Project 6

Integrated Management of Cassava Pests and Diseases

Annual Report 1999

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Contents

Preface

In 1999 IITA's research agenda was subdivided into a portfolio of 16 projects (Annex 1), around which these annual reports are prepared. These projects address different aspects of attaining sustainable increases in productivity of dominant farming systems and utilization practices in the various agroecologies of sub-Saharan Africa (SSA). Research and training activities carried out in the 16 projects are being implemented together with national program partners in order to increase the well-being of poor people in SSA through higher levels of food production, better income and nutritional status, and reduced drudgery particularly for women. Additionally, IITA serves as the convening center for the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA) and the Systemwide Program on Integrated Pest Management (SP-IPM).

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

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

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

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

Project 6
Integrated Management of Cassava Pests and Diseases

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Project rationale

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

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

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

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

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

Outputs

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

Background

An understanding of a pest's distribution and impact provides the basis for assessing the importance, and generating background information needed to design and execute appropriate intervention technologies. Evaluating farmers' constraints as influenced by biotic, abiotic, and socioeconomic factors within agroecosystems in collaboration with the clients assures the relevance and focus of proposed R and 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 Distribution and abundance of *Stictococcos vaysseirei* in the forest zone benchmark area of Cameroon

R.H., M.T., G.G., P.N., in collaboration with A. Nkakwa, and N. Ntonifor

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

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

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

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

6.1.3 Diagnosis and characterization of the whitefly and the whitefly-borne virus constraints of cassava and sweetpotato production

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

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

6.1.4 Cassava mosaic virus outbreak in the Republic of Congo

P.N., J.H.

FAO, on behalf of the government of the Congo asked IITA to send an evaluation mission to investigate phytosanitary problems on cassava. The main problem, it turned out, was an outbreak of CMD, whereby cassava of entire villages was almost totally destroyed by early stunting of the plants. A DNA analysis (through PCR) of infested leaves stored in alcohol, resulted in the discovery of ACMV, EACM, the Uganda variant (UgV; a hybrid of the two), and a second recombinant form. This is the first time that UgV, an especially virulent form of CMD, has been reported outside southeastern Africa. It is likely that the 'pandemic' can now spread into West Africa. The second recombinant form detected could indicate a separate recombination event in the Congo; alternatively, the numerous Rwandan fugitives who were settled in central Congo might have brought UgV into the Congo.

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

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

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

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 in understanding the problem and targeting the solution. Strategic and tactical models can be used to identify critical interactions, and to 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 Multitrophic interactions between cassava, *M. tanajoa*, and exotic predators

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

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

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

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

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

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

R.H., in collaboration with A. Onzo and M. Sabelis

Understanding within- and between-plant distribution and diurnal movement of CGM and associated predators can further our understanding of the interactions between predators and prey to develop sampling programs for population estimation and monitoring. The within-plant movement of cassava green mite *M. tanajoa* and its two most efficient exotic phytoseiid predators, *Typhlodromalus manihoti* and *T. aripo*, released and established in Africa was monitored in two field sites in Bénin every 3 months from August 1998 to June 1999. During a sampling day, whole plant sampling was conducted at 4-hour intervals over a 24-hour period starting from 12 o'clock to 8 o'clock the following morning. Analysis of the data showed that the within-plant distribution of *M. tanajoa* did not follow a diurnal pattern but fewer *M. tanajoa* were found in the upper part of the foliage compared to its normal distribution in the absence of efficient predators. The exotic predator *T. manihoti* also did not show any diurnal pattern in its distribution within cassava plants. It was confined to cassava leaves especially on young leaves but was never found in cassava tips. But the exotic phytoseiid predator species *T. aripo* showed a diurnal pattern in its within-plant distribution. Samplings at 12 noon, 4 pm, and 8 am, revealed the presence of *T. aripo* almost exclusively in the cassava tips, while at 8 pm, only 36 and 18% of *T. aripo* remained in the tips at the two field sites respectively. At midnight, 36 and 40% of *T. aripo* remained in the tips; while at 4 am, 65 and 53% of *T. aripo* were found in the tips. During these hours, individuals of the predator were found foraging on leaves and other plant parts. The mechanisms that prompt *T. aripo* to forage only at a given period of the night to hide in the tips before sunrise is still unknown. All mobile stages of the predator could be found on leaves and other plant parts during their foraging hours.

6.2.4 Impact of multiple predator introductions on cassava green mite biocontrol

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

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

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

R.H., in collaboration with D. Gnanvossou and M. Dicke

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

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

R.H., in collaboration with D. Gnanvossou and K. Neglou

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

6.2.7 Spore production potential of Brazilian and Béninoise isolates of *Neozygites floridana*

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

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

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

W. Meikle, in collaboration with C. Nansen and Y. Magnon

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

6.2.9 Interactions between cassava green mite and cassava mosaic virus disease

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

CGM/CMD interaction studies in the field and screenhouse were completed. In screenhouse studies, the effect of CGM infestation on CMD-free, mildly CMD-diseased, and severely CMD-diseased cassava plants was investigated. The effects of CGM and CMD were assessed in terms of their impact on a series of plant growth characteristics including: plant height, leaf length, petiole length, leaf number, and proportion of dropped leaves. Some evidence was obtained for a positive interaction between CGM and CMD from leaf length data. CGM infestation had no effect on the pattern of increase in average cassava leaf length between 3 and 7 months after planting for CMD-free or mildly CMD-diseased plants. For severely CMD-diseased plants, however, CGM infestation led to a significant reduction in average leaf length in comparison with the uninfested control. Follow-up studies will examine the effect of different viruses and virus combinations on interactions between CGM and CMD. Studies to assess the effect of CMD on the activity of the CGM predatory mite, *T. aripo* were initiated in collaboration with IITA's CGM Biocontrol Project.

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

J.P.L.

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

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

J.P.L.

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

6.2.12 Role of insects as vectors of cassava bacterial blight

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

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

6.3 Development, testing, and integrating IPM components

Background

Host plant resistance, biological control, and cultural practices form the basis of an ecologically sound and sustainable plant health management. Technologies are being developed to screen varieties in the laboratory, greenhouse, and the field for resistance mechanisms. Quantifying symptoms in relation to inoculum or population pressure is needed to select varieties with desirable resistance mechanisms. Cultural practices begin with the cutting material, include soil management, continue with intercrops and other interactions in 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 Culture of exotic phytoseiids

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

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

6.3.2 Improving cassava green mite biocontrol with cultural practices

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

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

6.3.3 Release of *Neozygites floridana* for the control of the cassava green mite

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

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

6.3.4 Persistence of the biological control of cassava mealybug

P.N

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

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

J.P.L, in collaboration with W. Sserubombwe

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

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

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

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

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

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

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

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

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

Nematodes are among the biotic factors that constrain cassava productivity. Severe damage of cassava due to root-knot nematodes (*Meloidogyne* spp.) has been reported from western Uganda and southern Mozambique. Using the differential host technique, the biological race of a root-knot nematode population implicated with causing severe damage in farmers' fields in Masindi District in Uganda was established as race 2 of *Meloidogyne incognita*. The performance of 25 cassava genotypes infected with the root-knot nematode population from Masindi was evaluated in a field experiment. A relatively low initial nematode pressure was able to cause significant ($P<0.05$) production losses of as much as 25% after 12 months in 16% of lines tested. The validity of screening for nematode tolerance using short-term pot trials was investigated by relating the results of early- (3 months), medium- (6 months), and long-term (9 months) pot experiments to the results of the 12-month field performance evaluation. The effect of root-knot nematodes on cassava sprouting was also tested for the two cultivars SS4 and 'Migyera' (TMS 30572) at two nematode infestation levels. Sprouting of the culltivar 'Migyera' was delayed and reduced at the higher infestation level. Cuttings pre-sprouted in polyethylene bags were less sensitive to nematode infestation in the establishment phase. These results indicate that cassava response to root-knot nematodes is cultivar dependent. Root-knot nematodes adversely affect cassava productivity in three ways: (1) by reducing plant establishment, (2) by decreasing the number of storage-roots formed, and (3) by reducing the size of the storage roots formed.

6.3.9 Mechanisms of resistance and host-pathogen interactions in the system cassava/ bacterial blight; analysis of plant and bacterial polymers and of low molecular inhibitory substances

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

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

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

6.3.10 Determination of infection rate, multiplication of *Xanthomonas campestris* pv. *manihotis* and determination of stomatal distribution and number in resistant and suceptible cassava plants

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

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

6.3.11 Reaction of local and improved varieties, and of individuals of the backcross (BC1) of TMS30572 x CM2177-2 (Latin American origin) to highly virulent strains of *X. campestris* pv. *manihotis* from different geographical origins

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

Twenty-four local and improved varieties from Togo were stem inoculated with 4 highly virulent *Xcm* strains from various geographical origins. The local variety Gbazekoute and the improved varieties CTM4, TMS 920057, TMS 91/02316, TMS4(2)1425, and TMOA378 showed resistance/tolerance to the inoculated strains. Several varieties are being tested by leaf inoculation with the 10 most virulent strains. Inoculating 19 local and improved varieties from Bénin/Nigeria by stem puncture and leaf infiltration with *Xcm* strains from various origins, races of *Xcm* could not be identified. Experiments with the BC1 population are ongoing.

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

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

In Togo, 24 cassava varieties collected from farmers' fields and from the National Cassava Collection were planted in 2 ecozones in 1998 and in 3 ecozones (littorial, forest, and wet savanna) in 1999. Symptoms of CBB and CMD were evaluated. In harvests after 6 and 12 months, root, stem, leaf weight, and number of leaves and of fallen leaves was determined in the inoculated treatment and the control. The local variety Nakoko was resistant in the field, but susceptible to inoculation with virulent strains of other geographical origins. In Bénin, 30 local varieties were tested for resistance in the forest savanna transition, the wet, and the dry savanna zones. Trials are being repeated for a second year.

