100% of the conidia produced under 12L:12D photoperiod were released in the dark phase. Germination of primary conidia started within 2 hr and increased with decreasing temperature between 13 and 28 °C. Percent germination of 20.1% at 13°C and 17.6% at 18 °C were significantly higher than 11.2% at 28 °C. There was no germination at 33 °C. High humidities (>95%) were necessary to effect germination. Germination at SD 0 (27.2%) and 0.2 (23.4%) and 0.2 (23.4%) were significantly higher than at SD 0.7 (0.4%), where germination began after 6 hrs and was observed only at 13, 18 and 23 °C. No germination was observed at SD 1.2. There was no germination among conidia maintained under continuous light. Temperature, humidity and light condition significantly affected the viability of primary conidia. Percent viability across all factors dropped from 98.4% after 0 hr (beginning of the experiment) to 23.4% after a 1-hr exposure to the tested conditions. Lower temperatures maintained higher viabilities with 86.3% of the conidia surviving after 18 hr at 18 °C, whereas almost all conidia died after 12 hr at 33 °C. Conidia survived less than 1 hr when exposed to SDs of 2.0 mm Hg or higher at any tested temperature.

Staeubli-Dreyer, B., J. Baumgaertner, P. Neuenschwander & S. Dorn. The functional responses of two* Hyperaspis notata *strains to their prey, the cassava mealybug* Phenacoccus manihoti. *Mitt. Schweiz. Ent. Ges. (in press).

The number of prey individuals attacked by larvae and adults of the coccinellid *H. notata* as affected by the density of its prey, the cassava mealybug *P. manihoti*, was studied in the laboratory. The functional response parameters of two strains of *H. notata*, one originating from Southern Brazil and one from Colombia, were compared. In the case of larvae there were no differences between the Brazilian and the Colombian strain. Adult females of the Colombian strain showed, however, a higher searching rate but a lower prey demand rate than females of the Brazilian strain. Overall, Brazilian females attacked more than Colombian females. If food was abundant, 11 to 15% of the prey individuals were injured by the predator without being consumed.

Staeubli-Dreyer, B., P. Neuenschwander, J. Baumgaertner & S. Dorn. Trophic influences on survival, development, and reproduction of* Hyperaspis notata *(Coleoptera, Coccinellidae) J. Appl. Entomol. (in press).

The coccinellid *H. notata* is associated with the mealybugs *P. manihoti* and *P. herreni*, on cassava in southern Brazil and the highlands of Colombia. Brought to Africa to help control the accidentally introduced *P. manihoti*, its range of target prey and plant food sources as well as its performance under conditions of food scarcity were investigated in the laboratory. *H. notata* showed a moderately narrow food spectrum which should allow survival in periods when *P. manihoti* is scarce without threatening a broad range of insects species:

H. notata survived, completed larval development and reproduced on *P. madeirensis* (Green) and *Ferrisia virgata* (Cockerell), which are alternate prey species of the family Pseudococcidae and occur abundantly in cassava fields and on ornamental plants in southern Benin. By contrast, development was not possible on less related taxa of the Sternorrhyncha, namely on *Aphis craccivora* Koch which occur on cowpea often intercropped with cassava and on the spiraling white fly *Aleurodicus dispersus* Russel infesting cassava, and many other food crops and ornamental plants. These alternate food sources allowed survival of the larvae and adults for a limited period only and neither moulting nor egg production were observed. Cassava pollen was unsuitable as a food source since it did not allow larvae to develop, females to oviposit, nor did it extend longevity of larvae and adults. Honey prolonged the life span of adults without allowing egg production, and is thus a suitable food substitute for adult *H. notata* during shipment to release destinations. The coccinellid larvae completed their development to the adult stage when fed from a range of ad libitum supply (consuming up to 6 mg per day) of cassava mealybugs to a minimal daily amount of 1 mg (consuming only approx. 0.8 mg per day). Females even laid eggs when fed with a minimal amount of 1.2 mg per couple and day. Larvae of the Colombian strain gained more weight before pupation, and the tolerance of larvae and adults to starving was more marked than in the Brazilian strain.

Staeubli-Dreyer B., P. Neuenschwander, B. Bouyjou, J. Baumgaertner & S. Dorn. The influence of temperature on life table of* Hyperaspis notata. *Ent. Exp. Applic. (in press).

The coccinellid *H. notata* was introduced into Africa for the biological control of the cassava mealybug, *P. manihoti*. Two cohorts of strains, one originating from Southern Brazil and Paraguay feeding on *P. manihoti* and one from Colombia feeding on *P. herreni*, were studied at different temperatures between 15 and 34 °C and age-specific life tables were constructed. Although in the areas of origin the climatical conditions and the food sources are different, the survivorship and developmental times at the same temperature differed little among the two strains, the Colombian strain being slightly more tolerant to high temperatures. Jacknife estimates of the intrinsic rates of increase (r_m) peaked very close to 30 °C for the two strains.

Toko, M., J.S. Yaninek & R.J. O'Neil, 1996. Response of* Mononychellus tanajoa *(Acari: Tetranychidae) to cropping systems, cultivars and pest interventions. Environ. Entomol. 25: 237-249.

The effects of cropping systems, pest interventions and cultivars on the population dynamics of the cassava green mite, *M. tanajoa*, were evaluated in two locations in Benin Republic, West Africa. Maize and cassava were intercropped at the beginning of the wet season, while a single release of the exotic predator, *T. manihoti* (= *limonicus*), or a bimonthly spray of the acaricide dimethoate were applied in the dry season. Intercropping cassava with maize had no significant effect on *M. tanajoa* and associated phytoseiid predator populations during the intercropping, dry and post-dry season cassava growth periods. The acaricide spray reduced *M. tanajoa* densities 50% below those of the predator and the control (no predator and no spray) treatments. *T. manihoti* (= *limonicus*) significantly reduced *M. tanajoa* densities by 20% below the control treatment at the end of the experiment. The cultivar "Agric" supported two to three times more mites per leaf than did TMS 30572. A *M. tanajoa* pest-management strategy that combines resistant cultivars and an efficient exotic predator is suggested.

Toko, M., R.J. O'Neil & J.S. Yaninek, 1996. Development, reproduction and survival of* Mononychellus tanajoa *(Bondar) (Acari: Tetranychidae) on cassava grown under soils of different levels of nitrogen. J. Exp. Appl. Acarol., 20: 405-419.

The effect of different levels of N on the development and reproduction of *M. tanajoa* was evaluated in greenhouse and laboratory studies using a range of soils with different levels of N concentrations. The effect was evaluated for *M. tanajoa* reared in one generation and for *M. tanajoa* reared in several, namely, three generations. Experimental treatments included cassava leaves from plants grown in soils from three representative field sites in southern Benin, and cassava leaves from plants grown in soil fertilized with different rates of nitrogen in the form of urea (46% N). There were no significant changes in relation to soil and thus to leaf N in developmental rates, preoviposition periods, longevity and egg production of *M. tanajoa* reared in either group of soils (untreated and fertilized), even for *M. tanajoa* reared under several generations. Our results are compared to those predicted by a simulation model of *M. tanajoa* population dynamics in relation to soil and leaf N, and discussed in terms of the rates of N applied, differences in host-plant conditions between greenhouse and laboratory and field studies, and in terms of relationships between N and other nutrients. The consistent lack of response to soil or leaf N of *M. tanajoa* tested in one or several generations suggests that if N is a key nutrient that drives *M. tanajoa* population densities, it doesn't act in isolation but most likely in combination with other nutrients.

Conference papers, workshop proceedings, abstracts, newsletters

Afouda, L. & K. Wydra., 1996: Virulence analysis of root and stem rot pathogens of cassava (*Manihot esculenta *Crantz) in West Africa and the development of methods for their biological control with antagonists. Mitt. Biolog. Bundesanstalt f. Land- und Forstwirtschaft, 50. Deutsche Pflanzenschutztagung, Münster, Germany, 23-26 September 1996, p. 634.

Root and stem rots are a major problem of cassava in the humid lowlands, and losses in excess of 80% of the potential production have been reported. Local cassava varieties are mostly susceptible to the rot pathogens. Rot-causing fungi were isolated from root and stem rot samples from Cameroon, Nigeria and Benin and identified as *Botryodiplodia theobromae, Sclerotium rolfsii, Rhizoctonia solani, Sphaerostilbe* sp., *Fusarium oxysporum, Fusarium semitectum* and *Fusarium* sp.

