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FINAL REPORT
CASSAVA CULTRE PROJECT

USAID PROJECT NO. 660-0077

IN COLLABORATION WITH
THE DEPARTMENT OF AGRICULTURE
AND RURAL DEVELOPMENT
REPUBLIC OF ZAIRE

International Institute of Tropical Agriculture
PMB 5320, Oyo Road, Ibadan, Nigeria.

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INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

OYO ROAD, PMB 5320

IBADAN, NIGERIA

JULY, 1985

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1. INTRODUCTION

Zaire is the largest cassava producing country in the world and the largest in Africa. Cassava is the most important staple crop in the country. It is grown on about 50% of all cultivated land and its' dominance is demonstrated by the fact that at least a third of the cultivated land in each of the eight regions is planted to the crop. Cassava roots provide more than 60% of the caloric needs for two-thirds of the population. Cassava leaves are the most popular vegetable in the country and are a very important source of good quality protein.

A serious disease of cassava appeared in the Region of Bandundu in 1969 which soon spread in epidemic proportions to Bas-Zaire and the two Kassai Regions. In these regions, many cassava fields were completely destroyed by the disease and prices went up as much as 10 fold. In 1973, the Commissioner for Agriculture and USAID/Zaire made an urgent request to the International Institute of Tropical Agriculture(IITA) in Ibadan, Nigeria to send scientists to Zaire to determine the cause of the disease and to advise on methods of control. An IITA team was provided and the disease was identified as cassava bacterial blight caused by Xanthomonas manihotis. It was at this point that the importance of research on problems related to cassava production became apparent to the government and it requested IITA to assist it in establishing the Programme National Manioc (PRONAM). To this end, a Memorandum of Understanding between the government and IITA was signed in May, 1974 by which IITA was to provide technical assistance and administer training with funds provided by the government. The research program was quickly initiated and rapidly grew. An IITA Plant Breeder arrived in Zaire in November of 1974 and by 1976, he had been joined by an Agronomist, a Plant Pathologist and an Entomologist. Para-professional training of national staff at IITA commenced immediately and, in 1977, the first PRONAM staff member had been admitted for studies towards a M.Sc. degree. Although substantial progress had been made, by 1977, the government was facing serious economic problems and it requested USAID assistance in support of the Project. In June 1978, a project paper was approved which provided $4.5 million for the continuation of the Project and a project grant agreement was signed with the government.

Actual implementation, however, did not begin until May 1980 with the conclusion of a contract between USAID and IITA. The Project completion date was 31 July 1985. This report presents a summary of the work performed under the contract and the results which were obtained.

2. PROJECT OBJECTIVES

The overall objective of the Project was to support and expand the capacity of PRONAM to conduct research in development of new technology for cassava production and to make this technology available for dissemination to the small farmers in Zaire. This was expected to play an important part in the effort to achieve the national goal of self sufficiency in food production.

Prior to the commencement of the Project, research activities were mainly concentrated at the Mvuazi research station. Under the Project, the research program at the Headquarters site was to be furthur developed while regional programs were to be established at substations representing principal agroecological zones. When the Project began, PRONAM was just five years old, but potentially useful research results were already being generated. Thus, the second major objective was to provide a link between the research program and various agencies and organizations that can serve an extension function in order to ensure that the research results of PRONAM are made available to the cassava growers. The specfic activities carried out to meet these objectives are described in the following section.

3. PROJECT ACTIVITIES AND ACCOMPLISHMENTS

3.1 STAFFING OF TECHNICAL ASSISTANCE POSITIONS

Table 1 shows the staffing of the technical assistance positions through the 5 year, 3 month period of the contract with IITA. When the contract was signed in May, 1980, the Plant Breeder and the Physical Plant Services Officer were already in place, having been carried over from the former GOZ/IITA project. The Plant Breeder served as acting Director until the Director/Agronomist position was filled in April, 1982. With the return from training of a national staff member with a PhD in plant breeding in 1983, it was recommended by IITA that the Plant Breeder position on the technical assistance team be converted to a position for a Farm Manager. This was accepted by USAID and a Farm Manager was provided, serving first on a three month consultancy and then assuming a long term position in October, 1984. There was a change of personnel in the Extension Agronomist (Kiyaka) position in October, 1983, but this was done with no discontinuity and there was an orderly handing over of the job. Because of the long delay experienced in construction of a training facility at Mvuazi, the Training Officer position was not filled until January, 1985. At this time, the training facility was near completion and although it was close to the end of the contract, it was deemed desirable to fill it as a comparable position would exist in the successor project. It may be seen that once positions were filled there was good continuity in staffing. All eight staff members present at the end of the contract are continuing on in positions in the follow-up project.

3.2 . THE RESEARCH PROGRAM

Research was carried out at three main sites (Fig. 1): Mvuazi, the National Headquarters in Bas Zaire Region, Kiyaka in Bandundu Region and Gandajika which serves the southern portion of Kasai Oriental and Kasai Occidental, southern Kivu and northern Shaba Regions. The research work has been a multi-disciplinary effort involving four subprograms: Plant Breeding, Plant Pathology, Entomology and Agronomy. The objectives and a summary of the principal findings made during the Project period are presented here. For more detailed information, the reader is referred to the PRONAM Annual Reports.

Table 1. Staffing of IITA technical assistance positions.

Position	1980	1981	1982	1983	1984	1985	Name
	←		Length of Project			→	
Director/Agronomist			Apr			→	F. E. Brockman
Administrative Officer			Jul			→	G. Servant, B.A.
Plant Breeder				May (Position discontinued)			T. P. Singh, Ph.D.
Entomologist		Mar				→	R. H. Hennessey, Ph.D.
Extension Agronomist (Mvuazi)	Nov					→	S. J. Pandey, Ph.D.
Extension Agronomist (Kiyaka)		Dec		Dec	(a)	→	W. Fiebig, B.Sc.; C. Burn
Training Officer						Jan →	D. J. Miller, Ph.D.
Physical Plant Services Officer						→	M. Veloso
Farm Manager				(Position added) Oct		→	C. B. Buyyala, B.Sc.

(a) Staff member hired by USAID on Host Country Contract.