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

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

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

6.3.14 Screening of cassava varieties for resistance to root rots

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

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

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

Background

Information resources are needed to facilitate processing, summarization, interpretation, and communication of the large and diverse databases. Large multidisciplinary databases are best exploited by a systems approach specifically designed to update, manage, and interpret dynamic data. Work already initiated along these lines includes development of text references, taxonomic resources, digitized interactive information resources, and decision support systems. Efforts will be made to identify and compile the gray literature on root crop plant protection, e.g., theses, dissertations, project documents, annual reports, etc., in each country into a database. 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.

Ongoing and future activities

6.4.1 Extension/farmer training materials

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

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

6.4.2 Interactive information media

R.H., J.S.Y., B.D.J., M.T., in collaboration with F. Fuloranmi, B. Gbaguidi, and A. Kagbahinto

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

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

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

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

6.4.4 Workshop manual: integrated management of cassava bacterial blight

K.W.

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

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

Background

Intervention technology is of little value until it is locally adapted, disseminated, and implemented. Getting this technology to the farmer is the last, but often the most difficult step to take. This is where NARES and farmers have an important role, but often lack the experience and training needed to achieve the objective. Developing technology in collaboration with end users and those most closely associated with adoption is a good way to start. Collaborative evaluation, dissemination, and implementation activities provide NARES with the 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 of exotic phytoseiids

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

A total of 72 240 actives of Piritiba and MGS strains of *T. aripo* were shipped from IITA for experimental releases in Angola, Democratic Republic of Congo (DRC), Malawi, Mozambique, Tanzania, and Zambia in 1999. Follow-up surveys indicated successful establishment and substantial spread in several sites in Bas-Congo of DRC and Nkhata Bay in Malawi; limited spread in Luapula Province in Zambia and Nampula province in Mozambique. Establishment in Angola is yet to be confirmed. In Bénin, Cameroon, Ghana, Guinea Conakry, and Nigeria, *T. aripo* was recovered in all previous release fields, has persisted for over 5 years, and is now found up to the edge of the dry savanna. *T. aripo* was found similarly distributed with similar levels in Côte d'Ivoire and Togo, where this predator was never intentionally released. *T. aripo* has also spread extensively in Uganda up to the northern dry regions, throughout the cassava growing areas of Kenya, and much of Tanzania (except in the Mara region and the area between the southern tip of Lake Tanganika, and the northern tip of Laka Nyasa, where releases have been made but follow-up surveys have not been conducted). In the Republic of Congo, *T. aripo* was found up to 300 km from a single release conducted in 1997. The predator has been reported from Liberia, Rwanda, and Burundi but the extent of spread in those countries is not yet known. Overall, *T. aripo* spread currently covers over a million km² where it reduces *M. tanajoa* populations by 30 to 60%. The establishment, dispersal, persistence, and population dynamics of *T. aripo* will continue to be monitored in 2000 in at least 12 countries.

6.5.2 Support to national programs

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

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

6.5.3 Impact assessment of exotic predatory mites

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

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

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

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

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

6.5.5 Evaluation of CMD-resistant cassava varieties in Kenya and Tanzania

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

More than 25 'improved' cassava varieties were evaluated in collaboration with Tanzanian NARS and responses to CMD described. Only three of the varieties had less than 60% CMD incidence at the highest inoculum pressure location, and were therefore considered for incorporation within the multiplication scheme. These were TMS 30572(6), TMS 81983, and TMS 30337. Through the OFDA/CMD project, support was also provided for the performance evaluation of more than 150 clones at Alupe, western Kenya, and the evaluation and multiplication of 14 clones targeted for 'fast-tracking' through the evaluation, multi-locational testing and multiplication process.

6.5.6 Targeted multiplication of CMD-resistant varieties in the zones affected by the pandemic of severe CMD in East Africa

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

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

6.5.7 Support for germplasm exchange in East Africa

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

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

6.5.8 Cassava pest and disease training

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

Several training courses in CMD, and general cassava pest and disease control, and cassava production and utilization were held in 1999. The training included: (1) a CMD awareness workshop for District Agricultural Officers, western Kenya, March 1999; (2) a cassava multiplication and planning workshop, Rakai and Masaka districts, Uganda, September 1999; (3) training of trainers course on cassava production, pest/disease management and postharvest utilization, western Kenya, June 1999; and (4) training of village leaders in CMD management, rapid multiplication and processing, Bukoba District, Tanzania, May 1999. Three additional types of training were organized in 1999. In one training course, NARS staff from several countries spent two weeks at IITA, Cotonou, where they received in-depth training in cassava green mite management. In a second training course, 14 plant pathologists from NARS from 9 countries in West and East Africa received in-depth training at IITA, Cotonou, in integrated management of bacterial diseases and root rots of cassava, and in classical and modern phytopathological methods. The third type of training involved in-country training of NARS extension officers, NGOs, and farmers' representatives from Bunda, Kahama, Mugumu, Musoma, and Tarime districts in Tanzania (4–7 October), and from Mukono (October 1999), and Rakai (November 1999) districts in Uganda. Participants in the in-country training represented 22,000 families/groups in Mara, 22,000 in Mukono, and 15,000 in Rakai who could/would be trained on CGM activities. In addition to courses, on-site, and bench training, two PhD and one MSc student completed their degrees, and several PhD and MSc students from various African countries are continuing their research on CBB (2), root rot pathogens (1), root-knot nematode (1), and cassava green mite (7).

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

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

A five-day stakeholder workshop, sponsored by IFAD, was held in Kampala, Uganda from 19–23 April 1999 to develop a comprehensive and broad-based approach to the implementation of CGM biocontrol in Kenya, Malawi, Tanzania, Uganda, and Zambia. Representatives from IITA, donor agencies, NARS, and NGOs from each of the targeted countries: (1) identifed the needs of the participating countries and determined ways to respond to those needs; (2) established a collaborative network among NARS, NGOs, and IITA to implement CGM activities and promote cassava IPM; and (3) developed and finalized workplans and budgets for 1999, and work agreements for the life of the project.

6.5.10 Collaborative research programs on bacterial diseases

KW

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

Completed Studies

Journal articles and book chapters

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

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

Borgemeister, C., K. Schaefer, G. Goergen, S. Awande, M. Setamou, H. Poeling, and D. Shcolz. 1999. Host-finding behavior of *Dinoderus bifoveolatus* (Coleoptera: *Bostrichidae*), an important pest of stored cassava: the role of plant volatiles and odors of conspecifics. Annals of the Entomological Society of America 92: 766–771.

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

Fessehaie, A., K. Wydra, and K. Rudolph. 1999. Development of a new semiselective medium for isolating *Xanthomonas campestris* pv. *manihotis* from plant material and soil. Phytopathology 89: 591–597.

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

The metapopulation dynamics of the African cassava food web is explored using a physiologically based tritrophic model. The interacting species are cassava mealybug and its natural enemies (two parasitoids, a coccinellid predator, and a fungal pathogen) and the cassava green mite and its natural enemies (two predators and a fungal pathogen). The metapopulation model is based on a single patch age-structure population dynamics model reported before. The same model simulates the mass number dynamics of each plant or animal species in each patch and the movement of animals between patches. Movement is based on species specific supply-demand relations. The pathogen mortality rate is a simple function of rainfall intensity. The within-patch species composition, their initial densities, and initial values of edaphic variables may be assigned stochastically. Sensitivity, graphical, and multiple linear regression analyses are used to summarize the effects of spatial and resource heterogeneity on species dynamics. Important plant level effects on higher trophic levels are demonstrated, and recommendations are made as to the appropriate model for different ecological studies.

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

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

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

Conference papers, workshop proceedings, abstracts, and newsletters

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

Assigbétsé, K., V. Verdier, K. Wydra, K. Rudolph, and J.P. Geiger. 1999. Genetic variation of the cassava bacterial blight pathogen, *Xanthomonas campestris* pv. *manihotis*, originating from different ecoregions in Africa. In: Plant Pathogenic Bacteria, Proceedings of the 9th Internatioal Conference, Center for Advanced Study in Botany, edited by A. Mahadevan, University of Madras, India, pp. 223–229.

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

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

Briddon, R.W., J.A. Farquhar, C. Roussot, G.K. Banks, I.D. Bedford, J.P. Legg, and P.G. Markham. 1999. Geminiviruses and whiteflies across Africa. Pages 75–76 in: Abstract. Proceedings of the 7th International Plant Virus Epidemiology Symposium, 11–16 April 1999 Aguadulce (Almeria), Spain.

Ferris, S., J.P. Legg, G.W. Otim-Nape, and J.A.B. Whyte. 1999. Dissemination and utilisation of mosaic-resistant cassava. Fifth technical report for the ACDI PL 480 Cassava Project.

Ferris, S., J.P. Legg, A. Bua, and J.A.B. Whyte. 1999. Dissemination and utilisation of mosaic-resistant cassava. Sixth technical report for the ACDI PL 480 Cassava Project.

Fessehaie, A., K. Wydra, and K. Rudolph. 1999. Cefazolin-Trehalose agar medium, a semi-selective medium for *Xanthomonas campestris* pv. manihotis (Xcm), the incitant of cassava bactertial blight. Pages 100–106 in: Plant Pathogenic Bacteria; Proceedings of the 9th International Conference, Center for Advanced Study in Botany, edited by A. Mahadevan. University of Madras, India.

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

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

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

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

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

Legg, J.P. and Okao-Okuja. 1999. Progress in the diagnosis and epidemiological characterisation of cassava mosaic geminiviruses in East Africa. Pages 74–78 in: Proceedings of the 7th International Plant Virus Epidemiology Symposium, April 11–16, 1999, Aguadulce (Almeria), Spain.

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

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

Sseruwagi, P., L.P. Legg, and G.W. Otim-Nape. 1999. An overview of the incidence of cassava mosaic disease in East Africa, 1998 update. Pages 87–88 in: Proceedings of the 7th International Plant Virus Epidemiology Symposium, April 11–16 1999. Aguadulce (Almeria), Spain.