After testing several methods for the quick evaluation of the virulence of the isolates and the quick screening of varieties, the most suitable method was used for the virulence analysis. Cuttings were inoculated with agar plugs with fungal cultures and incubated for five to seven days under moist conditions. After seven days, highly virulent strains had colonized the whole cutting. The evaluation was made by estimating the colonized area of the xylem and comparing the cuttings to a standard set of cuttings representing the classes 1 (no symptom) to 5 (whole cutting colonized). Fifty percent of the strains of *B. theobromae* and *Sclerotium rolfsii* were classified as highly virulent, colonizing the whole cutting and inhibiting sprouting.

Biological control methods, a promising means to control root and stem rots, are developed and will be integrated in a package of control measures. Therefore, fungal antagonists of the species *Trichoderma (Trichoderma harzianum, T. Koningii, Trichoderma* sp.) were isolated from rotten cassava samples and from the adjacent rhizosphere soil. In vitro antagonistic tests, most *Trichoderma* strains were highly effective against the pathogens with an inhibition coefficient higher than 85%. Promising *Trichoderma* isolates were used to elaborate mass-production methods with sorghum as a substrate and tested in pot experiments in the glasshouse.

Assigbétsé, K., V. Verdier, K. Wydra, K. Rudolph & J.P. Geiger, 1996. Genetic variation of the cassava bacterial blight pathogen,* Xanthomonas campestris *pv.* manihotis*, originating from different regions in Africa. IX International Conference on Plant Pathogenic Bacteria, Madras, India, August 26-29, 1996, p. 37.

An analysis of the genetic variation was conducted for the cassava bacterial blight pathogen from several cassava-growing countries in Africa. Strains of *X. campestris* pv. *manihotis* (Xcm) were collected from different locations (32 in Benin, 3 in Ghana, 6 in Cameroon, 5 in Nigeria, 5 in Uganda). At most of the sites, several infected leaf and stem samples were collected on both local and improved cultivars. One hundred and forty-three strains were analyzed for genotypic markers by three methods: ribotyping, RFLP analysis using 3 Xcm probes (2 genomic and 1 plasmidic probes) and plasmid profile analysis. All the strains were tested for pathogenicity under glasshouse conditions. Ribotyping and RFLP analysis with the two genomic probes revealed no diversity among Xcm strains, whereas 14 haplotypes (different DNA patterns) could be defined using the plasmid probe pF3. One main group consisted of strains from various geographic regions suggesting the occurrence of pathogen migration. Diversity was highest within Nigerian strains since 13 of the 14 haplotypes described in this study were detected in Nigeria. Furthermore, 6 haplotypes only occurred in certain specific regions. Also, differences in plasmid content were observed among Xcm strains. The results of genome analysis of Xcm and the occurrence of new haplotypes indicated that the bacterial blight pathogen is variable and that new forms developed in Africa, which are different from all types described before. The diversity of the pathogen population suggests a role of the host in causing differentiation of the pathogen.

Bieler, P., I. J. Ekanayake, R. Dossou, A.O. Sanni, K. Aihou, A.Y. Alhassan, R. Ahiabu & J.S. Yaninek, 1996. Production of high quality cassava planting materials: a collaborative effort. Tropical Root and Tuber Crops Bulletin, April issue.

Borowka, R., H.E. Hummel & P. Neuenschwander. Impact of various biological control agents directed against the cassava mealybug* Phenacoccus manihoti *Matile-Ferrero (Hom., Pseudococcidae) under conditions favoring high pest infestations in Malawi. Med. Fac. Landbouww. Univ., Gent (Proc. 48th Internat. Symposium for Crop Protect.).

Biological control of the cassava mealybug showed efficacy in Malawi, East Africa, under conditions of sandy soils without and with little mulch cover favoring high pest infestations. The predominant beneficial is the well-established exotic wasp *A. lopezi*. Other observed beneficials of secondary importance were indigenous coccinellids like *Exochomus troberto* Gerstäcker and *Hyperaspis aestimabilis* Mader. Another introduced exotic beneficial, *Diomus hennessyi* Fürsch (Col., Coccinellidae), although specifically adapted to cassava infested with cassava mealybug, established itself but was of marginal importance. A field trial revealed other important limitations of cassava production under those marginal conditions which favor high pest infestations. Choice of cultivar and agricultural practices are key variables.

Fessehaie, A., K. Wydra & K. Rudolph, 1996. Cefazolin-trehalose agar medium, a semi-selective medium for* Xanthomonas campestris *pv.* manihotis *(Xcm), the incitant of cassava bacterial blight (CBB). IX International Conference on Plant Pathogenic Bacteria, Madras, India, August 26-29, 1996, pp. 13-14.

The nutritional requirements of the *X. campestris* pv. *manihotis* (Xcm), the causal agent of cassava bacterial blight (CBB), especially its capability to utilize different carbon and nitrogen sources were studied. These tests led to the development of a basal medium which allowed good growth of the target organism, whereas luxurious growth of some saprophytes was suppressed. A further selective effect of the medium was achieved by incorporating three antibiotics into the basal medium. The new semiselective agar medium, designated

Cefazolin-trehalose agar medium (CTA medium), consisted of the basal medium yeast-trehalose-glucose-agar (YTGA) supplemented with antibiotics and had the following in g/l: 3.0 K_2HPO_4, 1.0 NaH_2PO_4, 0.3 $MgSO_4$ x 7 H_2O, 1.0 NH_4Cl, 9.0 D(+)-trehalose, 1.0 D(+)-glucose, 1.0 yeast extract, 25 ppm Cefazolin, 1000 IU Lincomycin, 2.5 ppm Fosfomycin, 200 ppm Cycloheximide, and 14 agar.

Plating efficiency of CTA was lower than that of YTGA medium. However, the recovery of Xcm from cassava leaves and shoot-tips was much higher on the semi-selective medium whereas contaminants and accompanying bacteria were reduced on CTA by 87%. Thus, the newly developed CTA medium appeared to be well suited for a sensitive and reliable diagnosis of the pathogen. It is suggested to use the medium for control strategies to eradicate infected planting material of cassava, as well as in epidemiological studies.

Fessehaie, A., K. Wydra, J.D. Janse & K. Rudolph, 1996. Characterization of strains of* Xanthomonas campestris *pv.* manihotis *(Xcm), incitant of cassava (*Manihot esculenta *Crantz) bacterial blight with physiological, biochemical and serological methods. Mitt. Biolog. Bundesanstalt f. Land- und Forstwirtschaft, 50. Deutsche Pflanzenschutztagung, Münster, Germany, 23-26 September 1996, p. 635.

Cassava is an important food crop for an estimated 400 million people in Africa, Asia and Latin America and one of the dominant starchy staples in the diet of the people in Sub-Saharan Africa. Cassava is the natural host of *X. campestris* pv. *manihotis*, incitant of bacterial blight. The pathogen is widespread in Africa, Latin America and Asia and has caused epidemics with high yield losses in many cassava-growing areas.

Three hundred and twenty-five strains were collected from Ghana, Benin, Nigeria, Cameroon and Uganda; reference strains were received from Congo, Zaire, Latin America and Asia. From all the strains the main pathological, biochemical, physiological and serological features were determined, and additional specific reactions were determined for a group of selected strains.

Metabolic fingerprints for the utilization of 95 C-sources were obtained using the Biolog system. Typical patterns for Xcm were detected and may be useful for the identification of Xcm isolates. To identify differences between the strains, the analysis of the metabolization was modified by evaluating the color intensity of the microplate wells and introducing the data into a modified program for complete linkage analysis. The analysis resulted in the formation of three groups and some ungrouped strains. African and Latin American strains did not form groups distinct from each other.

Two hundred and twenty-five strains from different origin were able to grow on culture medium with 0.2% starch. African strains metabolized starch only weakly, while Latin American and Asian strains varied widely in their ability to use starch, and their average starch metabolization was about 10 times higher than that of the African strains. Additional quantitative analysis revealed differences between the strains in the production of a-amylase, which was produced constitutively. Strains from Latin American and Asian origin were heterogeneous in amylase activity.

One hundred and seventy-four strains, including 30 reference strains from Latin America and Asia, were analysed by gas chromatography for fatty acid composition. The principal component analysis of the fatty acid methyl esters (FAME) revealed that the African strains formed a rather homogeneous group. Half of the strains from Latin American and Asian origin belonged to this group, while the other half of the strains were heterogeneous among themselves, different from the first group and did not form a homogeneous group.

African strains differed by their homogeneity from the heterogeneous Latin American and Asian strains in starch utilization as well as in fatty acid patterns. However, these characteristics were not correlated with virulence.