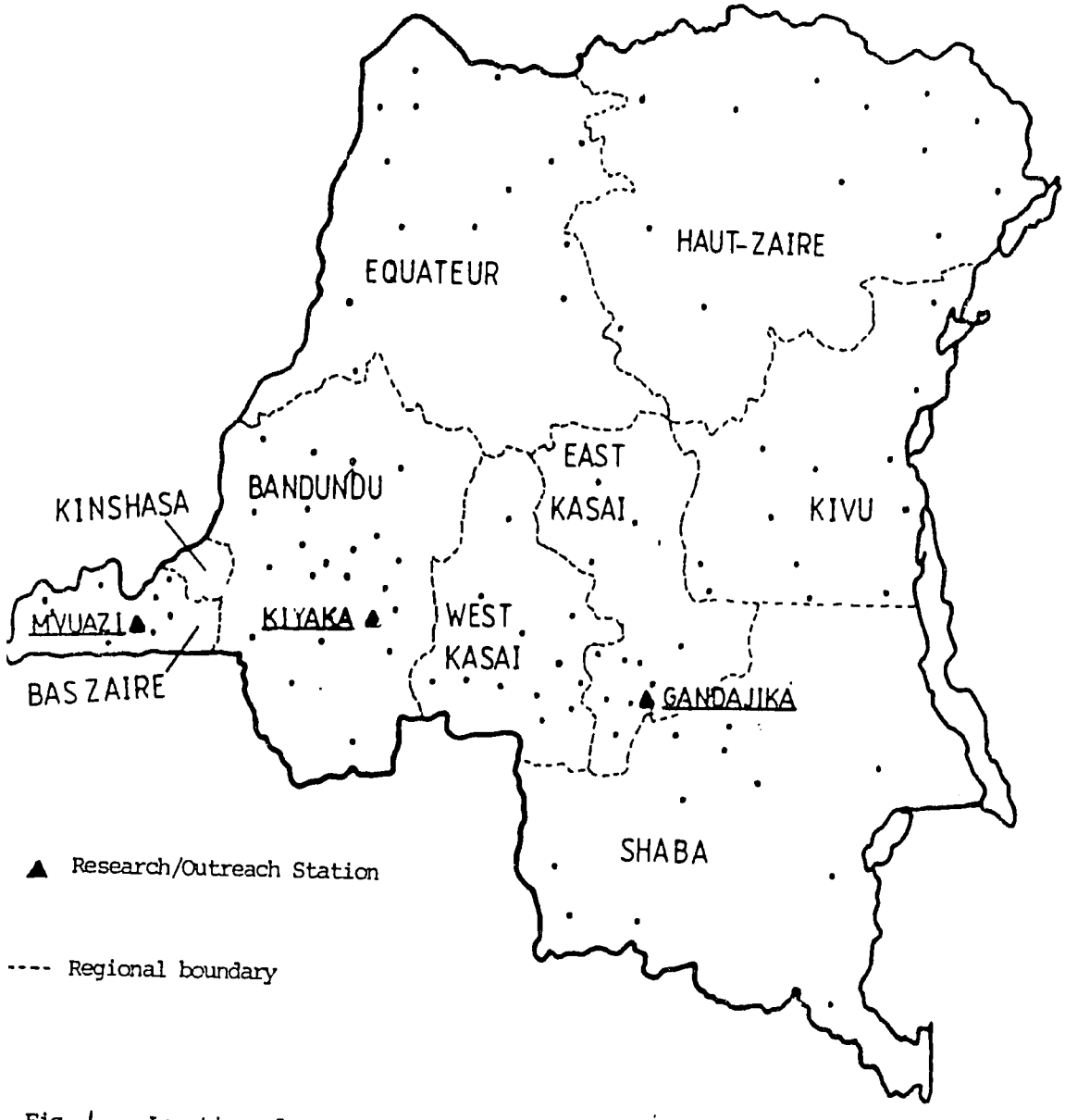

Fig. 1 . Location of PRONAM research/outreach stations. Each dot represents 1% of estimated cassava root production.

3.2.1. BREEDING

3.2.1.1. Objectives and strategy

PRONAM's breeding program addresses those production constraints which are amenable to genetic improvement. The objectives are:

a) to develop varieties with high yield potential. Cassava leaves are an important constituent of the diet in Zaire and attention is given to leaf yield as well as root yield.

b) to identify sources of resistance to major diseases and pests and to incorporate this resistance into varieties with high yield potential.

c) to develop varieties which are adaptable to a wide range of environmental conditions.

d) to develop varieties which give food products (of both roots and leaves) of good quality with good consumer acceptance. Low cyanide content in roots and leaves and high protein content in leaves are specific goals.

From the beginning, the breeding program has exploited a wide range of genetic variability. Local germplasm has been collected. A major source of genetic variation has been seed of improved populations and families introduced from the IITA, Ibadan Cassava Program which incorporates more than 2,000 Latin America and Asian sources. Eleven IITA developed cultivars have also been introduced in tissue culture form. Together, this provides the material for an active hybridization program. Genetic recombination is achieved by open pollination among selected parents which are grown in isolation and by controlled crosses made by hand pollination. The resulting progeny are subjected to a six stage selection process (Fig.2).

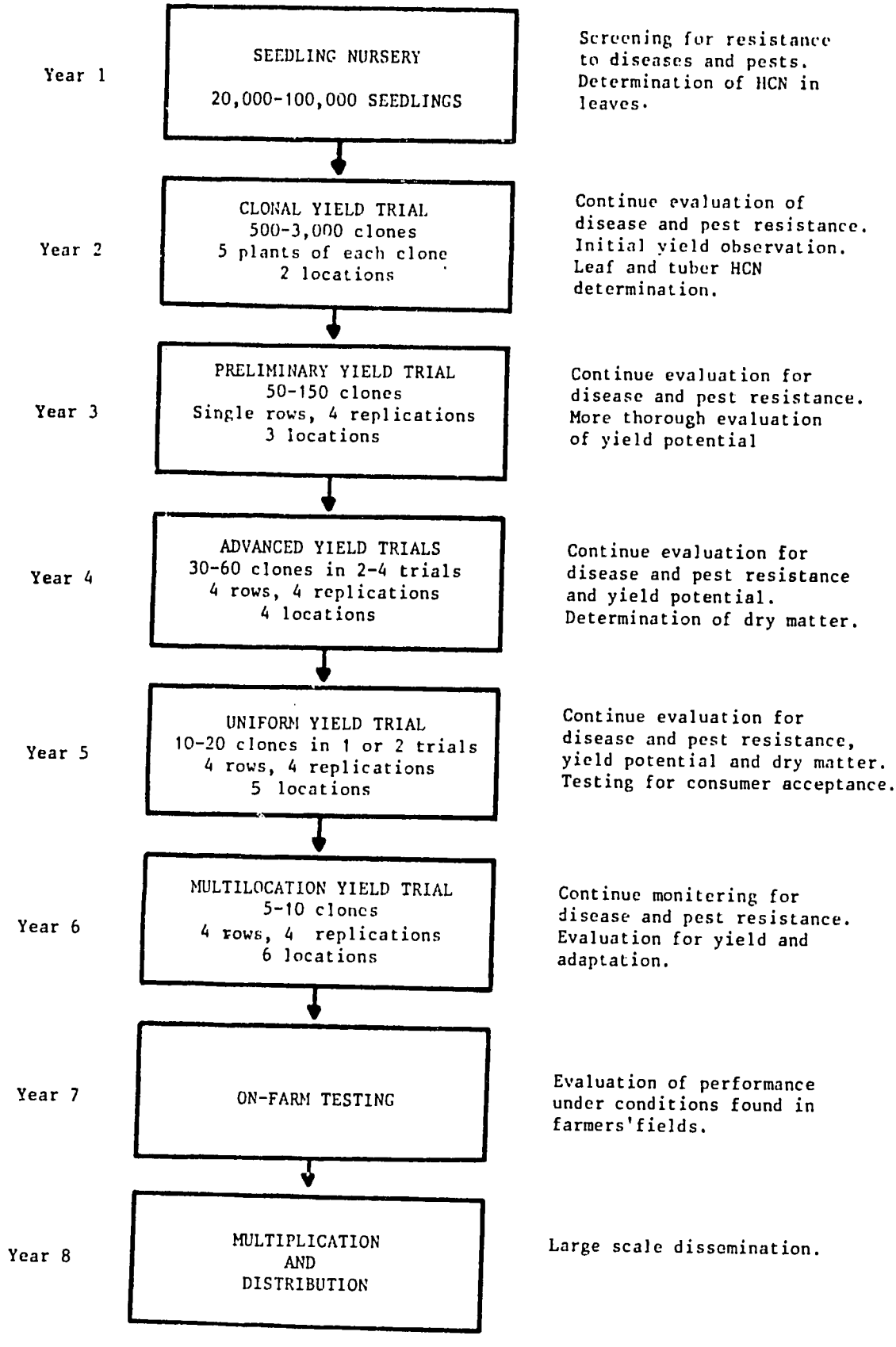

Fig. 2 PRONAM breeding procedures.

In the first stage, 20,000 to 100,000 seeds from the hybridizatio program are planted annually in a seedling nursery. Selection at this stage is primarily for disease and pest resistance. Planting is done early in the rainy season to provide best conditions for evaluation. Artificial inoculation with the cassava bacterial blight (CBB) pathogen is done by both stem injection and leaf abrasion. Plants are detopped about one and a half months before the end of the rainy season to enhance symptom expression of cassava mosaic disease (CMD). The removed tops are used to plant a separate nursery for screening for resistance to cassava mealybug (CMB). Screening is also done under ambient conditions for resistance to cassava anthracnose disease (CAD) and to cassava green mite (CGM). The semi-quantitative picrate technique is used to test for cyanide content in leaves and selections are made to establish low cyanide populations. (The leaf cyanide score has been shown to be closely related to root cyanide content.)

Between 500 and 3,000 plants from the seedling nursery are selected. Five cuttings from each plant are planted with a standard variety at two locations in the second year in the Clonal Yield Trial. Evaluation for disease and pest resistance is continued. Inoculation with CBB bacteria is again carried out at the main station as it is though all remaining cycles of selection. Detopping is not done as this would interfere with yield evaluation for which a rough estimate is obtained at this stage. Cyanide content of both leaves and roots is determined.

In the third year, the best 50-150 clones selected from the clonal yield trial are planted in the Preliminary Yield Trial in single row plots (10 m long) with four replications at three locations chosen to represent an appropriate range of environments for the region. Disease and pest resistance evaluation is continued. Statistically analyzeable yield data is obtained at this stage.