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

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

Wydra, K., V. Zinsou, and A. Fanou. 1999. The expression of resistance against *Xanthomonas campestris* pv. *manihotis*, incitant of cassava bacterial blight, in a resistant cassava variety compared to a susceptible variety. Pages 583-592 in: Plant Pathogenic Bacteria. Proceedings of the 9th International Conference, edited by A Mahadeva. Madras, India.

Wydra, K., A. Fessehaie, A. Fanou, R. Sikirou, J. Janse, and K. Rudolph. 1999. Variability of strains of *Xanthomonas campestris* pv. *manihotis*, incitant of cassava bacterial blight, from different geographic origins in pathological, physiological, biochemical, and serological characteristics. Pages 5–54 in: Abstract. 1996. Plant Pathogenic Bacteria, Proceedings of the 9th International Conference, edited by A. Mahadeva. Center for Advanced Study in Botany, University of Madras, India.

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

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

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

PhD completed in 1999

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

Cassava bacterial blight (CBB) caused by *Xanthomonas campestris* pv. *manihotis* (*Xcm*) is a limiting factor to cassava production in Africa. The aim of the study was to investigate the epidemiological and ecological aspects of the disease, to assess the yield loss in different ecozones, and to develop sustainable applicable methods for its control. The development of cassava bacterial blight and yield loss due to the disease were studied in the forest savanna transition and the dry savanna zones in Bénin using 2 cassava cultivars (the susceptible landrace BEN 86052 of Bénin and the improved genotype I30572 from IITA). The susceptible cultivar BEN 86052 developed stronger disease symptoms than the cultivar I30572 in the forest savanna transition zone as well as in the dry savanna zone. Symptom development depended on the quantity of rainfall after spray-inoculation. The relative fresh root yield loss in the susceptible cultivar BEN 86052 in the forest savanna transition zone ranged between 32 to 50%, while in the dry savanna zone, the yield loss was about 5.5%. In the forest savanna transition zone and in the dry savanna zone, similar fresh root yield losses ranging from 21 to 24% were obtained for the resistant cultivar I30572.

Under field and glasshouse conditions, possible alternative hosts of *Xcm* were investigated. In an artificially infected cassava field, frequently occurring weed species were collected to determine the presence of the pathogen. In the glasshouse, the same weed species transplanted in pots were infiltrated with a bacterial suspension of *Xcm*, and the development of *Xcm* populations was evaluated. On some weeds such as *Brachiaria deflexa* (Poaceae), *Dactyloctenium aegyptium* (Poaceae), *Mariscus alternifolius* (Cyperaceae), *Pupalia lappacea* (Amaranthaceae), *Solanum nigrum* (Solanaceae), *Talinum triangulare* (Portulacaceae), and *Tridax procumbens* (Asteraceae), *Xcm* survived epiphytically for at least 30 days under field conditions. On eight other plant species, *Xcm* survived at lower concentration and for a shorter time interval. After artificial inoculation in the glasshouse, *Vernonia cinerea* (Asteraceae), *Dactyloctenium aegyptium* (Poaceae), and *Brachiaria deflexa* (Poaceae) supported survival of *Xcm* for 60 days. None of the weed species developed cassava bacterial blight symptoms. These results imply that true alternative hosts could not be identified. The role of infected cassava debris in the survival of *Xcm* was studied under natural environmental and under glasshouse conditions. Under field conditions, rainfall decreased the survival period of *Xcm* in debris on the soil surface. The survival time of the pathogen was shorter in covered or buried debris than in debris left on the soil surface. Also, under glasshouse conditions, moistening lowered the survival period of *Xcm* in debris mixed with soil to less than 60 days. Under dry conditions, *Xcm* survived for more than 150 days. Free survival of the pathogen in the soil reached about 3 weeks with a very low population size.

The grasshopper *Zonocerus variegatus* is an insect which feeds on cassava plants. Its role in the spread of CBB was investigated under natural conditions by releasing the insects on infected cassava plants in cages and transferring them to healthy plants one week later. After feeding on infected plants, grasshoppers were contaminated and carried the pathogen on the mandibles, legs, in the intestine, and in high quantities in the faeces. The disease incidence was 44% compared to the control cage where it was 10%. The period during which a contaminated insect could lodge the pathogen and transmit it to cassava plants was less than 2 weeks. Cassava plants developed CBB symptoms when *Xcm* infested faeces were placed on leaves. The detection of *Xcm* in stems was performed in a first trial on 12-month old cassava plants of the susceptible cultivar BEN 86052 and the resistant cultivar 130572. The pathogen was detected in 64% of the specimens from the susceptible cultivar and in 36% of those from the resistant cultivar. Despite the absence of dieback on some plants of the susceptible cultivar BEN 86052, *Xcm* was detected and the highest concentration (6.8X10 CFU/g) was found on a plant without dieback. The pathogen was never detected on plants without dieback of the resistant cultivar 130572. The distribution of the bacterium in the plant appeared to be continuous as well as discontinuous. In a second trial, the upper, middle, and basal parts of resistant, semi-resistant, and susceptible cassava plants were analysed for the presence of the pathogen. The pathogen was detected in all parts of the resistant, semi-resistant, and susceptible genotypes and no correlation to the degree of susceptibility or resistance was found. Nevertheless, the lowest infection was found in the upper stem parts of resistant genotypes. The effect of intercropping on the development of CBB was studied by intercropping the local cassava landrace TME1 of Nigeria with maize (M) or cowpea (Co) on the same rows (CaMS1, CaCoS1) and on alternate rows (CaMS2, CaCoS2). Cassava monoculture allowed more severe disease development than intercropping. The best effect was observed by intercropping with maize in the row as shown by the following relation: Cassava > CaCoS2 > CaCoS1 > CaMS2 > CaMS1. Intercropped cassava and maize within rows or on alternate rows reduced the disease by 53% without considerably reducing the root yield.

Removal of CBB-diseased leaves was performed in a cassava field with artificially infected plants of the susceptible cultivar BEN 86052 to study its effect on disease development. Removal of infected leaves reduced the disease from 13 to 4%, but did not affect root yield. Removal of diseased leaves should be more effective with lowly susceptible cultivars. Infected cassava seeds of the landrace TME1 were subjected to treatment with hot water, hot air, or 70% ethanol to control *Xcm* in seeds. Hot water treatment (50 to 60 °C, 30 min.) resulted in 100% mortality of the pathogen without reducing seed germination. Also, hot air (65°C, 4 days) killed all the bacteria, without affecting seed germination. Soaking the seeds in 70% ethanol did not kill all the bacteria. Twenty-three cassava genotypes were grown in the forest savanna transition and the dry savanna zones of Bénin, and in the humid forest of Nigeria to screen for resistance to CBB. Studies on epiphytic leaf populations proved that the pathogen occurred epiphytically on all the inoculated genotypes. None of the screened 23 genotypes was found to be completely field resistant. All the genotypes developed CBB symptoms with variations in the degree of susceptibility. Thus, of the 23 screened genotypes, seven developed severe symptoms in all environments and consequently, were characterized by a high "Area Under Disease Progress Curve" (AUDPC) and were classified as susceptible. Six genotypes were moderately resistant. Eight clones were overall resistant. Using the "additive main effects and multiplicative interaction" (AMMI) model to group 20 genotypes and to compare their behavior in eight environments (inoculated and non-inoculated plots), six clones had a high AUDPC with TME1 having the highest, and 14 clones had a low AUDPC with I89/02078 being the least. Four clones (O88/01043, O89/00109, M84/00040, and M83/00001) showed negligible interactions with the environments and were stable. The environments in the humid forest zone of Onne (Nigeria) and in the forest savanna transition zone of Abomey-Calavi (Bénin) in 1997 were favorable for disease development. Relative dry root yield losses of 50 to 76.8% were obtained in certain genotypes. No relation was found between the AUDPC and the dry root yield because the most susceptible genotypes such as

TME1 and BEN 86052, and the resistant 130572 yielded similar dry root weight and the overall resistant genotype I89/02078 yielded the lowest root weight. Most of the inoculated genotypes contained a lower dry matter than the non-inoculated ones. Although devastating, CBB is a manageable disease and can be successfully controlled under the actual conditions of cassava producers in Africa by combining quarantine and sanitation measures, optimal farming systems, and the use of resistant cultivars.

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

A survey was conducted in 23 municipalities in central and southern Brazil to identify suitable sites for the collection of phytoseiid mites to be released in Zambia, as biological control agents against the cassava green mite *Mononychellus tanajoa* Bondar. The distribution and abundance of both predatory and phytophagous mites and other arthropods on cassava and surrounding vegetation were assessed. Interspecific associations between the various assemblages of predatory mites, their phytophagous prey, and plant hosts were determined. *Typhlodromalus aripo* DeLeon and *E. concordis* Chant were the most common predatory species on cassava, while *Mononychellus* spp. were the predominant phytophagous mite species. Other arthropods included cassava thrips *Scirtothrips manihot*, whiteflies *Bemisia* sp. and plant bugs *Vatiga illudens*. Different types of food were tested for their suitability as alternate food sources for *E. concordis* and *T. aripo*. *E. concordis* laid the highest number of eggs when fed pollen. *T. aripo* laid more eggs when given thrips larvae than when it was offered *M. tanajoa*, but it consumed higher numbers of cassava green mites than *E. concordis*. The biology of two populations of *T. aripo* from Joâo Pinheiro (Minas Gerais state) and Rio Verde (Goias state) was studied in the laboratory at four levels of temperature, 15, 20, 25, and 30 °C, and 12L: 12D photoperiod. Using linear regression models, the minimum temperatures required for development and the thermal constant (K) were estimated. Survival rates, sex ratios, and fecundity were also determined. Using values obtained above the net reproductive rate (Ro), intrinsic rate of increase (rn), generation time (G), doubling time (DT), and the finite rate of population increase (k), were also established. The eggs of the two populations were tested for tolerance to different levels of vapor pressure deficit (VPD). The vapor pressure deficit at which only 50% of the eggs hatched (VPD50) was calculated using the logit/response model.