Xcm strains, isolates from other *X. campestris* pathovars (pv. *cassavae*, pv. *malvacearum*, pv. *phaseoli*, pv. *pelargonii*), and strains of *Erwinia carotovora* ssp. *carotovora*, *Erwinia herbicola* and *Pseudomonas fluorescens*, were analysed by protein electrophoresis and Western blot. Bacterial proteins were extracted following the method described by Kersters (1990) and analysed by discontinuous SDS-PAGE. Each time two gels were analysed, one of which was stained with Coomassie Blue, the identical twin was electroblotted onto a nitrocellulose membrane and incubated with polyclonal antiserum produced against whole cells of Xcm (B.Boher, ORSTOM, France) to detect specific proteins. By this procedure, pathovar-specific proteins of low molecular weight were identified, which shall be used as antigen to generate now monospecific antibodies against Xcm.

Fessehaie, A., K. Wydra & K. Rudolph, 1996. Development of a semi-selective medium and use of serology for fast and sensitive detection of* Xanthomonas campestris *pv.* manihotis*, incitant of bacterial blight of cassava. Proceedings of the 4th European Foundation of Plant Pathology Symposium, Bonn, Germany, September 9-12 1996, 4 pages (in press).

Fessehaie, A., K. Wydra & K. Rudolph, 1996. Immuno-elektrophoretische Untersuchungen mit Proteinen von* Xanthomonas campestris *pv.* manihotis *für die Herstellung hochspezifischer Antikörper. Abstract for 'DPG Arbeitkreis Phytobakteriologie, Darmstadt, September 1996). Phytomedizin (in press).

Mégevand, B. Colony initiation, maintenance and mass rearing of phytoseiid predators of the cassava green mite, with special reference to quality control. Proceedings of an insect rearing workshop held during the Tenth Entomological Congress of the Entomological Society of Southern Africa, Grahamstown, South Africa, 3-7 July 1995 (in press).

The rearing of biocontrol agents is often an important limiting step in a biological control program. Establishing and maintaining laboratory colonies which produce natural enemies of sufficient quantity and quality for both experiments and releases are the main challenges facing rearing programs. Culturing natural enemies of phytophagous pests involves a triple-phased approach that includes rearing the natural enemy and the target pest (or an alternative host/prey), and multiplication of suitable host plants. At the International Institute of Tropical Agriculture (IITA), a production program for phytoseiid predators of the cassava green mite, *Mononychellus tanajoa* (Bondar), includes a mother culture system of pure and high-quality colonies to provide the inoculum needed for starting mass production. Rigorous rearing and isolation protocols, high food quality and a controlled environment are used to ensure healthy stock cultures. Two different systems are used to rear the predators depending on the predator's prey specificity. Monophagous predators are fed *M. tanajoa* reared on cassava. Oligophagous predators are fed a higher yielding alternative prey, *Tetranychus urticae* Koch which has been reared on groundnut. Mid-scale production is achieved in small tunnel-like screen houses with either *M. tanajoa* or *T. urticae*. General requirements and constraints in rearing phytoseiids are discussed, as well as issues of quality control.

Wydra, K. & W. Msikita, 1996. Survey of cassava (*Manihot esculenta *Crantz) diseases in different ecozones of West Africa and virulence analysis of strains of* Xanthomonas campestris *pv.* manihotis *causing cassava bacterial blight. Mitt. Biolog. Bundesanstalt f. Land- und Forstwirtschaft, 50. Deutsche Pflanzenschutztagung, MŸnster, Germany, 23-26 September 1996, p. 631.

The incidence and severity of six cassava diseases (mosaic disease, bacterial blight, anthracnose, *Cercospora* leaf spots: leaf blight, brown and white leaf spots) were recorded on 234

sites in different ecozones of four countries across the cassava belt of West Africa, and leaves with symptoms of bacterial blight were collected. Cassava mosaic disease was most prevalent with field and plant incidence near 100% in all ecozones and an average severity of infected plants between scores 2.3 and 3.4 on a 1 to 5 scale. A low plant incidence was observed only in the moist savanna and the mountain forest of Cameroon (29% and 38%, respectively) and in the transition forest of Benin (46%). Bacterial blight was present in all ecozones, with higher site incidence in the transition forest (61%) and the savanna zones (moist savanna 62%, dry savanna 42%) than in the rainforest (24%). The plant incidence in the wet savanna was the highest with 34%, and low in the rainforest with 4%. The average severity of infected plants was between scores 2.4 (dry savanna) and 3.1 (transition forest). Site and plant incidence of anthracnose disease was high in the rainforest across all countries with 90% and 64%, respectively, and low in the dry savanna (32% and 8%, respectively). The severity of the disease decreased towards the dryer ecozones. *Cercospora* leaf blight and brown leaf spots were frequent in all ecozones, while *Cercospora* white leaf spots were more expressed in the rainforest.

Three-hundred and thirty strains of *X. campestris* pv. *manihotis* were collected from all ecozones and analysed for virulence. After a comparison of the symptom development curves by principal component and cluster analysis, about 50% of the strains were classified as highly virulent. The most virulent strains are used to inoculate and select resistant cassava varieties. Integrated methods to control important cassava diseases are developed at the International Institute of Tropical Agriculture (IITA) in Nigeria and Benin.

Wydra, K. & W. Msikita, 1996. An overview of the present situation of cassava diseases in West Africa. Proceedings of the Sixth Triennial Symposium of the International Society for Tropical Root Crops - Africa Branch (ISTRC-AB), 22-28 October 1995, Lilongwe, Malawi (in press).
Surveys on the importance of cassava pests and diseases were conducted in Ghana, Benin, Nigeria and Cameroon in collaboration with the national programs. Two hundred and thirty-four sites evenly distributed across all ecozones where cassava is grown were inspected in the dry and wet seasons. An overview is given on the situation of the most important diseases in the four countries in the wet season in 1994.

Cassava mosaic disease (CMD) was identified as the most prevalent disease with an incidence near 100 % in all ecozones. Nevertheless, low average plant incidence was regionally observed in different ecozones (Cameroon, moist savanna: 29%, Cameroon, mountain forest: 38%, Benin, transition forest: 46%), whereas in most other regions and ecozones plant incidence was between 64% and 97%. The average severity of infected plants varied between score 2.3 and score 3.4 on a 1 to 5 scale. Cassava bacterial blight (CBB) was present in all ecozones across countries with a high regional importance in the transition forest (61% site incidence) and the savanna zones (moist savanna: 62% site incidence, dry savanna: 42% site incidence) and a low incidence in the rainforest. Plant incidence was highest in the wet savanna zone (32%). Average severities of infected plants between score 2.4 (dry savanna) and score 3.1 (transition forest) were observed. Site and plant incidence of cassava anthracnose disease (CAD) were high across countries in the rainforest (90% and 64%, resp.) and considerable in the transition forest zones (56% and 26%, respectively), while in the savanna zones this disease was less important. A high variation in average severity of infected plants between score 2 (dry savanna) and score 3.8 (mountain forest) was recorded. *Cercospora* leaf blight and brown leaf spots were frequent in all ecozones, mostly with high plant incidence between 50% and 98%, while white leaf spots were more expressed in the rainforest zone (plant incidence: 84%). The average severity of infected plants was low for the three *Cercospora* diseases.

Recommendations are given for the development of control strategies adapted to the local conditions, and research needs are prioritized.

Wydra, K., Zinsou, V. and Fanou, A., 1996. The expression of resistance against* Xanthomonas campestris *pv.* manihotis*, incitant of cassava bacterial blight, in a resistant cassava variety compared to a susceptible variety. IX International Conference on Plant Pathogenic Bacteria, Madras, India, August 26-29, 1996, pp. 100-101.

Cassava bacterial blight epidemics, which caused devastating losses in the 1970s in Africa, are recently reported from different areas in West, Central and East Africa. Detailed surveys in several West African countries revealed an increasing importance of the disease in the transition forest and especially the savanna ecozones. Varieties, which have been regarded as resistant, developed serious symptoms.

After infection by spray inoculation and stem puncture with a highly virulent strain of *X. campestris* pv. *manihotis* (Xcm), symptom development and the influence of the symptoms on the growth parameters have been recorded using a susceptible, local variety and a 'resistant' variety (TMS 30572) in field experiments in Benin, West Africa. Forty-two percent yield loss was observed in 7.5-month-old, susceptible plants after infection. The detailed evaluation of symptom development (percent of watersoaked spots, blight, wilt, dieback, occurrence of stem exudate) as well as of growth parameters (leaf, stem and root dry weight, number of leaves, number of fallen leaves) allowed the identification of several components of resistance.