The most promising 30-60 clones from the Preliminary Yield Trial are planted in the fourth year in Advanced Yield Trials with four row plots (10 m long) and four replications. These trials are planted at four locations. In order to keep the experiment to a reasonable size and variability

within desirable limits, two to four trials (depending on number of clones to be tested) are made up with about fifteen clones each and are planted at each of the locations. At this stage, dry matter content of the root is determined.

In the fifth year, the best ten to twenty clones selected from the Advanced Yield Trials are tested in one or two Uniform Yield Trials at five locations. Monitering of reaction to diseases and pests and evaluation of yield is continued. In addition, at this stage, root and leaves are transformed into the local food products (fufu, chikwangue, and pondu) and the quality evaluated by taste panels.

Five to ten of the clones performing best in the Uniform Yield Trial are still more widely tested in the sixth year in the Multilocation Yield Trial at six or more locations. The elite clones coming from this trial are then subjected in the following year to on-farm testing. Here their performance is evaluated under conditions found in farmer's fields and farmers' reaction to the new varieties is determined. Those varieties showing a superior performance and found to be popular with the farmers are then mutliplied on a large-scale and made available through various channels to cassava growers.

The breeding procedure described above is carried out from the three PRONAM main stations: Mvuazi, Kiyaka and Gandajika. In these breeding programs, varieties are being developed which are adapted to the most important cassava growing areas: Bas Zaire, Kinshasa and Bandundu, the southern part of Kasai Oriental and Kasai Occidental, southern Kivu and northern Shaba regions.

There are certain constraints inherent in cassava breeding which limit the rate at which genetic improvement can be made. One constraint is the length of time required to complete each selection cycle. For cassava, this is one year while for most of the other common food crops, it is much shorter. For these other crops, completion of two or more selection cycles may be possible

within a year. Another constraint is the multiplication rate which limits the rate at which planting material from a single plant selection can be made available for more thorough and wider testing. Nevertheless, PRONAM has made good progress in developing improved varieties in it's short existence.

3.2.1.2. Results

The first PRONAM improved variety was officially released by the Department of Agriculture in February, 1983. This was in the ninth year of PRONAM's existence and when viewed against the breeding procedure just described, it can be seen that this was accomplished in the minimum length of time. This variety was developed at Mvuazi and is recommended for general cultivation in Bas Zaire. It has a good level of resistance to CBB, CMD and CAD which provides yield stability (Fig.3). Because of its disease resistance, it has been named "KINUANI" which means "disease fighter" in the local language of Bas Zaire. The food preparations from roots and leaves are highly appreciated. The good performance of Kinuani is well illustrated by data from on-farm demonstration/trials carried out in collaboration with the National Fertilizer Program. In these trials, Kinuani has been compared with the local variety at three rates of fertilizer. The results from 135 of these demonstration/trials carried out over the past three years show that, on the average, Kinuani has given 35 per cent more yield than the local variety (Fig.4). Kinuani is also more responsive to fertilizer than the local variety. Kinuani is in high demand and has been under large-scale multiplication. PRONAM is cooperating with various organizations involved in agricultural development work to distribute it to farmers.

Much other promising material is at advanced levels of testing in the breeding program at Mvuazi. Particularly noteworthy is the performance of the IITA variety, TMS 30572, and several progeny of this clone. TMS 30572 was introduced in tissue culture form from IITA, Ibadan.

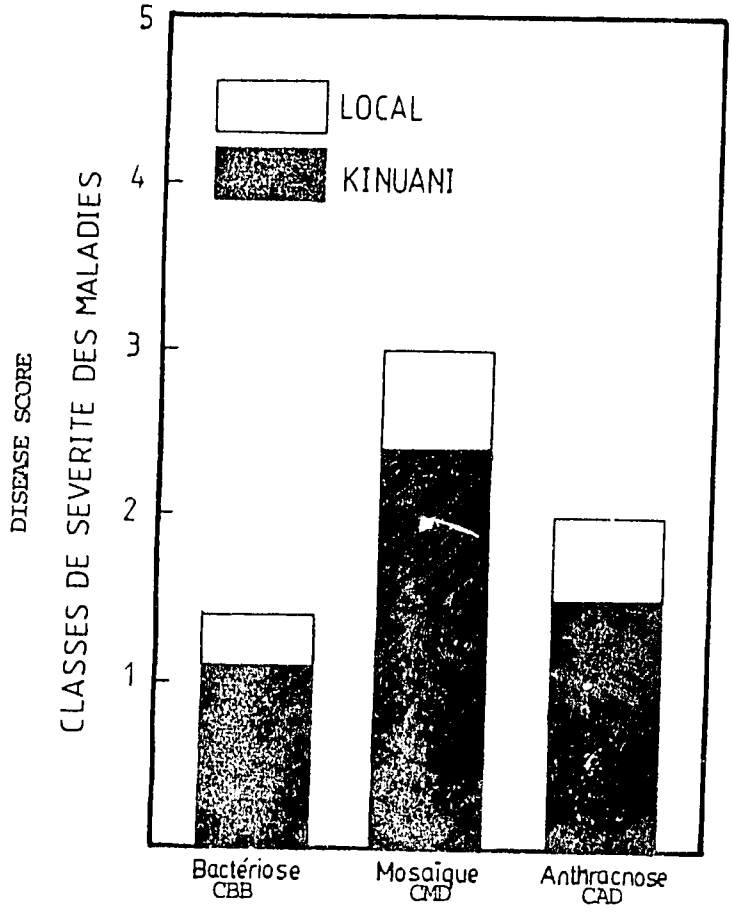

Fig. 3. Réaction de Kinuani et cultivars locaux aux principales maladies du manioc dans 88 champs de démonstration au Bas-Zaïre, M'VUAZI, 1985

Fig. 3. Reaction of Kinuani and local cultivars to the principal diseases of cassava in 88 demonstration plots in Bas Zaire, 1985.

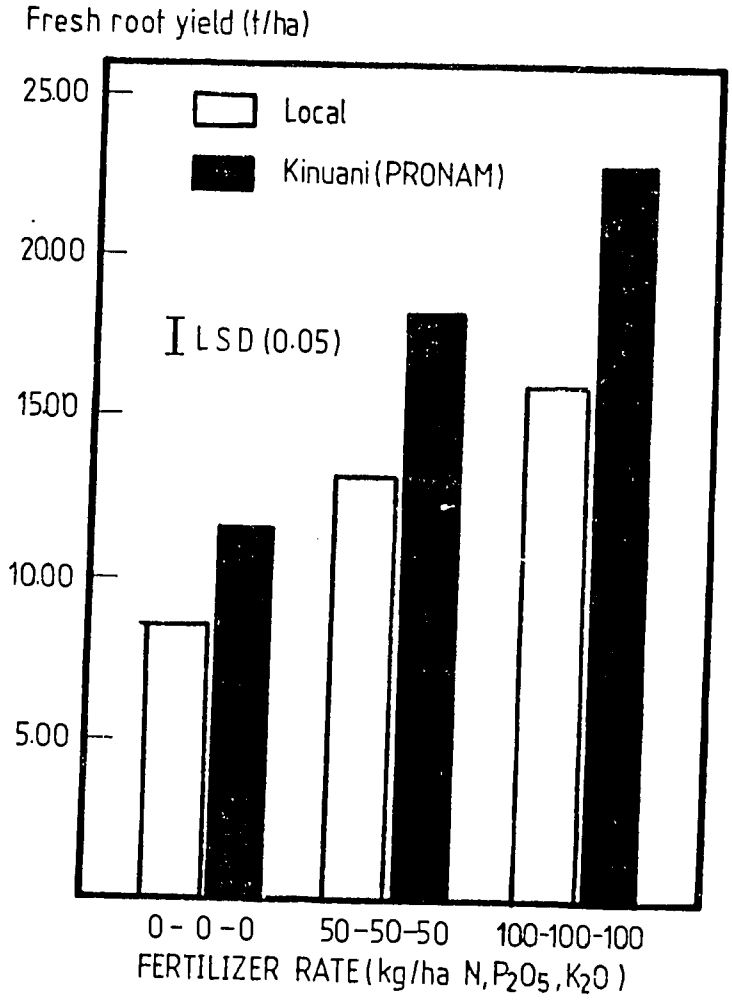

Fig. 4. Yield of variety Kinuani & Local at three rates of fertilizer. Results are means from 135 on-farm trials (Bas-Zaïre, 81-82 to 84-85).