MSc completed in 1999

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

TME1 and BEN 86052, and the resistant I30572 yielded similar dry root weight and the overall resistant genotype I89/02078 yielded the lowest root weight. Most of the inoculated genotypes contained a lower dry matter than the non-inoculated ones. Although devastating, CBB is a manageable disease and can be successfully controlled under the actual conditions of cassava producers in Africa by combining quarantine and sanitation measures, optimal farming systems, and the use of resistant cultivars.

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

A survey was conducted in 23 municipalities in central and southern Brazil to identify suitable sites for the collection of phytoseiid mites to be released in Zambia, as biological control agents against the cassava green mite *Mononychellus tanajoa* Bondar. The distribution and abundance of both predatory and phytophagous mites and other arthropods on cassava and surrounding vegetation were assessed. Interspecific associations between the various assemblages of predatory mites, their phytophagous prey, and plant hosts were determined. *Typhlodromalus aripo* DeLeon and *E. concordis* Chant were the most common predatory species on cassava, while *Mononychellus* spp. were the predominant phytophagous mite species. Other arthropods included cassava thrips *Scirtothrips manihot*, whiteflies *Bemisia* sp. and plant bugs *Vatiga illudens*. Different types of food were tested for their suitability as alternate food sources for *E. concordis* and *T. aripo*. *E. concordis* laid the highest number of eggs when fed pollen. *T. aripo* laid more eggs when given thrips larvae than when it was offered *M. tanajoa*, but it consumed higher numbers of cassava green mites than *E. concordis*. The biology of two populations of *T. aripo* from João Pinheiro (Minas Gerais state) and Rio Verde (Goias state) was studied in the laboratory at four levels of temperature, 15, 20, 25, and 30 °C, and 12L: 12D photoperiod. Using linear regression models, the minimum temperatures required for development and the thermal constant (K) were estimated. Survival rates, sex ratios, and fecundity were also determined. Using values obtained above the net reproductive rate (Ro), intrinsic rate of increase (rn), generation time (G), doubling time (DT), and the finite rate of population increase (k), were also established. The eggs of the two populations were tested for tolerance to different levels of vapor pressure deficit (VPD). The vapor pressure deficit at which only 50% of the eggs hatched (VPD50) was calculated using the logit/response model.

MSc completed in 1999

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

Postgraduate training

MSc/MPhil completed

Name	Country	Date	Sponsor[1]	IITA supervisor[2]
Fanou, A.	Bénin	96/99	BMZ	Wydra
MSc/MPhil in progress				
Banito, A.	Togo	98/01	EC	Wydra
Agboton, B.	Bénin	00/00	DANIDA	Hanna
Fagbemissi, R.	Bénin	99/01	IITA/DANIDA	Hanna/Coulibaly
Gogovor, Y.S.	Togo	99/01	DANIDA	Hanna
N'gunda, W.	Tanzania	99/01	IFAD	Hanna/Coulibaly
Neglou, K.	Togo	99/00	DANIDA	Hanna
Otema-Anyanga, M.	Uganda	99/01	IFAD	Hanna/Toko
Otim, M.	Uganda	99/01	RF	Legg
Owor, B.	Uganda	99/01	RF	Legg
Zinsou, V.	Bénin	98/01	EC	Wydra
PhD completed				
Fannou, A.	Bénin	96/99	BMZ	Wydra
Mebelo, M.	Zambia	97/99	IFAD/DANIDA	Yaninek/Hanna
PhD in progress				
Banito, A.	Togo	98/01	EC	Wydra
Gnanvossou, D.	Bénin	97/00	DANIDA	Hanna
Kidza, N.	Germany	97/00	DAAD	Speijer
Onyeka, J.	Nigeria	98/00	self	Dixon
Onzo, A.	Bénin	97/00	DANIDA	Hanna
Talwana, H.	Uganda	97/00	RF	Speijer
Witt, F.	Germany	98/01	EC	Wydra
Zannou, I.	Bénin	98/01	IFAD/DANIDA	Hanna
Zinsou, V.	Bénin	98/01	EC	Wydra

[1]DAAD: Deutscher Akademischer Austauschdienst, Germany; **DANIDA: Danish International Development Agency;** DBF: Daimler-Benz Foundation, Germany; EC; **IFAD: International Fund for Agricultural Development;** RF: Rockefeller Foundation, USA; BMZ: acronyms of other sponsors are given in the donors' list.

[2] Most MSc, all ARPPIS students and some externally sponsored PhD students do not have a direct IITA supervisor.

[3] Through the African Regional Postgraduate Program for Insect Science (ARPPIS).

Annex 1

Research Projects

1. Short fallow systems
2. Agroecosystems 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 management of *Striga* and other parasitic plants
9. Improving postharvest systems
10. Farming systems diversification
11. Cowpea–cereals systems improvement in the dry savanna
12. Improvement of maize–grain legume systems in West and Central Africa
13. Improvement of yam-based systems
14. Cassava productivity in lowland and midaltitude agroecologies of sub-Saharan Africa
15. Molecular and cellular biotechnology for crop improvement
16. Conservation and utilization of plant biodiversity

CGIAR Systemwide and Ecoregional Projects

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

Systemwide Program on Integrated Pest Management (SP-IPM)

Annex 2

Narrative summary	Indicators by the year 2002	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	▪ Greater food security through enhanced collection and conservation of genetic diversity ▪ Improved breeding strategies adopted which increase the efficiency of breeding programs ▪ Diverse source germplasm available and utilized by NARES ▪ Increased exchange of disease-tested planting materials between IITA and research partners ▪ Systematic collection, conservation, and utilization of plant genetic resources by NARS in sub-Saharan Africa	▪ NARS and IARC repor ▪ Seed-sector reports ▪ Workshop proceeding ▪ NARS cultivar releases	▪ Countries' willingness to share plant genetic resources

Narrative summary	Indicators by the year 2002	Means of verification	Assumptions
Agroecosystem Development Strategies & Impact Functional ecoregional research teams directed at poverty eradication through sustainable development of targeted agroecosystems	▪ NARS, IARCs, and ARIs working together in at least 6 ecoregional benchmark areas in the humid forest and moist savanna of West and Central Africa. ▪ Holistic, participatory research programs operational in the launched benchmark areas ▪ Policy decision-makers from West and Central Africa sensitized on relevant policies that facilitate the adoption of improved technologies ▪ Social returns to research demonstrated to convince donors to increase investments on agricultural research in SSA	▪ IARC, NARS, and reviev reports	• All partners remain committed to an ecoregional approach
Musa Systems Integrated production technology developed and tested for plantain/banana-based production systems	▪ Feasibility of IPM strategies demonstrated in benchmark sites ▪ Improved cultivars tested and released by NARS ▪ Sustainable resource and crop management practices adopted in benchmark sites and by NARS	▪ Project and NARS reports and publications ▪ Feedback from collaborators ▪ Benchmark site survey reports	▪ Materials meet quarantine standards ▪ Minimum NARS capacity
Maize–Grain Legume Systems Technologies that increase productivity of maize-grain legume systems in the Guinea savanna in a sustainable manner evaluated and disseminated	▪ At least 10% of farmers in the benchmark areas adopt technologies which increase land productivity and sustainability, including improved residue management, use of grain legumes to increase nitrogen fixation, and use of improved nutrient-efficient varieties of maize, soybean, and cowpea	▪ Survey of benchmark areas in collaboration with NARS	▪ Farmer has stake in long-term productivity ▪ Market can absorb increased production of grain legume crops

Narrative summary	Indicators by the year 2002	Means of verification	Assumptions
Cassava Productivity Improved and adapted cassava germplasm and production practices developed and evaluated in collaboration with NARS for sustainable production and utilization systems	▪ Diverse and multiple disease and pest resistant cultivars with superior and stable yield performance and acceptable food and feed characteristics available ▪ Increased yields and productivity for resource-poor farmers using these technologies, with less dependence on pesticide and chemical inputs ▪ Increased availability of low cost carbohydrate staple ▪ Increased cash income especially for women	▪ 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	▪ Increased availability of healthy planting materials of improved varieties to NARES and farmers ▪ Expanded genetic base of NARS' selection programs ▪ Increased inclusion of improved yam genotypes in NARS' agronomic trials ▪ Increased numbers of farmers growing yams	▪ NARS and project reports	▪ Effective networks in yam R & D
Cowpea–Cereals Systems Improved technologies that increase sustainable productivity of cereal/cowpea-based cropping systems evaluated and disseminated by NARS	▪ Improvement of local varieties will not only increase and stabilize food and fodder production but will also ensure in-situ conservation of cowpea landraces ▪ Through the dissemination of improved varieties and new cropping systems, farm families in the marginal lands of the dry savannas and the Sahel will improve their food security, livestock feed security, income generation opportunities, and the sustainability of their cropping systems, without requiring substantial inputs of labor, pesticides, and inorganic fertilizers	▪ NARS and IARC reports ▪ Adoption and impact studies	▪ Market can absorb increased cowpea grain and fodder

Narrative summary	**Indicators by the year 2002**	**Means of verification**	**Assumptions**
IPM Maize Reduced losses of maize to pests and pathogens through the use of IPM technologies	▪ Pest and disease levels will be significantly reduced and maize yields increased at selected locations ▪ Collaborating NARES will have the capacity to identify pests and diseases, assess yield loss, and stabilize maize yields using ecologically sustainable control technologies	▪ Survey data comparing pre- and post-intervention status of losses in target countries	▪ Effective links with implementing agencies maintained
IPM Legumes Reduced crop losses demonstrated in farmers' fields through IPM technologies which increase cowpea and soybean productivity in a sustainable manner	▪ At least 10% of cowpea and soybean farmers in three IPM use IPM ▪ Farmers obtain at least 25% higher revenue that those who do not use IPM	▪ NARS and NGO reports	▪ Conditions for adoption of IPM technologies remain favorable
IPM *Striga* Sustainable integrated parasitic plant management measures and components evaluated and disseminated	▪ NARS testing rotation-based integrated *Striga* spp. management in 15 SSA countries ▪ NARS disseminating integrated *Striga* spp. management in at least 5 SSA countries ▪ Annual reduction in *Striga hermonthica* damage annually corresponds, monetarily, to a $70 million annual gain for farmers in West Africa	▪ Country, IITA, and seed production agency reports	▪ Farmers continue to perceive *Striga* spp. to be problems for which adoption of new behavior/agricultural practices are worthwhile ▪ Market can absorb increased production of and adequate demand for non-host crops