Resistance/tolerance was expressed on several levels:

1) Level of inoculum threshold: The resistant variety showed no symptoms under low infection pressure (natural infection), while the susceptible variety developed 9-11% of leaf symptoms.
2) Inhibition of the development of blight symptoms: The intensity of leaf spots was the same in both varieties after artificial leaf inoculation, however, the development of spots into blight symptoms and wilting was suppressed in the resistant variety.
3) Influence on tuber yield: The same level of symptom expression had less influence on the tuber yield of the resistant variety as compared to the susceptible variety.

Leaf symptoms caused a higher yield reduction in both varieties than the partial dieback of stems after stem puncture. The 'resistant' variety was susceptible to stem inoculation.

Detailed symptom evaluations considering the first occurrence, the percentage and the duration of the different types of symptoms and their impact on the yield parameters (leaf number, leaf weight, stem weight, root weight) after spray inoculation with a highly virulent strains of Xcm is recommended to identify sources of resistance.

Wydra, K., A. Fessehaie, A. Fanou, R. Sikirou, J. Janse, K. Rudolph, 1996. Variability of strains of* Xanthomonas campestris *pv.* manihotis *(Xcm), incitant of cassava (*Manihot esculenta *Crantz) bacterial blight, from different geographic origins in pathological, physiological, biochemical and serological characteristics. IX International Conference on Plant Pathogenic Bacteria, Madras, India, August 26-29, 1996, pp. 53-54.

Cassava is a major food staple for an estimated 400 million people in Africa, Latin America and Asia. Cassava bacterial blight (CBB) is a serious disease, causing epidemics in most cassava growing regions worldwide. Surveys in four West African countries revealed the importance of CBB in the forest-savanna transition and in the savanna zones, but not in the rain-forest. Three hundred and twenty-five strains of Xcm were collected from Ghana, Benin,

Nigeria, Cameroon and Uganda; reference strains were received from Congo, Zaire, Latin America and Asia. From all the strains the main pathological, biochemical, physiological and serological features were determined, and additional specific reactions were ascertained for a group of selected strains.

Analysis of virulence revealed a high variability between the strains. After stem inoculation, few strains were weakly virulent, while the majority was classified as virulent and highly virulent. The percentage of highly virulent strains ranged between 30% and 70%, depending on the geographical origin. Highly virulent strains were isolated from each area.

Metabolic fingerprints for the utilization of 95 carbon sources using the conventional Biolog system, revealed a typical pattern for Xcm which may be useful for identification purposes. Semiquantitative evaluation of the color intensity of the microplate wells resulted in the formation of three groups and some ungrouped strains after complete linkage analysis. African and Latin American strains did not form groups distinct from each other.

From 225 strains of different origin, African strains metabolized starch only weakly, while Latin American and Asian strains varied widely in their ability to use starch, and their average starch metabolization was 10 times higher. Analysis of the enzyme activity showed that a-amylase was produced constitutively, and strains from Latin American and Asian origin were heterogeneous in amylase activity.

When 174 strains, including 30 reference strains from Latin America and Asia, were analysed by gas chromatography for fatty acid composition, the principal component analysis of the fatty acid methyl esters (FAME) revealed that the African strains formed a rather homogeneous group. Half of the strains from Latin American and Asian origin belonged to this group, while the other half of the strains were heterogeneous among themselves, different from the first group and did not form a homogeneous group. However, the physiological and biochemical characteristics were not correlated with virulence.

Bacterial proteins from Xcm strains, isolates from other *X. campestris* pathovars (pv. *cassavae*, pv. *malvacearum*, pv. *phaseoli*, pv. *pelargonii*), and strains of *Erwinia carotovora* ssp. *carotovora*, *Erwinia herbicola* and *Pseudomonas fluorescens* were analysed by electrophoresis and Western blot. By incubation with a polyclonal antiserum produced against whole cells of Xcm (B. Boher, ORSTOM, France) Xcm-specific proteins of low molecular weight were detected, which shall be used as antigen for the production of monospecific antibodies against Xcm.

Postgraduate training

Name	Country	Date	Sponsor	IITA supervisor
MSc				
Abole, Emmanuel	Ghana	94/96	ESCaPP/Winrock	Yaninek
Assogba, K. Françoise	Benin	94/96	ESCaPP/Winrock	-
Atanga, G.	Cameroon	95/96	ESCaPP/Winrock	-
Aylin, R.A.	Ghana	95/96	ESCaPP/Winrock	-
Mbofung, Gladys	Cameroon	95/97	ESCaPP/Winrock	Msikita
Ntumngia, R.	Cameroon	95/97	ESCaPP/Winrock	-
Okwuoma, Janet	Nigeria	95/96	ESCaPP/Winrock	-
Opoku-Asiama, Mary	Ghana	94/96	ESCaPP/Winrock	Yaninek
Sotomey, Marcelle	Benin	95/97	ESCaPP/Winrock	James
Torto, Gertrude	Ghana	94/96	ESCaPP/Winrock	-
Woode, Ruth	Ghana	94/96	ESCaPP/Winrock	-
Young, V.L.	Cameroon	95/96	ESCaPP/Winrock	-
PhD				
Fessehaie, Anania	Germany	93/97	BMZ	Wydra
Ojo, Joseph Bamidele	Nigeria	91/97	IITA	Yaninek

Annex 1

Research Projects

1. Short Fallow Stabilization
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
17. Improving the Dissemination of IITA's Research Results

Annex 2

Institute-wide logframe

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

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

Narrative	Indicators by the year 2000	Means of verification	Assumptions
Improving Postharvest Systems Postharvest technologies to provide utilization options for the food, feed, and agroindustrial sectors developed and disseminated in collaboration with NARS	• Increased number of end-products • Increased range of technologies in use in collaborating countries • Improved NARS capability for food systems research	• NARS and IITA reports • Monitoring tours and surveys	• Socioeconomic environment conducive to small business development
Short Fallow Stabilization Sustainable short fallow management systems developed in partnership with farmers	• Farmers in at least 30 communities in the benchmark areas and pilot sites are testing and evaluating short fallow systems • Farmers in the same 30 communities recognize improved soil conditions	• IARC and NARS reports • Benchmark and pilot site surveys	• Farmers are receptive to longer-term land management interventions
Farming Systems Diversification New and complementary income generating enterprises developed and evaluated with farmers in benchmark areas	• Farmers in benchmark areas achieve higher productivity and cash incomes through integration of new production enterprises	• IARC and NARS reports • Benchmark site surveys	• Sustained market for enterprise outputs
Biotechnology Molecular and cellular tools and products, for germplasm enhancement and dissemination of IITA mandate crops available to collaborating scientists	• Crop improvement programs in at least four countries in sub-Saharan Africa regularly employ techniques of cellular and molecular biology beyond the 1995 level	• IITA and NARS reports and publications • Training documentation	• Use of biotechnological tools will improve the efficiency of crop improvement activities
Improving Dissemination of Results Strengthened effectiveness of NARS in conducting research and in generating and utilizing improved technologies	• Increased number of scientists with higher degree • Improved effectiveness and impact of NARS research • Improved availability and use of information by NARS • Effective collaborative research arrangements and increased involvement of NARS in activities that are within IITA's mandate	• IITA and NARS reports • Joint publications and impact studies	• Increased financial and political support to NARS

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. These are described on pages 19 and 36.

The following section presents the goal and research highlights of each IITA project for 1996. 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. To increase farm productivity and arrest resource degradation in areas where population growth and intensified land use have forced farmers to reduce fallow periods. The specific purpose is to develop well-adapted and farmer-acceptable planted fallow systems, including cover cropping and tree-based fallow, which improve and maintain soil fertility while reducing weed problems.

Highlights

In germplasm screening work, over 40 fallow species were evaluated in the humid forest of Cameroon for vigor, habit, longevity, and disease susceptibility. Among 13 herbaceous legumes tested in the derived savanna, *Cajanus cajan*, *Crotalaria ochroleuca*, and *Pueraria phaseoloides* had better growth performance and residual effects on subsequent maize.

• In humid zone research on field practices and weed control, tillage increased the weed seed bank by 40% over no-till. The weed seed bank in a *Senna spectabilis* hedgerow system was twice as large as that in a no-tree system, possibly due to easier weeding in the latter. Slashing the exotic perennial *Chromolaena* 4–6 weeks before crop planting allowed the first flush of weeds to germinate. Subsequent burning and tillage destroys these weeds, significantly reducing weed pressure in groundnut. The technique was demonstrated, with success, in 12 farmers' fields in the humid forest zone. *Senna* mulch was eight to nine times more effective in reducing weed pressure than *Chromolaena*, *Pennisetum*, or *Calliandra*.