In Bandundu region, the PRONAM variety, F100, selected at Kiyaka has now been thoroughly tested and has demonstrated consistently good performance. It has a good level of resistance to CMD and CBB. It is well adapted to both the poor sandy soils of the plateau-savanna which are very extensive in the region and to the more productive but limited valley-forest soils. On the plateau, average yields of F100 are 7 to 10 tons/ha which is two to three time the yield of the local varieties. In the valleys, F100 gives 20 to 25 tons which is 50-100% better than the local varieties.

At Gandajika several promising varieties are at an advanced level of testing and large-scale multiplication has begun. Good progress has been made at Gandajika in identifying cultivars with resistance to cassava green mite.

Systematic screening for resistance to the cassava mealybug in a joint effort with the entomology program has resulted in the identification of a clone with a very high level of resistance. This clone identified as 70453 possesses the highest level of resistance yet reported from any cassava improvement program. (Supporting data is reported under Entomology Research Achievements.) However, other agronomic characteristics are less desirable. It has a low yield potential and is susceptible to green-spider mite and mosaic. Thus a major effort has been mounted to incorporate this resistance into high yielding, locally adapted clones. In the first year of this hybridization program, 823 seedlings from crosses were obtained. These were subjected to screening in the field under artificial mealybug infestation. One hundred and fifty-five plants were selected for further testing and will be planted out in clonal trials at Mvuazi and Kaniameshi (Shaba region). A still more intensive hybridization program is underway.

3.2.2. PATHOLOGY

3.2.2.1. Objectives

The efforts of the Pathology subprogram have been directed toward:

a) Collaboration with the breeding program in screening for resistance to the major diseases.

b) Studies of the etiology, epidemiology and control of the major diseases.

3.2.2.2. Results

a) Screening for resistance

Inoculum of strains of Xanthomonas campestris pv. manihoti selected for their virulence, is prepared and artificial inoculation for cassava bacterial blight (CBB) carried out in all selection cycles of the breeding program. Inoculation is done by both leaf abrasion and stem injection. Assessment for resistance to cassava mosaic disease (CMD) is performed in the seedling nursery after detopping of plants which has been found to intensify symptom expression. Evaluation for CMD resistance in later cycles in the breeding program and for cassava anthracnose disease (CAD) is done under natural conditons. This collaborative work with the breeding program contributed to the development of the recently released variety Kinuani. (The name Kinuani, in fact, means "disease fighter" in the local language of Bas Zaire). This variety has consistently shown a good level of resistance to CBB. Other varieties with good levels of disease resistance are at advanced levels of testing.

b) Cassava anthracnose disease

It has been shown that the etiology of cassava anthracnose disease (CAD), previously believed to be caused only by the fungus Colletotrichum gloeosporioides f. sp. manihotis also involves a sap feeding bug, Pseudotheraptus devastans. Inoculation by spraying of the fungal spores alone did not cause typical CAD symptoms. Feeding by the insect is apparently necessary for fungal colonization and canker development. It was furthur found that the fungus can be carried in the insect's body. Susceptibility to anthracnose infection appears to be related to the plant's reaction to insect puncture. More susceptible clones develop longer and deeper cankers after the puncture than less susceptible clones. No differences have been found in virulence among isolates of C. gloeosporicides f. sp. manihotis from different sources. Other studies indicate that cassava plant debris left in the field after harvest can be an important source of inoculum of the fungal pathogen.

c) Cassava bacterial blight

Yield loss, due to cassava bacterial blight (CBB), of leaves, which are an important constituent of the diet in much of Zaire, was studied. Inoculation of a CBB susceptible clone resulted in loss of more than 60% of edible leaves while the production of edible leaves by the resistant variety, Kinuani, was not appreciably reduced by inoculation.

d) Cassava mosaic disease

It was found that, as the level of severity of cassava mosaic disease (CMD) in planting material increased, the incidence and severity of the disease in the resulting crop rose significantly and growth and yield dropped significantly. Thus, disease development, growth and yield depend not just upon the presence or absence of infection in the planting material but upon the severity of the infection.

No differences were observed between CMD susceptible and resistant clones in feeding preference or rates of population build-up of the whitefly, Bemissia tabaci, vector of CMD. Disease distribution is mainly by infected planting material.

Certain clones which are highly resistant to CMD at IITA, Ibadan were found to be susceptible at Mvuazi. CMD symptoms in the latter environment seemed to differ somewhat from typical CMD symptoms in Nigeria. This suggests that there may be differences in strains of the cassava mosaic virus between Nigeria and Zaire. Further studies are underway in collaboration with IITA, Ibadan and the University of Wageningen, Netherlands to establish whether or not different strains of CMD virus exist.

e) Interaction of Bacterial Blight and Anthracnose

Infection of the same plants by both CBB and CAD pathogens has been frenquently observed under field conditions. Studies have shown that inoculation with the bacterium followed by the fungus causes more severe leaf wilting and dieback and longer stem lesions than does inoculation with either pathogen alone. Results indicate that C. gloeosporioides f. sp. manihotis is a weak pathogen by itself but that, in the presence of X. campestris pv. manihotis, severe crop losses can occur.

f) Stem-tip dieback disorder

In 1980, a previously undescribed disorder of cassava was observed in Bas Zaire and is becoming an increasingly serious problem. It results in death of tertiary branches during the dry season and decay of tuberous roots. Studies to date have provided the following information:

- Attempts to reproduce symptoms with Pseudomonas spp., Collectotrichum gloeosporioides f.sp. manihotis and Glomerella cingulata isolated from stems showing symptoms have been unsuccessful. Sclerotium rolfsii has been repeatedly recovered from decayed tuberous roots of affected

plants. In a pot test, 20% of the plants planted in soil inoculated with the fungus developed symptoms while no plants in uninoculated soil did so. Futher tests are underway.

- Definite differences among clones in incidence of symptoms has been observed.

- Symptoms did not develop when a resistant scion was grafted on a susceptible stock while they did develop when the reciprocal grafts were made.

- No difference was found in stem-tip dieback or in percentage decayed tuberous roots between plants from cuttings from healthy plants and those from cuttings of plants affected with the disorder.

- Roguing of affected plants at the first occurrence of symptoms did not prevent appearance of symptoms in other plants.

- It was observed that the incidence of stem-tip dieback varied regularly with planting date. Cassava planted late in the rainy season was less affected than early planted cassava.

- Mulching has reduced the incidence of affected plants.

- Reduction in dieback incidence and percentage of decayed tuberous roots occurred with increasing rates of potassium fertilizer up to 150 kg K_2O/ha.

g) Post harvest deterioration

Severe deterioration of cassava roots can occur during drying and storage. Several fungi have been identified as being associated with this spoilage. Some of these are known to include strains that produce toxins

which may cause chronic illnesses. There appear to be differences between cassava clones in fungal colonization. There are great differences in deterioration associated with different methods of processing.

h) Root rot

Incidence of root rot was found to increase when harvesting was delayed beyond twelve months. The earlier developed variety 02864 was observed to be the most susceptible of those tested while Kinuani had a very low incidence.

i) Effect of mixed cropping on disease severity

Studies showed that the severity of CBB and CMD was reduced when cassava was intercropped with maize as compared to cassava grown as a monocrop. Intercropping with groundnut did not affect disease severity. It seems that maize may provide a physical barrier restricting dispersion of inoculum.

3.2.3. ENTOMOLOGY

The PRONAM entomology section was established in 1976 as a response to the threat posed by the introduction into Zaire of a new pest insect, the cassava mealybug (CM). Several years later a second pest, the cassava green mite, invaded Zaire. The control of these two pests remains the primary goal of the PRONAM entomology staff. This work was carried on into the Cassava Outreach Project. The main method of achieving control has been the introduction of natural enemies from the pests' native home, a method known as "classical biological control". Also, an effort has been made in cooperation with the PRONAM breeding section to locate sources of pest-resistance in cassava varieties. The pursuit of the primary goal and the employment of the two complementary strategies--biological control and resistance breeding--has involved studies in natural history, biogeography, population dynamics, and insect/host-plant interrelations.

3.2.3.1. History of the cassava pest problem in Zaire.

The cassava mealybug, Phenacoccus manihoti, a minor pest of cassava in South America, was accidently imported to Zaire in the early 1970s. In 1973 it was discovered in Kinshasa. From there it spread rapidly througout much of the African cassava belt, causing different amounts of damage in Africa's diverse ecological zones. Worst-case estimates of the annual economic loss to the CM have been as high as $ 1.8 billion.