Narrative summary	Indicators by the year 2002	Means of verification	Assumptions
IPM Cassava Sustainable cassava plant protection technologies developed, tested, and implemented in collaboration with NARS	▪ Pest damage will be reduced and cassava yield significantly increased to benefit resource-poor farmers ▪ Participating NARS will benefit from increased capacity to manage cropping systems, increase and stabilize cassava productivity, provide income and food security, foster environmental protection, and also from the exchange of genetic resources and technical information	▪ IARC, NARS, and NGO reports	▪ New major pests do not arise ▪ Good links with NGOs
Biological Control Biological control of pests and weeds in farming systems	▪ Reduced crop damage ▪ Reduced pesticide use ▪ Maintenance of biodiversity and safeguarding environmental quality ▪ Maintenance of sustainability of farming systems	▪ Socioeconomic and faunistic surveys and impact studies ▪ Pesticide use statistics	▪ Efficient biological control agents continue to be identified
Improving Postharvest Systems Postharvest technologies to provide utilization options for the food, feed, and agro-industrial sectors developed and disseminated in collaboration with NARS	▪ Information from selected countries highlighting opportunities for improved postharvest technologies ▪ Increased efficiency on harvesting, drying, storage, processing, and marketing of crops ▪ Expansion in the utilization of crops leading to food security, income and employment generation and poverty eradication ▪ Increased capacity for postharvest research and development within regional networks, NARS, NGOs, and CBOs	▪ NARS and IITA reports ▪ Monitoring tours and surveys	▪ Socioeconomic environment conducive to small business development

Narrative summary	Indicators by the year 2002	Means of verification	Assumptions
Short Fallow Systems Sustainable short fallow management systems developed in partnership with farmers	▪ Farmers in at least 30 communities in the benchmark areas and pilot sites are testing and evaluating short fallow systems, with farmers in those communities recognizing improved soil conditions ▪ Increased productivity through 2 or more improved fallow systems validated in benchmark sites in at least 4 EPHTA countries ▪ At least 10 NARS promoting validated short fallow systems	▪ 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	▪ At least 5 countries in SSA will regularly employ new techniques of cellular and molecular biology for germplasm development and dissemination ▪ Transgenic cowpea with *Maruca* and virus resistance, and *Musa* lines with antifungal protein gene will be ready for dissemination to interested parties ▪ Genetic linkage maps for IITA mandate crops for marker-assisted selection will be available	▪ IITA and NARS reports and publications ▪ Training documentation	▪ Increased support of governments in the region to the use of molecular and cellular tools for improvement of crop plants

Annex 3

Project 6 logframe

Project planning matrix (ppm)	Project ref. no.: 10	Project title: Integrated control of cassava pests*	Estimated project duration: 7 years	PPM Revised February 2000

Summary of objectives/activities	Objectively verifiable indicators	Means/sources of verification	Important assumptions
Overall goal to which the project contributes Cassava productivity increased and sustained through the reduction of crop losses due to pests and diseases in SSA	*Indicators that the overall goal has been achieved* • Cassava production significantly increased by the year 2003	• National and international cassava production statistics • Published impact data	*For sustaining objectives in the long term* • Political situation remains favorable
Project purpose Develop, test and implement, in collaboration with various partners, effective and environmentally safe cassava plant protection technologies to reduce pre- and post-harvest losses caused by pests and diseases.	*Indicators proving that the project purpose has been achieved by end of project* • National programs in at least 10 countries have the knowledge and technology in biological control, host plant resistance and/or cultural practices for the control of 2 major pests by 2003 • Pest damage reduced by at least 20% for 2 of the major pests targeted in 10 countries and cassava yield increased significantly in these countries by 2003	• IITA reports • NARS reports • Project evaluation reports	*For achieving the overall goal* • New major pests do not arise
Results/outputs R1 Incidence, abundance, severity and diversity of pests assessed and the associated yield loss determined R2 Multitrophic interactions of major cassava pests evaluated	*Indicators proving that the results/outputs have been achieved by end of project* • Diagnostic surveys completed by end of 2001 • Diversity of at least 5 pests and natural enemies characterized by 2001 • Yield loss due to at least 4 major pests ascertained by 2001 • Epidemiology/population dynamics of at least 4 pests and/or natural enemies investigated by 2001 • At least 3 pests and their interactions with natural enemies and host plants are characterized by 2001 • At least 3 plant/pest/natural enemy interactions determined by 2001	• Survey reports/databases • Publications • IITA reports • Special projects reports • Publications	*For achieving the project purpose:* • NARS/networks commitment remain favorable • NARS/networks commitment remains favorable

	• • •	• •	• NARS/networks commitment remains favorable
R3 Biological control technologies, host plant resistance, improved cultural practices and IPM technologies developed and tested	• Biological control of CGM achieved in at least 7 countries by 2001. • Pathogenic fungi tested in Benin and phytoseiid species tested against CGM in 13 countries by 2001 • Sources/mechanisms of resistance identified for at least 3 pests by 2000 • Screening methodologies developed for at least 2 pathogens by 2001 • Effect of cultural practices on CGM in Benin and Nigeria assessed by 2001 • Improved screening methods developed for at least 3 pests by 2001 • Virus diagnostic tools established for cassava mosaic and CBSD in at least 2 countries by 2002	• IITA and NARS reports • Publications • Project and network reports	
R4 Information resources for sustainable cassava pest control developed and disseminated	• Training manuals, guides and other relevant cassava plant health management decision support tools produced by 2002 • NARS collaborating countries have access to current cassava IPM information by 2002	• Cassava resource databases • Training materials inventory • IITA distribution list of resource materials	• IITA and NARS distribution networks remain favorable
R5 Capacity of NARS and farmers to evaluate, disseminate and implement intervention technologies enhanced	• At least 5 training courses on control strategies held by 2001 • At least 13 scientists from at least 6 countries complete postgraduate training in cassava IPM by 2002 • At least 180 extension agents in not less than 10 countries trained and provided with technical materials to disseminate sustainable cassava plant protection techniques by 2002 • At least 180,000 farmers in not less than 10 countries have the knowledge and technologies to implement sustainable cassava IPM practices 2002, and at least 100 farmers trained in cassava multiplication in at least 3 countries by 2001 • Impact of exotic natural enemies of CGM assessed with NARS in 9 countries by 2002 • At least 10 varieties evaluated together with farmers for resistance to at least 3 pests in at least 3 countries by 2002	• IITA and NARS reports • Project and network reports • Postgraduate student theses • NGO reports	• NARS extension systems remain favorable • NARS/networks commitment remains favorable • Universities in Africa assure commitment to postgraduate training

*** pest = pests, diseases, weeds and vertebrates**

Annex 4

Research Highlights

IITA's work is structured as 16 multidisciplinary research projects. Some projects focus on production systems for specific crops or crop combinations; others are thematically oriented and can involve many crops. Most of the projects cut across the agroecological zones for which IITA's work is targeted. IITA also serves as the convening institute for the systemwide program for integrated pest management.

This section presents the highlights of each project for 1999. These summaries are not a complete account of the work begun or completed during the year; rather, they describe some key scientific results and are intended to give the reader an insight into the breadth of the research themes and problems being investigated by IITA scientists.

Project 1
Short fallow systems

- 491 seedlots totaling over 800 kg of herbaceous seed of cover crops were distributed to international agricultural research centers (IARCs), national agricultural research systems (NARS), and nongovernmental organizations (NGOs) in and outside Nigeria. This can be compared to a total of 355 seedlots weighing just over 300 kg in 1998 and 171 seedlots weighing just over 100 kg distributed in 1997.
- The ^{13}C natural labeling technique demonstrated that ^{13}C analysis of weed samples could be used to quantify how the proportion of C_3 and C_4 weeds in the biomass changes in response to shading by crops.
- Site- and species-specific responses of *Mucuna pruriens* and *Lablab purpureus* to the addition of Togo rock phosphate (RP) were observed for a series of trials on a toposequence representative of the northern Guinea savanna (NGS). *Mucuna* significantly enhanced the release of P from RP and increased grain yields of the following maize crop.
- Improved maize production and soil fertility management practices were tested in a participatory on-farm trial in the NGS. The improved practices (plant density, variety, fertilizer application) increased the yield and gross margin from 1.6 t/ha and 4600 naira/ha (farmers' practice) up to 4.1 t/ha and 19 600 naira/ha.

Project 2
Agroecosystems development strategies and policies

- About 180 maize varieties and 200 cassava cultivars were released by NARS of 20 countries in SSA between 1965 and 1998. IITA materials represented about 50% for maize and 80% for cassava of the germplasm incorporated in the new varieties for the 1990s, which resulted in a yield advantage of about 53% for maize and 49% for cassava. This increase in annual production could deliver food security to a further 23 million people.
- Ex-post impact assessment at household level indicated high returns to investment (increases of 65–88% for maize yield, 31–71% for net income, efficiency in the use of other inputs, and risk reduction in both physical and financial returns) for farmers who had adopted *Mucuna* cover crop technology.
- An analysis of food consumption in the 2 major cities in the humid forest of Cameroon indicated that 43–50% of urban households consumed less than the minimum requirement of 2400 kcal/day/adult equivalent. Between 18% and 46% of children aged 6–59 months were deemed stunted.
- Farmers in the dry savannas of Nigeria with good market infrastructure ranked indicators for measuring the likely impacts of the new dual-purpose cowpea variety as follows: income generation (55.1% of responses), food security (17.9%), social benefits (14.2%), and ecological benefits (12.8%). The same ranking was recorded in villages with poor markets though there was a higher preference for food security.
- Potential monetary returns (measured as discounted net present value) could range from US$550 to US$740/ha if carbon sequestered by conversions of degraded *Chromolaena odorata* bush land to multistrata cocoa agroforest were to be traded in a carbon market.