• In the derived and southern Guinea savanna, fallow system trials addressed the use of *Mucuna* and other herbaceous legumes to suppress the weed *Imperata*. In the northern Guinea savanna, the rotation effects of herbaceous legumes (*Mucuna*, lablab, cowpea, and Crotalaria) were studied in trials in farmers' fields. Results showed that integrated organic and inorganic inputs are necessary to achieve better maize yield. In the humid forest zone, on-farm trials were launched in several villages to evaluate, in cooperation with farmers, planting patterns and field practices for short-term tree-based fallow.

Project 2: Agroecosytem Development Strategies

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

Highlights

• Several studies were carried out to characterize resource management in the forest margins benchmark area of southern Cameroon. A census of 520 farm households in six research villages identified resource-use patterns and livelihood strategies. A survey of over 80 nongovernmental organizations (NGOs) focused on NGO involvement in natural resources management (NRM) activities. A survey on inland fisheries was completed in 40 villages and a census was taken of more than 15,000 fishers (more than half women). Geo-referenced digitized maps have been developed to improve understanding of fishing communities. Work also started on development of indicators for assessing the sustainability of agroecosystems in the benchmark area.

• In a newly defined northern Guinea savanna benchmark area in Nigeria, researchers conducted a baseline resource management survey, in order to assess resource-use patterns and define target

domains for future research. A complementary survey was carried out on farmers' attitudes towards soil conservation and current use of soil conservation practices.

• Geo-referenced vegetation surveys were conducted in the southern Guinea savanna, a coastal savanna benchmark area in Benin, and the forest margins benchmark area in Cameroon. These surveys are helping to explain the distribution and severity of major weeds, particularly *Imperata cylindrica* and *Chromolaena odorata*.

• In the savanna zone of Cameroon, researchers assessed the effects of policy shifts on the financial competitiveness of several agroforestry-based NRM technologies for maize production. The technologies were found to have a high level of financial and social profitability. Moreover, their financial competitiveness increased markedly after currency devaluation.

• A study was carried out in Benin in order to determine the reason for rapid farmer adoption of mucuna (a herbaceous legume) cover cropping technology. Economic analysis showed that mucuna cover cropping as a second season fallow is profitable. Complementary adoption research showed that the driving forces of adoption are farmer concerns with weed control and soil improvement.

• Factors influencing adoption of mechanized cassava processing technologies were determined, using data from ten major cassava-producing countries in Africa. Shortages of female labor, easy farmer access to market centers, and the desire to produce convenient cassava food products were found to be the key determinants.

• Progress was made in developing models to assess crop water needs in the humid and subhumid zones of Africa. Databases have been generated for developing and testing predictive models of crop water requirements under different cropping systems.

Project 3. Biological Control and Biodiversity

Goal. To enhance the livelihood of farmers and preserve biodiversity by investigating biological control of pests and weeds in the farming system, as well as by implementing control measures. The emphasis is on pests and weeds that cut across IITA's ecoregional zones. The project also houses biosystematics research. Self-sustaining solutions are developed for and with national research and extension systems or village organizations.

Highlights

• Field trials for the biological control of grasshoppers and locusts using the fungus *Metarhizium flavoviride* were carried out by the national programs of Benin, Chad, Gambia, Mali, Niger, and Senegal. Farmer participatory trials in Mali and Niger were very promising for future implementation of the technology at the village level.

• The persistence of *M. flavoviride* was shown to be a major advantage over fenitrothion, the most common insecticide used in grasshopper control. Ecotoxicological studies showed no impact by *M. flavoviride* on nontarget insects in the field, while the chemical pesticide caused major reductions in nontarget populations.

• IITA's mass production facility for biological pesticides can now annually produce enough spores to treat 4,000 ha. Spores can be stored at ambient temperature for at least one year without loss of viability. The new museum building provides IITA with a biosystematics infrastructure of international standard.

• IITA hosted a BioNet conference and became the network-coordinating institution for taxonomic activities in West Africa.

• *Anagyrus mangicola*, a parasitoid for controlling the mango mealybug, has become widely established in Côte d'Ivoire, a major mango-growing area.

Project 4. Integrated Management of Legume Pests and Diseases

Goal. To reduce the risk of legume crop loss in farmers' fields in sub-Saharan Africa by developing integrated pest management technologies that increase cowpea and soybean productivity in a sustainable manner.

Highlights

• On-farm surveys of soybean diseases in Nigeria confirmed the widespread severity of frogeye leaf spot and the slow spread of red leaf blotch. Sclerotia of the blotch fungus *Dactuliochaeta glycines* survive at least 12 months when buried in soil and spread in infected crop debris mixed with seed. Avoiding introduction of this pathogen into new fields is advised.

• New cowpea breeding lines with superior levels of resistance to *Maruca vitrata* (syn. *M. testulalis*), *Megalurothrips sjostedti*, and other cowpea pests were identified in field tests. Some lines showed little susceptibility to bacterial blight under field conditions.

• High levels of resistance to pod borer (*M. vitrata*), pod-sucking bug (*Clavigralla tomentosicollis*), and storage bruchid (*Callosobruchus maculatus*) were identified in two non-*Vigna* food legumes. Seed lectins and other extracts had a major role in resistance of *Sphenostylis stenocarpa* to these pests.

• The proportion of grain yield lost to insects was smaller in elite cowpea breeding lines, such as IT90K-277-2, than in the local cultivar, Dan'Ila, in trials with and without insecticide in Kano State, Nigeria.

• New ecotypes of the cowpea storage bruchid were identified in Nigeria.

• The potential for insect pests to shift from cowpea to soybean over time was demonstrated.

• A semiselective medium for quick detection of *Xanthomonas campestris* pv. *vignicola* was developed. Differences in virulence of bacterial isolates from 10 countries (six in Africa) were not associated with geographic distribution.

• A database was developed on the role

of habitat modifications in the management of cowpea pests to help identify interventions complementary to host plant resistance and biological control.

Project 5. Integrated Management of Maize Pests and Diseases

Goal. To reduce pre- and postharvest losses of maize due to pests, diseases, and fungal grain contaminants. Expected outputs include knowledge about the biology and ecology of pests and disease organisms; cultural management options for reducing losses; resistant maize germplasm and the tools needed by national programs to conduct adaptive germplasm screening; biological control options; and development and extension of integrated pest and disease management systems.

Highlights

• Advances in host plant resistance and biological control of stem borers were seen in 1996. Three synthetic borer-resistant populations were screened under artificial infestation of *Sesamia calamistis*, and TZBR Eld 1 underwent the 7th cycle of improvement under increased *Eldana* infestation. An East African parasitoid of *Sesamia calamistis*, *Cotesia sesamiae*, released in Benin in late 1995, is field established, and is spreading.

• The Nigerian Downy Mildew Eradication Campaign had moderate success during 1996. The disease spread into Lagos State, Nigeria, but still has not moved into Benin Republic. In Ibadan, spore trap catches in 1996 were 40% of their 1995 level and 24% of their 1994 level, indicating a strong decline in the epidemic.

• It was determined that resistance to *Stenocarpella macorspora* ear rot is controlled by dominant effects with some epistasis. Insignificant correlation between the ear rot and the leaf blight caused by the same fungus indicates separate genetic mechanisms.

• *Teretriosoma nigrescens*, the predator of the larger grainborer, *Prostephanus truncatus*, has continued to spread from its 1995 location. *P. truncatus* populations continued to decline wherever the predator had become established.

• Field inoculation techniques for *Fusarium moniliforme* and *Aspergillus flavus* were effective; the procedure can be easily adapted by national programs.

• Of some 700 isolates of *Aspergillus flavus* taken from soils in Benin, 21 were found to produce no toxin. These will be tested as competitive biocontrol agents against toxic strains of the fungus.

Project 6. Integrated Management of Cassava Pests and Diseases

Goal. To increase cassava production in Africa by developing, testing, and implementing sustainable plant protection measures in collaboration with national agricultural research and extension systems (NARES) and client farmers.

Highlights

• The exotic cassava green mite predator, *Typhlodromalus aripo*, was found in 11 countries (spread over 400,000 km^2 in West Africa alone). Pest populations were generally reduced by 50% and yields increased by one-third in farmers' fields in Benin.

• Local networks of farmers, extension agents, and scientists were set up in Benin, Cameroon, Ghana, and Nigeria to address farmers' demands and facilitate the exchange of control practices.

• The project developed a curriculum reflecting assessed needs for sustainable cassava plant protection, as well as didactic training materials, for farmers' field schools.

• Researchers identified a mixed cropping system for cassava bacterial blight control. They also identified high resistance to cassava bacterial blight, cassava anthracnose disease, and African cassava mosaic virus in local clones and breeding lines in Benin and Nigeria.