The PRONAM entomology section was established in 1976 specifically as a response to the threat posed by CM. In that year devastating outbreaks occurred in Bas Zaire. More outbreaks occurred in 1977. Heavy losses in Bandundu accompanied the spread of the pest into that region in 1978. Root yields dropped drastically. In the dry season leaves became contaminated with mealybugs and mealybug products such as wax and honeydew. Planting material became scarce, and that which was available was contaminated by small, immature mealybugs ready to infest the next cassava crop.

A second pest native to South America, the cassava green spider mite, arrived in eastern Zaire in the mid-1970s. Although damage caused by the green mite was not so spectacular as that caused by CM, it nonetheless ranked as a major pest.

By the time that AID begun its support for PRONAM in 1980, the green mite had spread throughout most or all of Zaire. Its damage in most areas was not known. The CM was assumed to be still expanding its range, but its actual distribution and damage were unknown. Insecticidal control was not feasible because of the great expense, low effectiveness, dangers in application, and risks of poisonous residues. Cultural control measures were effective but extremely limited in applicability because of patterns of land use and economic restrictions. Resistant varieties were unknown in Zaire. Native natural enemies were of unknown effectiveness.

To define Zaire's cassava pest problems and to develop effective methods of control, the International Institute of Tropical Agriculture (IITA) with funding from AID engaged an entomologist to replace the entomologist who had left PRONAM in 1978. The resumption of work in entomology early in 1981 followed shortly after the initiation of an Africa-wide cassava pest biological control program at IITA. This program was to furnish exotic natural enemies of the two cassava pests for release in Zaire. Since 1981, work in entomology has concentrated on determining the distribution and damage of the

two major cassava pests (especially the mealybug), releasing exotic natural enemies, assessing the effectiveness of the natural enemies, and screening clones for resistance to mealybug.

3.2.3.2. Distribution and damage of the CM

In a huge country such as Zaire, the determination of an insect's distribution can be a formidable task--doubly so if the distribution is continually changing. Nonetheless, over a period of four years a reasonably accurate picture of the CM's distribution has been pieced together through surveys (Fig. 5), by correspondance with knowledgeable people in remote areas, and by studies of climatic and vegetation maps. The known distribution of the CM is presented in Fig. 6. The figure also indicates qualitatively the amounts of damage occuring in various parts of the CM's range. The status of CM in central Bandundu and the Cataractes Subregion of Bas Zaire is a matter of special interest. This is the area that was devastated during the years 1976-77 (Baz Zaire) and 1978 (Bandundu). Since that time, CM damage has declined drastically, and CM there can no longer be considered a severe pest. The effectiveness of a CM control program in this area can be evaluated only if the reasons for the decline are understood. If CM has subsided to the current low level as the result of predation by native insects, the control might be permanent, although certainly fluctuating somewhat from year to year. If, on the other hand, weather factors are responsible, we would expect further pest outbreaks when periods of weather favorable to the mealybug return. The existing evidence points strongly to the second explanation--weather. In the Mvuazi area, fluctuations of CM damage from 1976 to 1983 were correlated with the number of days with measurable rainfall during the dry season. If the number of rainy days/dry season is taken as the key factor, five years between 1950 and 1984 have been dry enough in the Mvuazi area to provoke outbreaks causing severe damage. Other evidence, more indirect but potentially of great value, is found in data collected by the National Oceanic and Atmospheric Administration meteorological satellites. Images based on these data show the amount of green-leaf biomass over the entire African continent. The area of Zaire with low-to-moderate biomass in the

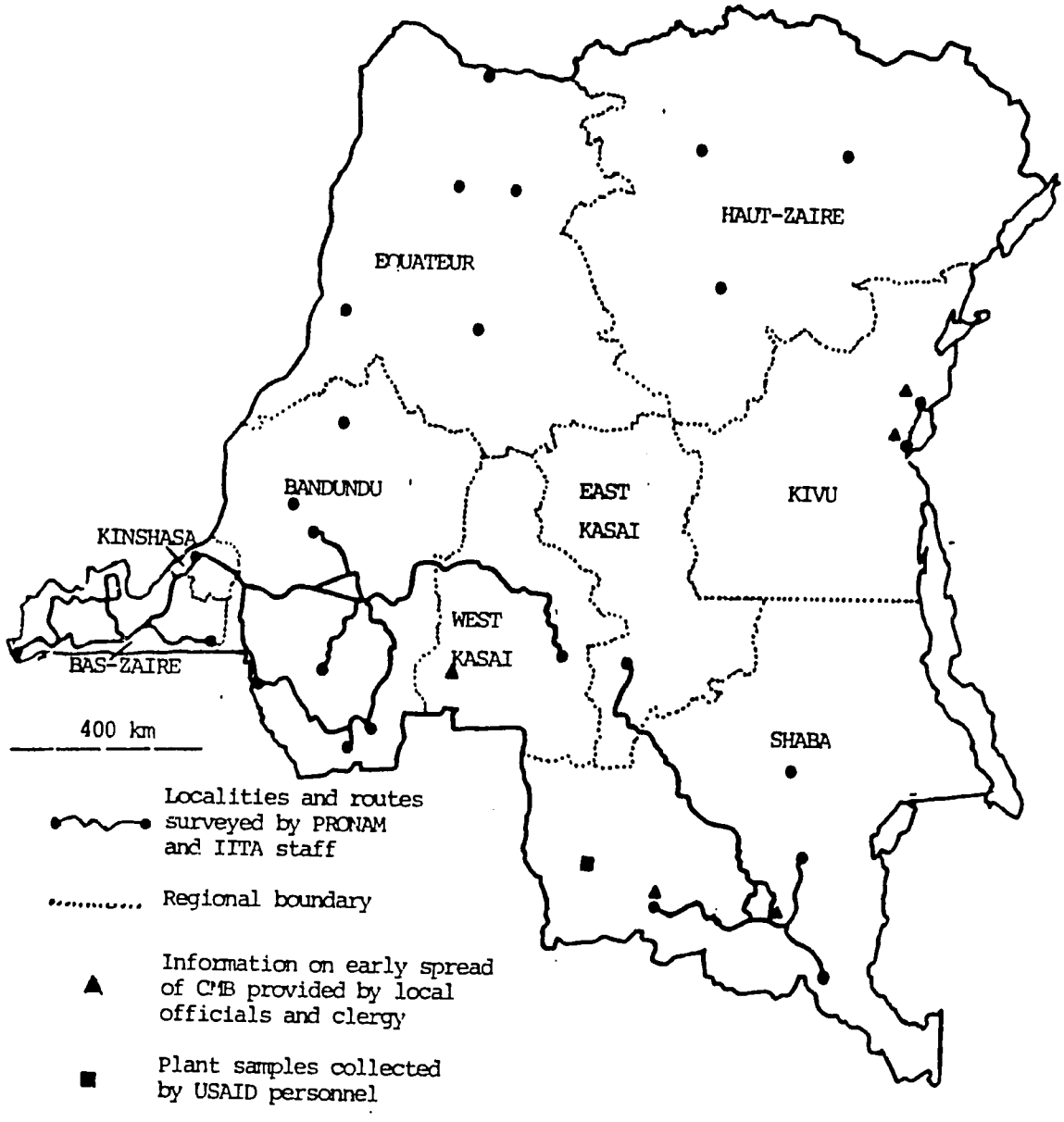

Fig. 5 . Localities and routes surveyed for cassava mealybug, 1982-1985.