Project 3
Biological control and biodiversity

- In Benin, socioeconomic studies confirmed that termites are a priority pest, paving the way for the development of a microbial control product.
- Green Muscle™, developed by Lutte biologique contre les locustes et sauteriaux (LUBILOSA), has been recommended by the FAO locust pesticide referee group as the only product having "low environmental risk" over all categories, and "unlikely to present acute hazard in normal use" according to the WHO human toxicity classes, opening the doors to the widespread use of this novel technology.
- Under the stewardship of LUBILOSA, and following its successful registration in South Africa, NPP, a commercial producer of Green Muscle™, has applied for registration to the Interstate Committee on Drought Control in the Sahel (CILSS) Pesticide Committee in most Sahelian countries.

- Commercialization of Green Muscle™: NGOs in Mali and Niger have bought Green Muscle™ for the first time, and a large order has been placed by a major stakeholder (Lux-Development together with the Niger DPV) involved in grasshopper control.
- The impact of biological control on water hyacinth is now clearly visible over large areas and was publicly acclaimed in Uganda, Tanzania, and Benin by the local population and by national authorities.
- Within the framework of functional biodiversity, the insect museum has been updated by 21 000 specimens and now houses the second largest insect reference collection in West Africa.
- More than 100 national scientists, technicians, and students were trained at various levels in biological control methods, IPM, geographic information systems (GIS), and impact assessment. Audio and visual materials were produced on water hyacinth and *Striga* control.

Project 4
Integrated management of legume pests and diseases

- Orchid and snowdrop lectins were found to be insecticidal to *Maruca vitrata* and hence may be used to control this pest through transgenic approaches.
- Affinity-purified lectins from African yam beans (*Sphenostylis stenocarpa*) were tested against pod-sucking bugs (*Clavigralla tomentosicollis*) and cowpea weevils (*Callosobruchus maculatus*) using an artificial seed system, and were demonstrated to be lethal to both pests.
- A thorough screening of *Mucuna* spp. as a possible source of insecticidal compounds revealed a novel protein that is highly toxic to *M. vitrata*.
- Pre-release surveys to assess thrips species composition and their natural enemies on cultivated and wild host plants were carried out from the coastal savanna of Ghana through the Sudan savanna of Burkina Faso between March and September 1999. The flower thrips *Megalurothrips sjostedti* was present on all known host plants. The local parasitoid *Ceranisus menes* was the only species found associated with the thrips on some host plants. This confirms results from previous studies in Benin.
- The exotic thrips parasitoid *Ceranisus femoratus* was successfully established at the IITA Benin Station. After the initial release on *Tephrosia candida*, the parasitoid is already spreading on adjacent cowpea fields and on *Centrosema pubescens*. First experimental releases in southern Ghana were effected late October on *C. pubescens*.
- Investigation of the efficacy and dynamics of *C. femoratus* in Cameroon was continued. The parasitoid is now ca. 150 km from Yaoundé, where it was first seen.
- Twentyseven extension trainers from 9 countries participating in the cowpea IPM project were trained as facilitators of participatory learning and experimentation in farmers' field schools. They, in turn, trained 125 farmers at 5 cowpea IPM farmers' field schools.

Project 5
Integrated management of maize pests and diseases

- A sustained reduction of downy mildew of maize in Nigeria has been achieved through a combination of public and private support for the extension of agrotechnological solutions.
- Simplified store evaluation procedures, designed to help farmers reduce pesticide use and make sound economic decisions, were developed and incorporated in extension courses conducted by IITA in collaboration with NGOs.
- It was discovered that planting of trap plants (grasses) as border rows of maize fields is not a viable option for stem borer control in West Africa because it considerably increased maize damage by rodents.
- As part of collaborative research work with the US Department of Agriculture (USDA), 76 IITA inbred lines were evaluated for resistance to aflatoxin accumulation, using a laboratory kernel screening assay. At least 18 inbred lines were found to have aflatoxin levels as low as or lower than the most promising resistant genotypes identified by USDA. These lines also showed protein profiles which were not found among inbred lines developed in the US.

- Five maize varieties with varying levels of resistance to *Sesamia* and/or *Eldana* were identified to have cross-resistance to *Busseola fusca*. These varieties were successfully deployed in on-farm trials in the Cameroon forest region.

Project 6
Integrated management of cassava pests and diseases

- Africa-wide implementation of cassava green mite (CGM) biological control by exotic phytoseiid predators continued. The exotic phytoseiid predator *Typhlodromalus aripo* is now found in 17 countries, and has newly colonized parts of the dry savanna of West, Central, and East Africa. The predator has been recently established in parts of the subhumid tropics in Malawi, Mozambique, and Zambia. Where this predator has been present for 3 or more years, cassava productivity has increased between 15 and 43%.
- Brazilian isolates of the fungus *Neozygites floridana* have been successfully established in southern Benin. This pathogen can potentially complement CGM biocontrol on cassava varieties that are not preferred by exotic phytoseiid predators.
- To combat cassava mosaic virus disease (CMD) in northwestern Tanzania, Kenya, and Uganda, IITA, in collaboration with its public and private sector partners, facilitated the multiplication and distribution of resistant cassava and imposed phytosanitary restrictions on the movement and cultivation of CMD-diseased cassava germplasm.
- The hybrid virus associated with the spread of severe CMD in East Africa, and known to be present only in the Great Lakes region, was recently found in a CMD outbreak area in the central plateau of Congo.
- Among 24 widely grown cassava varieties in Togo, 4 from IITA and 4 from Togo were shown to be resistant to several highly virulent cassava bacterial blight strains collected from wide geographic origins.
- Two MSc and 3 PhD students completed their studies, and 72 NARS staff received training on various aspects of integrated management of cassava pests. In addition, NARS and farmers in 7 countries participated in field evaluation of the impact of pests and diseases on cassava productivity.

Project 7
Improving plantain- and banana-based systems

- RAPD and AFLP markers were used to assess the genetic diversity and phylogenetic relationships of representative samples of East African highland bananas (EAHB) and West African plantains. Safety duplication of the *Musa* collection was also achieved.
- Ploidy levels and genome composition of elite *Musa* germplasm were determined, and genetic bridges for crossing between plantain cultivars (triploids), that cannot be directly intercrossed, were developed. A silver staining procedure was developed to visualize pre-prophase meiotic *Musa* chromosomes and facilitate analysis of reproductive behavior across ploidy and genome groups. This has enhanced breeding methodology for plantain improvement at Onne.
- One diploid and 3 tetraploid hybrid progenies of EAHBs were selected for their superior bunch weight and resistance to black Sigatoka. The first seeds from tetraploid ´ diploid crosses were also obtained.
- A root sampling method based on soil cores, which captures more than 80% of the root size but only requires 5% of the time needed for whole plant excavation, was developed. Likewise, an efficient screening method for resistance to plant parasitic nematodes was developed, enabling host resistance assessment within 3 months from inoculation of single root segments.
- Screening of 45 accessions against banana weevil showed that plantains were the most susceptible, followed by EAHB, exotic bananas, and then wild or hybrid diploids. Antibiosis associated with corm hardness, corm size, and resin/sap production was the most important resistance mechanism. The heritability of total inner damage was 87%, indicating that selection for resistance would be efficient. Insect-repellent green manures *Canavalia*, *Mucuna*, and *Tephrosia* had no effect on weevil adult numbers or rhizome damage, due to the sedentary life of the weevil.
- IITA collaborated with NGOs (Shell, Agip) in Nigeria to disseminate new cooking banana varieties which have now been adopted by farmers and occupy about 26% of total fields, representing a 9-fold increase since introduction nearly 2 decades ago.

- To promote the use of clean planting materials and reduce the spread of nematodes, training was carried out for 1623 farmers in Uganda, 659 in Zanzibar, and 234 in Rwanda, resulting in the treatment of 4480 suckers in Uganda, 5000 in Zanzibar, and 1050 in Rwanda.

Project 8
Integrated management of Striga *and other parasitic pests*

- Results of on-station legume rotation trials in Mokwa, Nigeria, showed that 2 years of legume rotation is more beneficial than 1 year legume rotation or continuous cereal cropping for improving soil conditions and reducing the impact of *Striga* on subsequent cereal crops.
- Two *Striga hermonthica*-tolerant varieties of maize, EV DT-W 99 STR CO and TZEW-Pop ´ 1368 STR CO, showed superior performance in regional *Striga* trials.
- Results of experiments conducted to improve methods for artificial infestation with *Striga* in maize breeding trials and to reduce the cost of infestation revealed that higher levels of infestation were attained when maize was grown in single stands at 25 cm intra-row spacing than with 2 plants per hill at 50 cm spacing. Rates of 3000 germinable *Striga* seeds per hill were sufficient to achieve a good level of infestation.
- Tests revealed that the modified agar gel assay method works well for screening maize genotypes for low production of *Striga* germination stimulant, and for identifying maize genotypes that are high stimulant producers and yet tolerant to *Striga* infestation due to other mechanisms of resistance.
- Molecular markers have been identified that show polymorphism between *Striga*-susceptible and -resistant genotypes. Reliable phenotype data were obtained in field trials at two locations, which will be utilized in mapping the resistance genes in these populations.