• Two new diseases were identified in Benin, Ghana, and Nigeria: *Curvularia lunata* stem and leaf blight and *Nattrassia mangiferae* root and stem rot.

• A 10 MB relational database on cassava protection, production, and socioeconomic constraints found in all production zones of Benin, Cameroon, Ghana, and Nigeria was completed.

Project 7. Improving Plantain- and Banana-based Systems

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

Highlights

• A collection of selected East African highland banana landraces, IITA hybrids, and other accessions was established at the East and Southern Africa Regional Center, Uganda. The identification of fertile landraces paved the way for breeding this gene pool.

• Selected diploid banana hybrids showed high parent heterosis, offering good opportunities for further use as male parents.

• The presence of banana streak virus (BSV) was confirmed in Cameroon and mealybugs that serve as BSV vectors were identified.

• Virus-free and tolerant hybrids were introduced for the establishment of clean nurseries in Uganda. BSV-tolerant and BSV-resistant hybrids were identified and described, following trials in seven African countries. New secondary triploid hybrids of the second generation were selected for high yield and BSV resistance.

• Nematode species profiles were established in Ghana, Nigeria, Uganda, and Rwanda, and associated yield loss was found to reach 40%. Nematode-resistant *Musa* genotypes were identified. Techniques for obtaining clean planting material for nematode and weevil control were transferred to farmers' groups.

• Methods for better in vitro sporulation of the fungus responsible for black sigatoka disease were developed. Unexpectedly, the presence of yellow sigatoka was confirmed in lowland ecologies of West Africa.

• Links with national agricultural research systems were sustained with the publication of three issues of the *MusAfrica* newsletter and with the hosting of the international banana conference in Uganda. Support was also given to the tissue culture laboratory at Kawanda, Uganda.

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 prototype crop and land management program for effective and sustainable integrated *Striga* control was developed for African farmers. A 6-ha block of land at Mokwa in the middle belt (moist savanna) of Nigeria was infested with *S. hermonthica*. This site will be used to validate the management program on a scale similar to that on a "real farm" situation, and to demonstrate its efficacy to extension staff and farmers.

• Field tests with soybean lines selected in the laboratory reconfirmed the accuracy of IITA's laboratory method for identifying nonhosts that produce a high level of germination stimulant. Six parental lines, selected for their ability to germinate *S. hermonthica*, were used to develop breeding lines for this "false-host" trait.

• In field trials, cereal seed treatments with selected bacteria isolates were successfully used, both to reduce parasitism of *S. hermonthica* and to increase grain yield by 60–100% compared with the untreated controls.

• Backcross progeny derived from the wild species *Zea diploperennis* were screened under artificial infestation with *S. hermonthica* in the field for the first time. Half the progeny were higher yielding and supported fewer emerged *S. hermonthica* plants than the resistant hybrid check, 9022-13.

• An early-maturing maize population, TZE Composite 5, showed a good level of tolerance to *S. hermonthica* and *S. aspera* in multilocational trials.

• In on-farm testing in Nigeria, farmers recognized the value of resistance of cowpea to *S. gesnerioides* and *Alectra vogelii* and requested further seed supplies.

• Projects for molecular mapping of *Striga* spp. resistance in maize and cowpea were developed in collaboration with CIMMYT and the University of Virginia, respectively. These will begin in 1997.

Project 9. Improving Postharvest Systems

Goal. To engender a quality-based, market-oriented focus to plant breeding and to develop improved technologies that enhance crop handling, food processing, product development, food quality and safety, storage, and marketing. These activities aim to capitalize on food production by reducing losses, increasing storage life, and adding value to primary goods.

Highlights

• A new postharvest laboratory was established in Uganda to backstop postharvest research in East and Southern Africa, with a focus on cassava and bananas.

• A pan-African postharvest newsletter, *Postharvest Systems*, was initiated in collaboration with GTZ, at the request of national agricultural research systems (NARS).

• A total of 57 prototypes developed by IITA's postharvest engineering unit were documented and tested; fabrication diagrams are available.

• An engineering fabrication network was established in Nigeria and Ghana, in collaboration with Global 2000.

• Processes for obtaining high-quality cassava flour have been developed, tested, and adopted by farmers and processors in Nigeria in four states. Four food processing companies are being supplied by these flour producers.

• Cyanide testing equipment have been delivered to several NARS in East, West, and Southern Africa for testing the safety of cassava roots and products. Personnel have been trained to use them.

• Improved cassava varieties with low cyanide content have been released to national research programs in West Africa.

• A series of regional training courses was conducted to train researchers, extension workers, entrepreneurs, and farmer groups in postharvest research and value-added activities for local staple crops.

Project 10. Farming Systems Diversification

Goal. To increase smallholder productivity and cash income in West and Central Africa by developing, with farmers, new and complementary income-generating enterprises.

Highlights

• In the forest margins benchmark area of Cameroon, baseline studies were completed on urban perimeter horticultural production, lowland (inland valley) cultivation, options for integrating small livestock, and fish farming. The horticulture survey showed there are important gender differences, with women dominating marketing activities and production of leafy greens. Monocultural production systems are used by 60% of households. The inland valley survey, carried out with 65 farmers in six villages, showed that there is no water control in two-thirds of lowland fields. Nearly all farmers fallow their lowland fields, with most using short fallows of 1–4 years. Focus-group discussions held in 45 villages as part of the livestock study confirmed that in most households, meat or fish protein is consumed less than once a week. Technologies for feeding small livestock in the dry season is a potential intervention point. A baseline inventory of 830 fish farms, followed by a survey with 81 current and former fish farmers, showed a dropout rate over 50%. The main causes appear to be lack of labor, engineering problems, and lack of knowledge and guidance.

• In the northern Guinea savanna benchmark area, a survey of 100 agropastoralists in 10 villages addressed

the use of crop residues as livestock feed. Four major storage methods for crop residues have been identified. Grain legumes (mainly cowpea and groundnut) are stored differently than cereal residues.

• Field evaluation of multistrata tree-food crop systems continued in the forest margins benchmark in Cameroon. In one activity, food crops were planted into 6- and 17-year old *Terminalia ivorensis* plantations thinned to two densities. In another activity, six farmer fields in three villages were planted to mixed fruit tree stands (citrus, avocado, mango, guava) and eight farmer fields in two villages were planted to a pure stand of Satsuma mandarin. In 1997, hedgerows will be added for mulch production and food crop planting will start.

• Another forest margins trial addressed high-value crop production. Researcher-managed tomato plots were established on 10 farms to evaluate nematode problems. Preliminary observations indicate that fungal and bacterial diseases, along with viral infections and insect damage, are at least as important as nematode problems.

• In the northern Guinea savanna benchmark, four trials of early maize adaptability to inland valleys were conducted jointly by researchers and farmers over two seasons. Important management problems were encountered, e.g., density, date of planting, and waterlogging. Nevertheless, there appears to be good potential for profits.

Project 11. Cowpea-Cereal Systems Improvement in the Dry Savanna

Goal. To develop adoptable crop varieties and agronomic practices for the Sudan savanna and Sahel that 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

• Evaluation, selection, and genetic improvement of African cowpea landraces continued in 1996. From evaluation of 150 local cowpea varieties from several African countries, the best nine varieties were selected for improvement through back crossing.

• Multiple pest and disease resistance is still central to the cowpea breeding program. In 1996, a total of 843 breeding lines were screened for resistance to *Striga gesnerioides*, *Alectra vogelii*, aphid, thrips, bruchid, bacterial blight, and viruses. Several lines were selected with multiple resistances. Several new breeding lines yielded 1.5–2.5 t/ha grain with two insecticides sprays and 0.5–1.5 t/ha grain without insecticide sprays in sole crop. When intercropped with millet, with no insecticide application, the most promising breeding lines gave 0.3–0.7 t/ha grain yield, compared with less than 0.2 t/ha for the local varieties.

• A new germplasm line, TVu 12349, tested over the last two years, was the most promising dual-purpose line, with 1.2 t/ha grain and 8.9 t/ha dry fodder, compared with the best improved line, IT 93K-398-2, with 1.6 t/ha grain and 2.7 t/ha fodder. TVu 12349 is also highly resistant to scab, *Septoria*, and bacterial blight. It is now used as a parent in the breeding program.

• Preliminary studies on cowpea fodder quality have shown major varietal differences for protein content, digestibility, and effect on milk yield.

• Trials were conducted in the Sudan savanna to evaluate improved varieties of millet, sorghum, and cowpea under the traditional intercropping practice of one row of cowpea with one row of cereal (either millet or sorghum). Results showed the total system productivity can be increased by 50%–100% by using improved varieties in the traditional system.