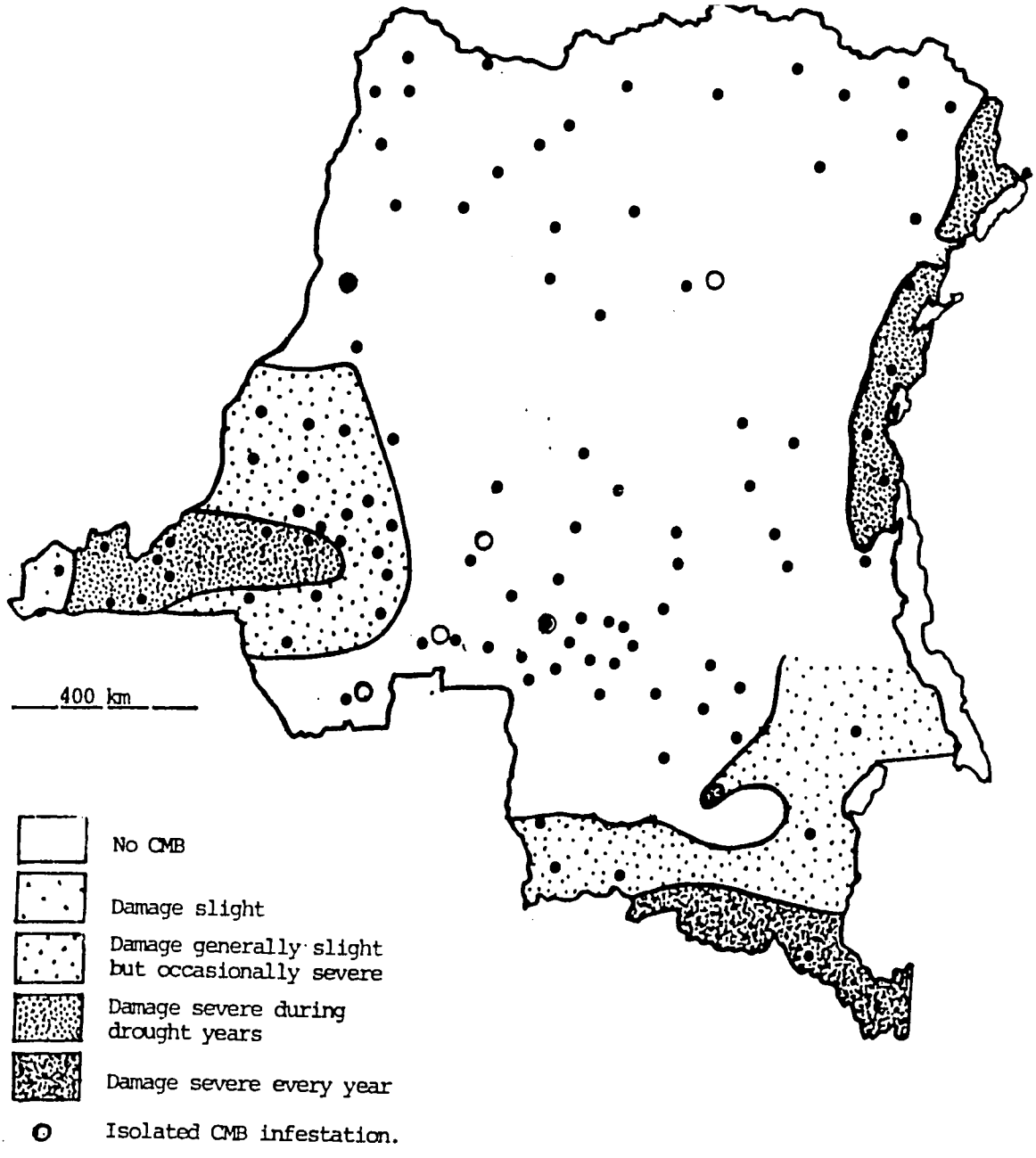

Fig. 6. Current distribution and damage of the cassava mealybug (CMB). Each dot represents 1% of estimated cassava root production.

month of October in three years (1982-84) corresponds fairly closely to the CM's area of distribution. The details of the reasoning are not crucial here; the important point is that this correspondance indrectly suggests the importance of weather factors in determining the CM's distribution, and, presumably, also the amount of damage. Therefore, it seems likely that, in the absence of effective controls, the devastating outbreaks seen in Bas Zaire and Bandundu would eventually recur. A similar situation appears to exist in the North Kivu Subregion.

In Shaba, as in Zaire's western regions, severity of CM damage varies greatly from one geographic area to another. Widespread, heavy damage occurs in the clear Zambezian forest of the extreme South. Large losses also have been reported at Bukama and at Malemba-Nkulu, which lie at opposite ends of a marshy area several hundred kilometers north. Damage in other parts of Shaba where CM occurs is generally light, although in individual fields or in small groups of fields damage may be very severe. The CM's total depressive effect on manioc production cannot be estimated solely on the basis of losses in yield. In some areas, such as Kazenze to the west of Kolwezi, production is declining partly as a result of farmers'fear of yield losses, even though yield losses averaged over large areas may be small. Apparently, heavy CM damage to a single field can frighten neighboring farmers into abandonning the cultivation of manioc, even when fields of those farmers never have been heavily damaged.

A calculation of annual national yield loss requires some assumptions about yield losses in the different regions illustrated in Fig. 6. One set of reasonable assumptions leads to an estimate of 5% average annual loss to cassava mealybug in Zaire.

If the annual yield loss held constant at 5% every year, and if the burden of loss were distributed evenly among the populace, then CM would not be a major problem in Zaire. Unfortunately, as already pointed out, yield losses can vary greatly from year to year, and most of the known variation in the past has occurred in Bas Zaire and central Bandundu, the two regions

that supply the inhabitants of Kinshasa with their staple food. Several factors increase the potential danger of this situation.

1. A great many people in Kinshasa are already malnourished and could not withstand any considerable reduction in their intake of calories (cassava tubers) or proteins and vitamins (cassava leaves).

2. The population of Kinshasa has grown since the last CM outbreak in 1978, and further growth is likely (the urban population of Zaire grew at an annual rate of 6% in the 1970s).

3. The roads in the interior are deteriorating so that much of the cassava produced cannot be brought to market in Kinshasa.

Thus, the comfortably low estimate of 5% annual yield loss actually disguises the possibility of a food crisis in Kinshasa and serious food shortages in parts of Bandundu and Bas Zaire. Such a crisis might appear suddenly-- in the time between the 2nd and 4th mealybug generations following the end of the annual rainy season. The prevention of a food crisis has been a major goal of the biological control program against the cassava mealybug.

3.2.3.3. The green mite in Zaire

The pests in Zaire commonly refered to as "green mite" actually can be assigned to at least two species, Mononychellus tanajoa and M. progresivus. There is considerable disagreement among taxonomists over the identities of particular specimens, so the distributions of the species in Zaire is still uncertain. Ecological differences must certainly exist, but their nature is unknown. Studies are underway that may help to define these differences, but no preliminary results are available.

The green mite has been found in all parts of Zaire surveyed

except the mountainous regions around Goma. Usually it is most severe in South Central Zaire, an area that includes the population centers of Mbuji Mayi, Gandajika, Kananga, Kaniama, and Kamina. Losses in these places in 1984 were especially high. In parts of East Africa losses may reach 70%. Since the aforementioned areas of South Central Zaire produce about 18% of Zaire's cassava, a 50% loss to green mite there would represent a 9% loss for Zaire as a whole. Indigenous natural enemies of the green mite sometimes are abundant, but they do not appear to give control.

3.2.3.4. Releases of natural enemies of CM and green mite

Seven species of natural enemies have been imported from South America by way of IITA for the biological control of cassava pests in Zaire (Table 2). Five species have been released against CM and two against the green mite. Fifty-nine separate releases have been made in five of Zaire's nine administrative regions (including Kinshasa). A total of about 90,000 insects and mites have been released. Most of the releases have been direct; i.e., the IITA Biological Control Unit has shipped the natural enemies to Zaire, where they have been released promptly in the field. A few releases of Diomus sp. and Hyperaspis jucunda were indirect; i.e., IITA shipped the insects to Mvuazi, where they were first multiplied in rearing cages. One release of Epidinocarsis lopezi was made by collecting immature individuals in the field and transporting them to another locality. Thirty-three releases were made solely by PRONAM personnel, ten solely by entomologists of the Biological Control Unit, and sixteen by a combined PRONAM-Biological Control Unit team.

3.2.3.5. Establishment of Diomus sp.

The predatory ladybird beetle Diomus sp. was first released in Zaire simultaneously with Epidinocarsis in July, 1982. Since that time, it has been released at a total of 13 sites in five administrative regions. So far, Kinshasa is the only place in Zaire where Diomus has become established, and in fact, it is the only place in Africa where Diomus has become

Table 2.--Natural enemies of cassava pests released in Zaire, 1982-1985.

Species	Family	Common name	Target species	Trophic level
Allotropa sp.	Platygasteridae	none	CM	parasite
Diomus sp.	Coccinellidae	ladybird beetle	CM	predator
Epidinocarsis lopezi	Encyrtidae	none	CM	parasite
Hyperaspis jucunda	Coccinellidae	ladybird beetle	CM	predator
Hyperaspis notata	Coccinellidae	ladybird beetle	CM	predator
Sympherobius maculipennis	Sympherobiidae	brown lacewing	CM	predator
Neoseiulus anonymus	Phytoseiidae	none,	green mite	predator
Neoseiulus idaeus	Phytoseiidae	none	green mite	predator

established. (The beetle has been released in many West African countries.) Diomus was not recovered in Kinshasa until the end of the 1985 dry season. Huge numbers of adults and larvae were present (up to 450 on a shoot tip 10 cm long), and CM populations were being rapidly reduced. The predator's area of distribution is about 120 km².