Project 9
Improving postharvest systems

- Four groups of 15 farmers from Burkina Faso, Cameroon, and Côte d'Ivoire were trained by farmers from Benin in the technique of yam chip processing and derived culinary preparations in Benin. The trained farmers have started to disseminate the technique in their own countries.
- A regional agricultural research and development network called FOODNET was set up in Eastern and Central Africa to focus on market research and promote production and sale of value-added agricultural products. It seeks to strengthen links between the private and public sector and to provide regional training in market analysis. A web site for the project (http://www.cgiar.org/foodnet) became accessible in December 1999.
- For the first time, cassava germplasm was screened for iron and zinc content in the tuberous roots; a wide genetic variation was found (1.3–64.80 ppm for iron content and 1.40–36.10 ppm for zinc content). A weak and positive relationship was observed for iron and zinc.
- Fifty improved cowpea varieties were evaluated for food composition and physicochemical characteristics. Results obtained indicated that there were significant differences among the varieties for all the parameters evaluated.
- Studies on tropical ataxic neuropathy (TAN) in Nigeria showed that the condition is still prevalent, but that low intake of fish and beef, the major sources of sulphur-containing amino acids in this community, rather than dietary cyanide exposure from cassava consumption is the likely causative factor. It was also established that excessive cassava production was not necessarily linked to high dietary cyanide exposure and the disease "konzo" when cassava processors adhered to safe processing practices.
- An auger-type husking and polishing mechanism (rice mill) coupled with a suction blower for cleaning was developed. The mill, which has a capacity of 60–80 kg/h, tested satisfactorily for parboiled rice with a milling recovery as high as 68%, hulling efficiency up to 90% on first pass and 98% on second pass, and with broken milled rice below 20%.
- In Ghana, two small-scale companies, Delabac Ventures and Darkruby Enterprise, were given training in soybean processing and were assisted to obtain a grant from the Organization of African Unity (OAU)/Semi-Arid Food Grain Research and Development (SAFGRAD) Technology Transfer and Commercialisation Program. Delabac Ventures has launched 5 soy-based products: Soya Yoghurt, Soya Vita, Soya Vita Plus, Soyalac, and Pure Soya Powder.

Project 10
Farming systems diversification

- Long-term cocoa agroforest establishment trials were initiated on degraded lands with 34 farmers in southern Cameroon.
- Ongoing characterization of existing cocoa agroforests in southern Cameroon revealed that these are among the most biologically diverse and the most "forest like" of agricultural land-use systems in SSA.
- The Multi-institutional Sustainable Tree Crops Program in West and Central Africa was launched. A program coordinator to be based at IITA will be in place early in the year 2000.
- Agronomic factorial trials showed significant yield response from wood ash in combination with poultry manure on 2 important peri-urban agricultural enterprises—tomatoes and the leafy vegetable known as jute mallow *Corchorus olitorius*. The combined use of ash and manure proved more profitable than the predominant practice of using inorganic fertilizer.
- Estimates on the economic efficiency of mixed farming systems in the drier savannas of Nigeria indicated that there are high potentials for improving crop–livestock systems because only 15% of farmers achieved more than 80% of efficiency and only 1.25% could be considered as having reached the efficiency frontier (> 90% of efficiency), out of a random sample of 559 crop–livestock farmers.
- Results from goal mathematical programming models from another sample of farmers with livestock in the northern Guinea savanna of Nigeria indicated that making systems efficient in areas with poor market access produces benefits to the small-scale farmers that are similar to those achieved by systems in areas with good market infrastructure.

Project 11
Cowpea–cereals systems improvement in the dry savannas

- Some of the new improved cowpea varieties combining resistance to major diseases, insect pests, and *Striga gesnerioides* showed over 50% higher yield potential than existing improved varieties, with 1.5 t/ha grain and 3 t/ha fodder in the Sahel and 3 t/ha grain and 5 t/ha fodder in the Sudan savanna.
- Dry season cowpea became very popular in Nigeria and over 2000 farmers grew the improved cowpea variety IT89KD-288.
- A date of planting trial in the dry season indicated that some heat-tolerant cowpea varieties can be successfully grown between 25 March and 25 June permitting a wheat–cowpea–rice intensive crop rotation in northern Nigeria where large irrigation schemes are in operation.
- Screening for drought tolerance and root characteristics revealed that cowpea varieties IT96D-604, IT95K-222-3, IT90K-222-5, and IT95K-1115-10 were most drought tolerant. IT96D-605 also showed a deeper root system under water stress condition compared to other varieties.
- An IITA/German Agency for Technical Cooperation (GTZ) initiative on farmer-to-farmer diffusion of improved cowpea seed gained popularity in northern Nigeria. From the initial 36 farmers in 1997, over 2500 farmers produced seed of the improved cowpea variety IT90K-277-2 in 1999.
- Food quality analysis of 52 cowpea varieties indicated significant genetic variability for protein, fat, and iron content. The top 4 improved varieties had 17% higher protein and 12% higher iron content than the mean of 4 popular local varieties.
- IITA, ILRI, ICRISAT, the International Fertilizer Development Center, and the University of Durham, UK, have begun working together to develop a novel holistic approach to on-farm research, bringing together complementary component technologies from the various institutes in a "best bet" (BB) package. The BB package includes recommended crop varieties as well as crop, livestock, and soil management practices. These are being evaluated in terms of biophysical and socioeconomic parameters, together with the farmers. With funding from the Systemwide Livestock Program, and working with NARS partners in northern Nigeria, the approach expanded from 11 farmers in one village in 1998, to 23 farmers in this same village and a further 21 farmers at a new location in 1999. Crop grain and fodder yields were substantially more for the BB treatments as compared to local practices; likewise, small ruminants fed with the harvested fodder gained more weight on BB than on local treatments. Similar trials have also commenced with 18 farmers in Niger, and preparatory characterization studies are underway in Mali.

Project 12

Improvement of maize–grain legume production systems in West and Central Africa

- In a late-maturing open-pollinated maize variety trial tested across locations, the 3 top ranking new varieties produced 11–15% higher yields than a commercial hybrid check, Oba Super I. A new stem borer-resistant variety, Ama TZBR-W, had 10% higher yield than Oba Super I. A *Striga*-resistant variety, ACR97 TZL COMP1-W, was as productive as the commercial hybrid.
- Two *Striga*-resistant, early-maturing maize varieties produced over 7000 kg/ha yields at Sinematialli under *Striga*-free conditions, which were comparable to yields of the best early-maturing varieties. These varieties also performed well under artificial *Striga* infestation at Ferkéssedougou.
- Thirteen maize varieties were compared at 0, 30, and 90 kg N/ha in Mokwa, Nigeria. Grain yields of the latest cycle of selection from the low N-tolerant pool (C2) were comparable to that of an N-efficient hybrid, Oba Super II, at low and medium N levels. This variety produced higher yields than Oba Super II at the high N level and had good agronomic features.
- Three early-maturing soybean varieties, TGx1871-12E, TGx 1740-2F, and TGx1871-5E, produced 20–35% higher grain yields and 9–27% more fodder than TGx1485-1D in the Guinea and Sudan savanna zones. These varieties also have increased resistance to pod shattering and enhanced nodulation.
- A cowpea–maize rotation trial was conducted for 2 years (1998–99) in 2 villages in the derived savanna. In the relatively poor fields, application of 45 kg urea-N/ha and 45 kg cowpea haulm-N/ha produced maize grain yields comparable to those of plots receiving 90 kg urea-N/ha. In the relatively fertile soils, the combined use of urea and cowpea haulm yielded about 80% of the grain of those plots receiving 90 kg urea-N/ha.
- An on-farm trial comparing the benefits of legume–maize double cropping systems to that of full-season maize with up to 90 kg N/ha fertilizer was carried out for 2 years (1998–99) in degraded fields in the NGS. A partial budget analysis showed that double cropping maize with legumes was more profitable than full-season maize. For each year, grain legume–maize double cropping systems and full-season maize gave higher benefits per hectare than *Mucuna*–maize double cropping.

Project 13

Improvement of yam-based systems

- Only yam mosaic virus (YMV), genus Potyvirus, and *Dioscorea alata* virus (DaV), genus Potyvirus, were found to infect *D. rotundata* and *D. alata* in Ghana while many of the leaf samples with virus-like symptoms tested negative for the 7 viruses known to infect yams in West Africa.
- New sources of genetic resistance to YMV were identified. Five accessions of *D. rotundata*, 2 of *D. alata*, and one of *D. bulbifera* were demonstrated to have high levels of resistance to the virus.
- Application of recently developed screening techniques to 220 accessions of *D. rotundata* revealed variation in susceptibility to the yam nematode (*Scutellonema bradys*) and the root knot nematode (*Meloidogyne incognita*). Two accessions of *D. dumetorum* (from Ghana and Cameroon) proved highly resistant to *S. bradys*.
- A survey was carried out on the domestication of wild yams in 2 regions of Benin as part of an investigation of its potential role in farmer participatory selection. During interviews of 360 farmers in 36 villages, 93% of the farmers in Nago region and 70% in Fon knew of the practice, 36% and 22%, respectively, could describe the techniques used, and 14% in both regions are practicing it or had done so recently.
- The number of virus-tested yam clones certified for international distribution increased to 70 with the addition of 5 each of *D. rotundata* and *D. alata*. About 26 000 in vitro plantlets and 16 000 minitubers of such clones were produced out of which 5400 and 13 906, respectively, were distributed to NARS collaborators.