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. In 1996, the project continued to develop improved varieties of maize, soybean, and cowpea that will have a positive impact on the cropping system, and to develop cultural practices that maximize the benefits of grain legumes to maize in a crop rotation system.

Highlights

• Advances were made in the development of maize varieties with high N-use efficiency (NUE). A total of 198 families from a low N-tolerant pool were screened under low and high N. Uniform stress was obtained, and differences observed. In the low nitrogen site, the commercial hybrid with relatively good NUE yielded 2.4 t/ha of grain, whereas the three best selections averaged 3.2 t/ha. Farmers have articulated their need for varieties that perform well with a moderate amount of N fertilizer. The results suggest this is attainable.

• About 50 soybean breeding lines known to be high yielding and possessing other good agronomic traits were evaluated for nitrogen fixation at three Guinea savanna locations. Most of the breeding lines had 40–50% of their total nitrogen produced through fixation (from the atmosphere), with 50–60% taken from the soil. However, three breeding lines were identified that derived 60–63% of their nitrogen from fixation. These lines will be used to improve this trait in other soybean germplasm.

• The effect of several soybean harvesting methods and residue management practices on performance of the subsequent maize crop was evaluated at four sites in the Guinea savanna. All soybean rotation treatments gave higher maize grain yields than maize followed by maize without N fertilizer (maize control). The clearest (significant) benefit of soybean rotation was observed when soybean residue was returned and incorporated, but the yield was still lower than that obtained when 20 kg N/ha was applied to the maize.

• In certain parts of the Guinea savanna, where the growing season is approximately 180 days, farmers plant an early-

maturing cowpea variety at the beginning of the wet season. After harvesting the grain, they plant maize. A trial to evaluate this cropping system was conducted on two farmers' fields. The maize grain yield following cowpea was comparable to the maize grain yield following native fallow with 30–60 kg N/ha applied.

These findings are being used to quantify desired genetic improvement targets for both NUE (maize) and N fixation (grain legumes).

Project 13. Improvement of Yam-Based Systems

Goal. To ensure that farmers achieve a sustainable increase in the productivity of yam-based systems through the adoption of improved technologies.

Highlights

- Surveys in Uganda and Tanzania showed yam production (frequently managed by women) to be a valuable component of the farming and food systems in the areas studied. In a survey of the predominant crops in the southern Guinea savanna of Nigeria and their production dynamics, yam was classified as the first-priority crop in over half of the 1,268 cells surveyed.
- Good progress was made in characterizing viruses infecting *Dioscorea* species in Nigeria and the development of appropriate diagnostics for their detection. IITA currently has the most comprehensive set of diagnostics for yam viruses in the world.
- A three-year study of leaf spot disease, which has produced comprehensive data on yield losses due to yam anthracnose, was completed.
- A rapid laboratory method was developed to screen isolates of yam anthracnose (*Colletotrichum gloeosporioides*) for virulence on detached leaves of yam.
- Studies were initiated in the southern Guinea savanna of Nigeria to develop strategies for integration of herbaceous legumes in yam-based systems for maintenance of soil fertility and control of weeds.
- The first regional variety trial of *D. rotundata* in West Africa was initiated with national program collaborators in Ghana, Togo, Benin, and Nigeria. Multiplication of planting materials of introduced germplasm continued in 11 countries in West and Central Africa, in preparation for an expansion of the trials. Four breeding lines were included in the first set of yam trials under the Nationally Coordinated Research Project (NCRP) in Nigeria, as a prelude to formal release of varieties.
- Nine new genotypes of *D. rotundata* were certified for international distribution after virus testing, bringing the total number of virus-tested genotypes to 32.
- In surveys in Ghana and Nigeria, the farm-level economics and adoptability of various micropropagation techniques were compared with those of commonly used methods of seed yam production. The findings will contribute to the development of national-level strategies for disseminating new varieties.

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

- A total of 577,053 seeds, covering 3,149 families of broad-based improved populations and special-trait populations of cassava, were distributed to national programs in 15 countries.
- IITA received 22,700 seeds collected from local landraces, constituting 180 families from five countries. This is part of an effort to exploit favorable traits in African landraces, including resistance to African cassava mosaic disease (ACMD) and cassava green mite (CGM).
- Characterization of IITA elite cassava genotypes for food quality was completed; these genotypes are now being used as parents in the breeding program to enhance food-quality traits for specific end uses. Several cassava genotypes with very low and stable cyanogenic potential (CNP) across several agroecological zones were identified. In collaborative work with the International Livestock Research Institute, 183 elite cassava genotypes were evaluated for foliage yield and suitability as livestock feed, as well as quality. Large genetic variation for edible forage production, crude protein, and dry-matter digestibility was observed.
- Early bulking cassava genotypes adapted to the inland valley ecosystem (6-month growth cycle) and with desirable agronomic and quality characteristics were identified from among elite breeding lines. These selections are available as certified in vitro plantlets for distribution to national research programs. The genotypes are also suited to the upland ecosystem, thus permitting two harvests in one year.
- Long-term experiments on agronomic and physiological aspects of production systems in the lowland savanna and forest-savanna transition zones yielded results that will be used to formulate improved production packages. The packages will cover cassava-based cropping systems for inland valleys, intercropping systems for uplands, and improved husbandry practices for enhanced and sustained yields.

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

• The regeneration of cowpea based on the protocol developed in 1995 is now routine. Transformed cowpea was obtained in 1996; T0, T1, and T2 plants are being evaluated and characterized.

• Somatic embryos were obtained from root suspension cultures of yam.

• Lectins and secondary metabolites isolated from African yam bean (AYB) showed high levels of suppression of insect growth for the major cowpea pests (*Maruca vitrata, Clavigralla tomentosicollis,* and *Callosobruchus maculatus*).

• Thirty-five African cassava landraces (34 resistant to African cassava mosaic virus (ACMV) and one a susceptible check), along with seven improved IITA varieties, were characterized by random amplified polymorphic DNA (RAPDs) genetic markers. Among the landraces, 13 were found to be genetically distant from both the other resistant landraces and the improved varieties. This suggests that these landraces might carry other sources of genes for resistance to ACMV.

• More than 300 A and B genome microsatellites have been isolated, in collaboration with the United States Department of Agriculture, for use in genetic analysis, germplasm characterization, and marker-assisted breeding of *Musa*.

• Microsatellite markers have been used to demonstrate definitively that recombination occurs during the formation of 2n megaspores in plantain, and that true breeding banana accessions can possess significant levels of heterozygosity. Both observations have significant implications for the design of crossing programs for *Musa* genetic research and improvement.

• An immunocapture PCR method was developed for detection of banana streak virus (BSV).

• Surveys of cassava mosaic disease, in collaboration with SARRNET and EARRNET in Kenya, Tanzania, Uganda, Malawi, and Zambia, confirmed the usefulness of monoclonal antibodies in detecting ACMV and East African cassava mosaic virus (EACMV). EACMV was detected for the first time near Lake Victoria in contiguous locations in Kenya and Tanzania, and also northeastern Zambia in Luapula Province, indicating that the earlier reports of nonoverlapping geographic distribution of these two viruses are no longer tenable.

Project 16. Conservation and Genetic Enhancement of Plant Biodiversity

Goal. To improve the conservation and utilization of plant biodiversity to contribute in a sustainable manner to food security in sub-Saharan Africa. The project will result in improved availability and more efficient utilization of plant genetic resources by national programs and other partners.

Highlights

• Considerable progress was made in the conservation of yam genetic resources through further exploration, and through further research on conservation methods. A total of 227 accessions of both cultivated and wild yam species was collected from Cameroon, Benin, Côte d'Ivoire, and Guinea-Conakry. A medium capable of maintaining a very wide range of genotypes and species of yam for 11–15 months before subculturing was identified.

• Significant progress was made by EARRNET member countries in collecting cassava germplasm. A total of 1,245 accessions was collected, including 280 accessions in Rwanda, to restore those that were lost during the recent civil unrest.

• Screening of local germplasm over the past two years resulted in identification of 60 new accessions of local cassava that are resistant to ACMD, about 35 accessions of yam resistant to yam viruses, and 5 accessions of close relatives of cowpea with moderate levels of resistance to *Maruca* pod borers.

• Impressive progress was made in broadening the genetic base of yam breeding populations. More interspecific hybrids were made between and among four yam species (*D. rotundata, D. cayenensis, D. togoensis,* and *D. praehensilis*). Some hybrids are in clonal evaluation trials.

• The genetic inheritance of drought tolerance, photosensitivity, and branching behavior in cowpea was elucidated.