The establishment of Diomus in Kinshasa but not elsewhere in Africa may be attributed to a unique form of cassava grown in that city. This form is a perennial, tuberless, hybrid of cultivated cassava (Manihoti esculenta) and a tree cassava (M. glaziovii). Its rough stems and perennial habit apparently permit the CM to maintain higher-than-usual populations during the rainy season. These higher populations must greatly favor the predatory beetle, which is not as adept at locating its mealybug prey as is the parasitic Epidinocarsis wasp.

3.2.3.6. Establishment and spread of Epidinocarsis

One year and four months after the first introductions of Epidinocarsis (Fig. 7) in Zaire, the parasite had spread over an area of 60,000 km² in Bas Zaire. This rapid spread may be attributed to man's intervention more than to some unusual dispersal power of the parasite. Small merchants in Bas Zaire and Bandundu transport bundles of cassava leaves in great quantities, sometimes over long distances. Also, people of these regions carry bundles of cassava leaves as gifts, when visiting friends or family. Mealybugs that have been parasitized by Epidinocarsis remain attached to terminal stems and leaves and are in this way carried into new regions. By the end of 1984, Epidinocarsis had expanded into Bandundu, and its total area of distribution in western Zaire was 80,000 km². Currently (August, 1985) it occupies almost all of Bas Zaire and large parts of northern and central Bandundu, a total area of about 130,000 km² (Fig 8). This large area produces about 14% of Zaire's annual cassava crop, and it represents over 20% of the CM's area of distribution in Zaire. It is important to note that the current range of Epidinocarsis includes about 60% of

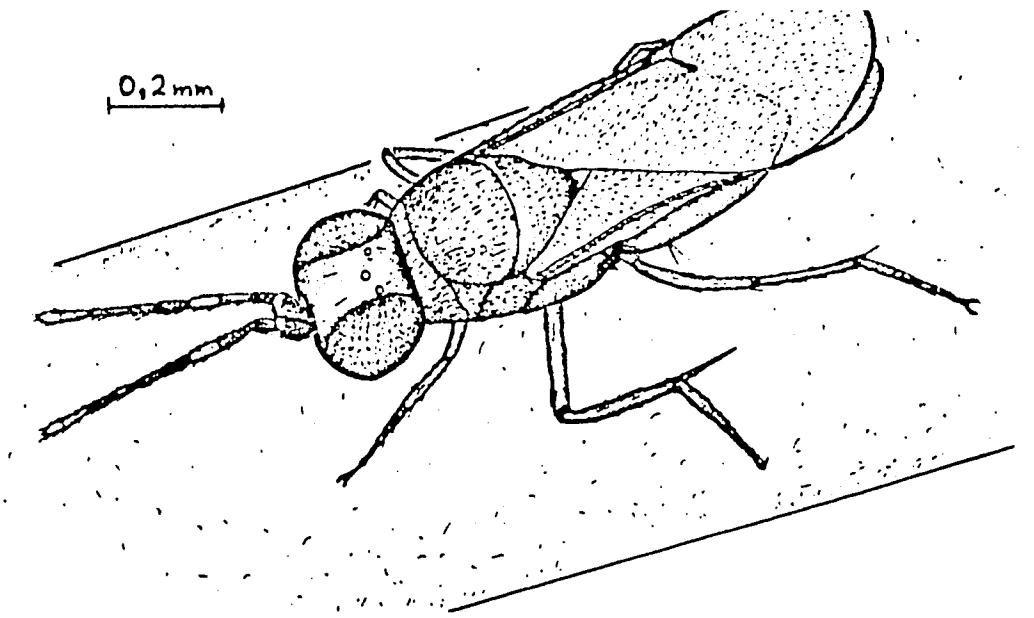

Fig. 7 . Female of Epidinocarsis lopezi, the introduced parasite of the cassava mealybug.

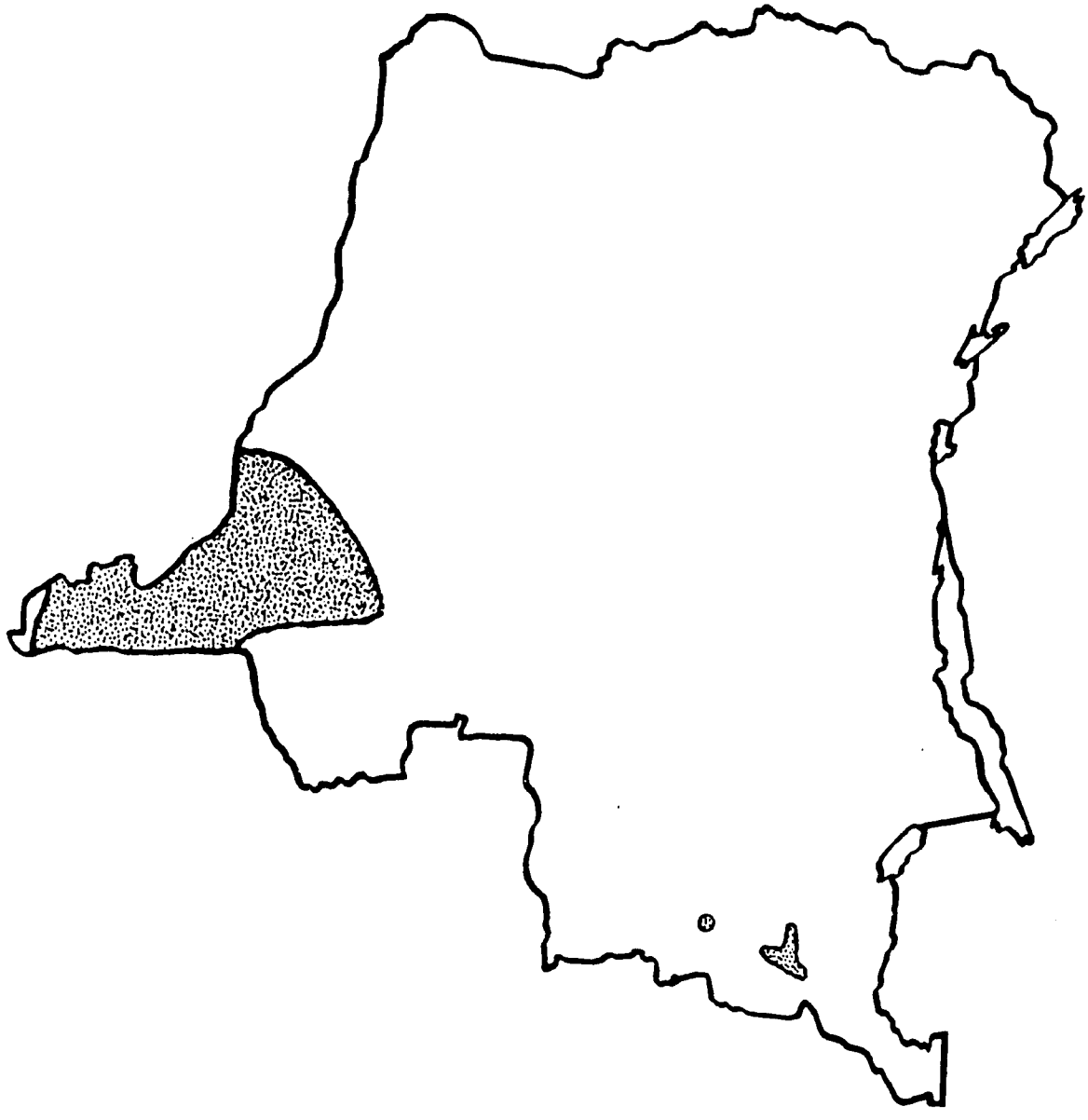

Fig. 8 . Distribution of Epidinocarsis lopezi in Zaire as of July, 1985.

the area where mealybug damage is severe every year or where severe mealybug outbreaks have occurred.