Project 14

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

- Genotypes with high levels of resistance to CGM, CMD, and cassava brown streak disease have been identified for the midaltitude, highland, and lowland ecologies of East and southern Africa.
- 408 genetically broad-based and certified virus-free cassava genotypes were made available for international distribution. A total of 17 085 in vitro plantlets were distributed to 11 NARS in SSA, including 10 000 and 4000 CMD-resistant genotypes provided to Tanzania to combat the CMD outbreak and to Chad national programs for drought mitigation, respectively. In addition, 451 092 seeds from 405 families of genetically broad-based and special trait populations segregating for desirable traits were distributed to 13 NARS in SSA.
- 581, 496, and 263 advanced cassava clones adapted to the midaltitude and highland agroecologies of East and southern Africa were introduced from IITA's Eastern and Southern Africa Regional Center (ESARC), Uganda, to Kenya, Tanzania, and Rwanda, respectively, under the open quarantine facility. 84 and 81 clones from these stocks were also introduced to the Democratic Republic of Congo and Burundi national programs from the national program of Rwanda.
- Over 500 landraces and 400 improved genotypes have been characterized into 6 distinct diversity groups, which will form the basis of future heterotic studies. Furthermore, the landraces had higher sources of resistance to root rots than improved genotypes.
- 400 clones evaluated in performance trials at ESARC gave storage root yields ranging from 8.3 to 114 t/ha with most clones having dry matter content between 35 and 40%, while 30% of the clones outyielded the local check and 4 clones yielded over 100 t/ha. In addition, 10 of the clones evaluated in western Kenya showed a yield potential of over 150 t/ha, suggesting that the cassava yield plateau has been shattered.
- Genotypes with higher root nitrogen (1.1–10.1 g/kg DM), low cyanogenic potential (1.12–12.93 mg HCN/100 mg of fresh weight of roots), and high zinc (1.40–36.10 ppm) and iron content (1.3–64.80 ppm) have been identified. This indicates the potential for genetically fortifying cassava with iron and zinc while enhancing higher root N and low cyanogenic potential.
- Uganda and Malawi officially released 6 and 3 additional CMD-resistant varieties, respectively, from IITA-derived germplasm.
- The capability of NARS and NGOs to undertake cassava research was enhanced through a training workshop for 14 breeders from 9 African countries, and courses on agronomy and rapid multiplication techniques for 110 technicians and extension workers in East and southern Africa.

Project 15

Molecular and cellular biotechnology for crop improvement

- Progress has been made in the optimization of parameters for cowpea transformation through: (a) transient GUS gene expression following *Agrobacterium*-mediated transformation, (b) establishment of antibiotic thresholds for selection of transformed cowpea tissues, and (c) development of shoot elongation and rooting media. Having well-rooted cowpea plantlets in tissue culture helps to avoid loss of these plantlets when they are transferred to soil for hardening.
- T1 plants transformed with viral coat protein and insect resistance genes have been generated and preliminary screening of 30 T1 plants by polymerase chain reaction amplification of the viral coat protein sequence has revealed 6 positive lines.
- A genetic linkage map of yam (*D. rotundata*) based on AFLP markers was developed with 107 markers in 12 linkage groups (total length 585 cM) for the male parent and 116 markers in 13 linkage groups (total of 700 cM) for the female parent.
- A genetic linkage map of yam (*D. alata*) based on AFLP markers was developed. The map consisted of 338 markers mapped on 20 linkage groups with a total length of 1055 cM.
- AFLP and RAPD markers associated with QTL for yam mosaic virus (YMV), genus Potyvirus, were identified.

- Polyclonal antisera were raised against 3 *Dioscorea* viruses, 3 viruses infecting herbaceous legumes, one cassava virus, and one banana virus.
- An improved protocol for cassava cryopreservation was developed with 60% recovery. Cryopreservation of yam meristems gave a maximum of 35% recovery.
- A culture medium that can support growth and plantlet formation of 2 week old immature seeds of *D. alata* was developed and used to rescue one *D. alata* cross.
- Cyclic somatic embryogenesis was achieved from meristems and immature leaf lobes of both local and improved cassava genotypes. Organogenesis (shoot formation) was obtained from cotyledon pieces of those somatic embryos.
- A Memorandum of Affiliation was signed between IITA and the Center for the Application of Molecular Biology to International Agriculture (CAMBIA).

Project 16

Conservation and utilization of plant biodiversity

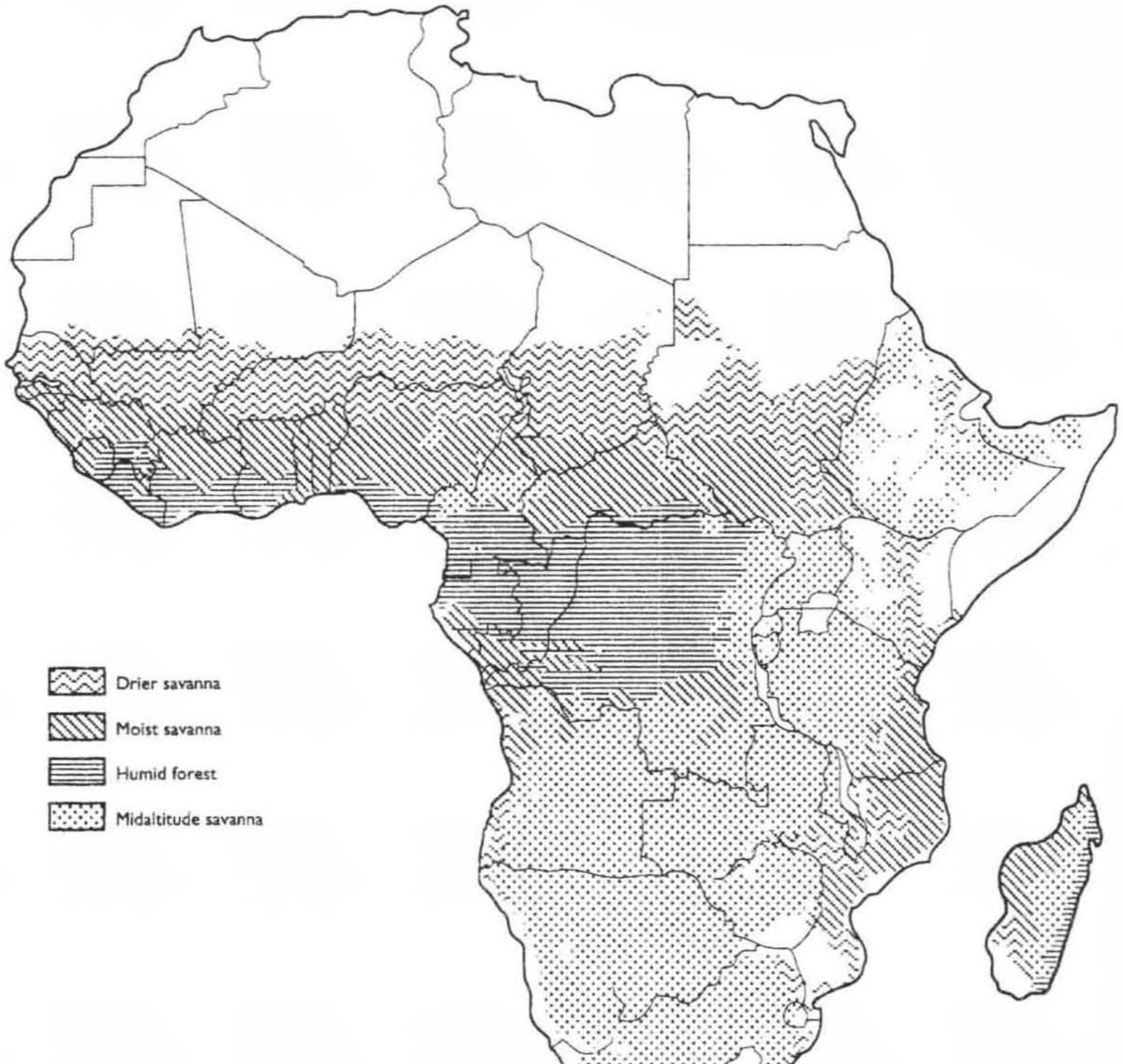
- Investigation on storage of yam pollen under liquid nitrogen for long-term conservation and for use in hybridization programs showed great promise.
- Through meristem culture, over 200 accessions of germplasm of 5 cultivated yam species and 6 wild species were successfully transferred from fields to in vitro culture. The National Root and Tuber Improvement Program in Ghana was assisted in the cleaning-up of viruses from 7 varieties of sweetpotato for large-scale multiplication and distribution to farmers for cultivation.
- The efficiency of conventional serological diagnostics has been increased by developing protocols that reduce the duration of enzyme-linked immunosorbent assays from about 2 days to just over 1 hour.
- Selective media have been standardized to enhance quick identification of highly destructive bacteria (*Xanthomonas manihotis*, *X. cassavae*, and *Pseudomonas*) in cassava.
- Agronomic and botanical descriptors and RAPD markers were used to assess the potential breeding values and genetic diversity, and to help identify probable duplicates of local cassava germplasm collected from West Africa. Fortyeight accessions identified as having high levels of resistance to African cassava mosaic disease exhibited considerable variation in agronomic performance, morphological characteristics, and DNA banding patterns.
- Ploidy levels and genome composition of elite *Musa* germplasm were determined, and genetic bridges for crossing between plantain cultivars (triploids), that cannot be directly intercrossed, were developed. This has enhanced the breeding method for plantain improvement.
- A computerized database for IITA maize international trials developed over the past 10 years was established. Efforts are being made to link this with a GIS, for use in targeting introduction and development of germplasm for specific environments, to enhance the impact at farm level.

Systemwide program

Integrated pest management

- NGOs are playing an increasingly important role in encouraging farmers to adopt IPM approaches to crop protection problems. With the support of the CGIAR NGO Committee and the SP-IPM, IITA-Benin hosted a workshop for NGO participants from 14 African countries, providing them with insights into the latest IPM technologies and extension approaches. Participating researchers from 4 international research organizations, in turn, gained a better understanding of NGO perspectives on the research-to-implementation process. An e-mail discussion group was formed to enable participants to continue to work together on various IPM research and extension issues.
- Continuing in its efforts to achieve better coordination and broader awareness of the IPM research of the IARCs, the SP-IPM worked with the Impact Assessment Group of the CGIAR to collect information documenting the role of IPM research in sustainable agricultural development. The work of IITA on cassava pests was among the efforts highlighted in a report tabled at International Centers Week and soon to be available for wider distribution.

Annex 5



Map of agroecological zones