• Following the successful development of plantain-derived diploids (TMP2x series), the focus shifted to the production of banana diploids (TMB2x) as male progenitors. Several crosses were made and evaluated at Onne, Nigeria, of which three were selected as the most promising diploid banana hybrids: TMB2x 5105-1, 6142-2, and 9128-3.

• Significant achievements were made in developing and applying diagnostic techniques for the safe movement of germplasm. Polyclonal antisera and/or monoclonal antibodies to 80 characterized viruses are now available for the detection of the known viruses in many crops. Another 39 partially characterized antisera are also available.

• The mode of transmission of *Dactuliochaeta glycines*, the fungus causing red leaf blotch of soybean in Africa, was determined. It is externally seedborne as sclerotia or in infected debris mixed with seeds. It is, therefore, important not to distribute soybean seed from endemic areas. Sclerotia and infected crop debris can be removed by vacuuming or washing the seed.

Project 17. Improving the Dissemination of IITA's Research Results

Goal. To strengthen the effectiveness of NARS in the generation and utilization of appropriate research results. Major activities are training, training materials development, research collaboration (both network- and project-based), the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA), bibliographic services, and public awareness building.

Highlights

• IITA supported the training of 152 graduate research fellows and students, of whom 59 began and 41 completed their work in 1996. In addition, 25 research training associates had individual, nondegree attachments to IITA.

• Group training courses were conducted for 291 participants (21% women), with

the collaboration of 21 partners such as regional centers, research networks, and NARS.

• Training was provided to 42 IITA graduate researchers in statistical computing, training and communications, and writing proposals for research grants.

• A study was designed to evaluate the impact of IITA training, covering trainees from 39 countries. Evaluations of 28 training events (14 at IITA headquarters, 6 in NARS, and 8 within research projects) were carried out and reports produced. Work progressed on the design of a training database and a directory of donors was compiled.

• The Training Materials Unit produced 10 new research guides (three English, seven French), three slide collections, two videos, and 11 posters. Work also began on two interactive CD ROMs. The Unit also instructed NARS personnel in the development of training materials and successfully market-tested training materials with a diverse audience at the Ghana Book Fair.

• The Moist Savanna Consortium and the Humid Forest Consortium of EPHTA were officially launched. Participating countries signed a memorandum of understanding describing their commitments and obligations, as well as those of IITA as the program convener.

• Collaboration increased with national and international partners, such as the Empresa Brasileira de Pesquisa Agropeucária (EMBRAPA, Brazil), the UN Food and Agriculture Organization, and international agricultural research centers. Similarly, links have been strengthened with three regional research-coordinating bodies: the Association for the Strengthening of Agricultural Research in Eastern and Central Africa (ASARECA), the Conférence des responsables de la recherche agronomique africains (CORAF), and the Southern Africa Centre for Cooperation in Agricultural Research (SACCAR).

• The five-year Research Project on Maize and Cassava (RRPMC) was concluded. Under the project, NARS of seven West and Central African countries carried out 44 research activities. The results demonstrate that they have been strengthened through the availability of improved, high-yielding genetic materials, postharvest technology and new product development, integrated pest management, training, staff exchanges, and infrastructure development.

• A multiplication expert was recruited for the project entitled Accelerated Multiplication and Distribution of Improved Cassava and Sweetpotato Planting Materials as a Drought Relief Measure in Zimbabwe, Lesotho, and Swaziland. The project's steering committee met to review workplans and cost estimates for 1997. Activities began in all three countries.

• A project entitled Promotion of Seed Production and Marketing in West Africa began. Funded by Germany's Gesellschaft für Technische Zusammenarbeit (GTZ), the project is being carried out in collaboration with Ghana's Crops Research Institute (CRI). It aims to strengthen the seed sector in West Africa through advice, networking, institutional support, and the promotion of seed technology and fast propagation methods for root and tuber crops, as well as banana and plantain.

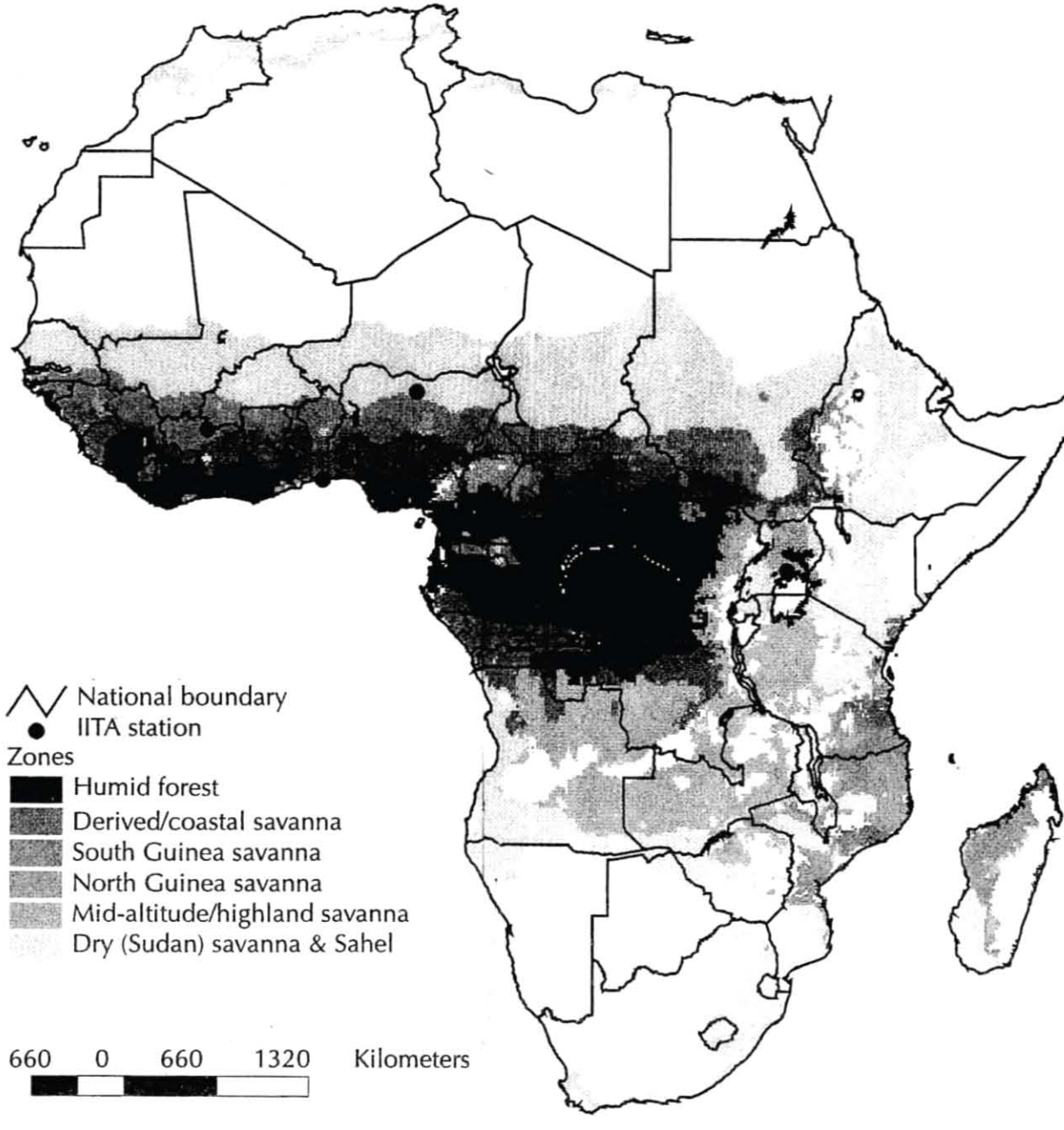
• Three networks in which IITA has strong participation continued their collaborative work. They are the West and Central Africa Collaborative Maize Research Network (WECAMAN), the Southern Africa Root Crops Research Network (SARRNET), and the East Africa Root Crops Research Network (EARRNET). The networks exchange germplasm, conduct joint research and varietal trials, organize monitoring tours for members, promote the multiplication and distribution of planting materials, and work on postharvest technologies.

• The Public Affairs Unit helped increase the visibility of IITA's work by collaborating with Gabon-based Afrique Numéro Un Radio on the broadcast of a regular program on agriculture. German and Nigerian TV and radio also covered IITA's work and 164 articles appeared in foreign and local newspapers and magazines.

• A total of 4,437 university students visited IITA in 1996, compared with 1,750 in 1995.

• The IITA library copied about 20,000 pages of journal articles and book chapters in response to requests from NARS researchers. Five NARS librarians received training at IITA in library management and automation. Micro CDS/ISIS software was distributed to three NARS.

Annex 4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