3.2.3.6. Effectiveness of Epidinocarsis lopezi as a biological control agent

Since the PRONAM entomology program has emphasized biological control as a solution to the problem of the CM, and since Epidinocarsis lopezi is the only introduced natural enemy to become widespread, the question of the effectiveness of this parasite is extremely important. Intensive studies aimed at this question perforce have been limited to the Bas Zaire Region, where PRONAM headquarters are located. Several factors have limited the success of studies in this region. First, as already discussed in the section on distribution and damage of the CM, CM populations in Bas Zaire had already declined greatly when the first releases of natural enemies were made in 1982. When experimental plots have been infested artificially in mid-dry season, the proportion of plants remaining infested has been too low to provide the relativily large numbers of samples needed for statistical analysis. CM colonies are more likely to become well established on the plants early in the dry season, but at that time of year the large numbers of CM needed for artificial infestations cannot be found in farmers' fields. CM colonies grown in the screenhouse for the purpose of artificial infestations are destroyed by a locally occurring natural enemy, a predatory cecidomyiid fly. As a result of all these problems it has been necessary to carry out evaluations of Epidinocarsis in large numbers of farmers' fields, and to compare CM populations in areas where the parasite occurs with those in areas where the parasite has not yet arrived. To further complicate the situation, Epidinocarsis has spread quickly, so that the test has rapidly expanded and the control area has rapidly contracted. In Bas Zaire the only area that may still be free of the parasite is a narrow strip along the coast. Comparisons of CM in Bas Zaire in areas with and in areas without Epidinocarsis suggest that the parasite is, in fact, pushing the low CM populations even lower. However, the effect is necessarily subtle, and the most useful measure of the parasite's effectiveness (i.e., increase in crop yields) has not been possible. In Nigeria, where CM populations generally are higher,

IITA entomologists have excluded Epidinocarsis from control plots by treatments with insecticide and by the use of sleeve cages. CM colonies so protected multiplied much faster than unprotected colonies. Hence, there is solid experimental evidence for the effectiveness of Epidinocarsis in Nigeria.

3.2.3.7. Ecology of Epidinocarsis lopezi

The surveys conducted to monitor the spread of Epidinocarsis in Zaire have produced considerable information on the ecology of the parasite and its host. The most important information will soon appear in professional journals. For the purposes of this terminal report, it is necessary only to mention briefly the major conclusions. The accidental introduction of the CM in Zaire resulted in the immediate appearance of an intricate food web that had not existed previously. Parasites, predators, and scavengers proliferated in cassava fields. After Epidinocarsis was released, still other insect species invaded the cassava ecosystem to exploit the parasite as a new food source. Over 100 species of insects in this new food web have now been identified in Africa, and most of these occur in Zaire. At the outset of the ecological studies, it appeared that some of these new arrivals might have a very negative effect on the biological control project. However, additional research has suggested that the effects are, at worst, only mildly negative. Another discovery has been that Epidinocarsis has a characteristic numerical response to changes in populations of its host. When host populations are low, increases in host density are matched by rapid increases in numbers of Epidinocarsis. However, this relationship rapidly becomes less pronounced as pest numbers increase, so that by the time that CM populations reach 40 mealybugs per cassava shoot, the number of parasites per shoot is no longer increasing. The conclusion is that Epidinocarsis can be effective only at the low pest populations that occur every year during the rainy season and at the beginning of the dry season. Epidinocarsis may delay the build-up of mealybug populations to economic levels, but it cannot reduce the populations after they become high.

3.2.3.8. Selection of cassava varieties resistant to mealybug.

A clone with an extremely high degree of resistance came to light at PRONAM/ Mvuazi in 1981 as the result of screening by the breeding section of many thousands of plants grown seeds from IITA. It appears that high resistance to mealybug is very rare; to the best knowledge of PRONAM reseachers, PRONAM clone 70453 is at the moment the only cassava clone in the world with proven high resistance to mealybug. The resistant plants show two interesting characteristics--ability to retard development of mealybug populations, and tolerance to mealybug attack.

The results of one resistance test are depicted in Fig. 9. This figure, though impressive, does not give a full indication of 70453's resistance. So far all tests have been terminated at an early stage of infestation (e.g., after five to eight weeks), while the number of mealybugs on susceptible control plants is still low enough to make counts of them feasible. If an experiment is allowed to continue, the suceptible plants become covered with mealybugs--hundreds or even thousands occurring on each leaf. The number of mealybugs on leaves of 70453 does not increase, and it may even decrease. Repeated infestations of plants of 70453 do not serve to establish growing mealybug colonies at the shoot tip or on the apical leaves, although colonies often form lower on the stem, where they can do much less damage. Individual mealybugs attacking the tip cause stunting, but although growth slows, it does not stop. The sessile adult mealybugs at the tip are left behind as the tip grows away from them.

PRONAM's breeding section is performing crosses to determine whether or not 70453's tolerance and resistance can be combined with high yield and other desirable traits in other clones. Clone 70453 has not been released to farmers because of its sensitivity to green mite and low yield.

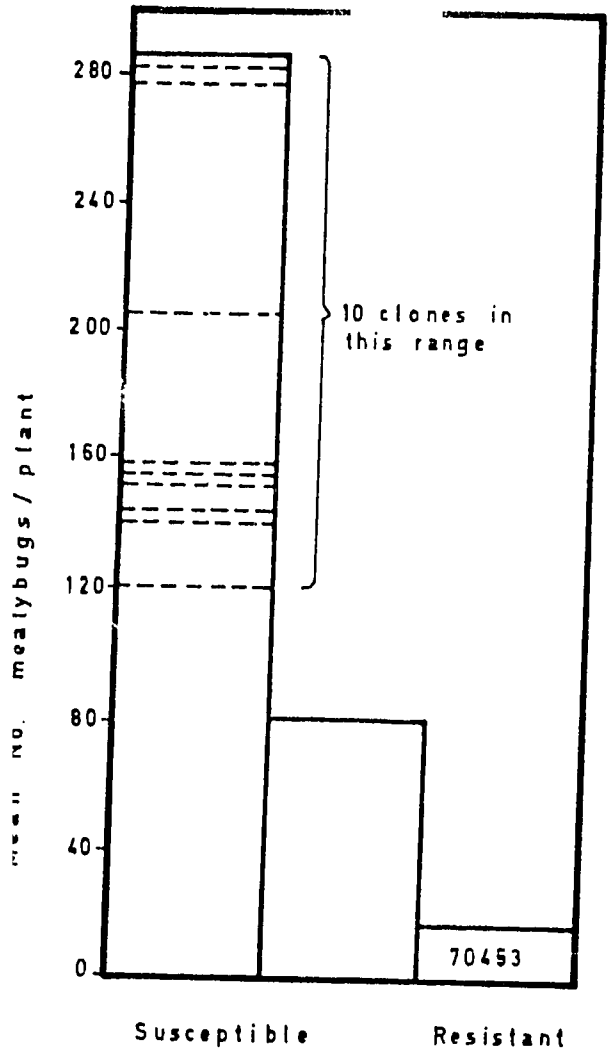

Fig. 9 . Number of mealybugs on resistant clone 70453 and eleven other clones eight weeks after infestation.

3 2.4. AGRONOMY

3.2.4.1. Objectives and background

It is well recognized that there is great potential for increasing cassava yields in Zaire through improvement of crop husbandry. The agronomy subprogram is responsible for finding ways to exploit that potential. Thus, principal objectives are to identify factors limiting production which are amenable to improvement through crop management and to develop improved cultural practices that will give maximum economic yield. In addition, the agronomists collaborate with the plant breeders to determine the effect of various agronomic factors on the performance of newly developed varieties and with the entomologists and pathologists to develop cultural practices which reduce insect and disease damage. Research carried out in the first five years of PRONAM, prior to this project, had made possible the elaboration of a set of farmer recommendations. Data was obtained which allows PRONAM to make recommendations on such factors as time of planting, planting material (choice, preparation and storage), plant density, weed control and leaf harvesting. With some of this more basic work behind them, PRONAM agronomists were shifting their focus to certain specific themes as the Project began. Several of these research areas require observations over an extended period of time so, in many cases, results are still preliminary.

3.2.4.2. Results

a) Maintenance and improvement of soil fertility.

Although cassava has a reputation as being a crop which can produce even on poor soils, it has been demonstrated that low soil fertility is a constraint severely limiting cassava yields in much of Zaire. PRONAM has conducted some fertilizer trials at the request of the National Fertilizer Program which desired information from more controlled experiments to supplement its' work in on-farm fertilizer testing. These are providing basic information on nutrient requirements in locally important soils and information

that can be applied directly by some farmers who are in a position to use inorganic fertilizers. However, in the view of PRONAM, it is the use of organic fertilizer materials that could be of most benefit to the large majority of small farmers in the near future. Thus soil fertility research in that area has been emphasized.

- Response to NPK. Root yield responses were found with up to 200 kg K_2O/ha and 150 kg N/ha. Significant responses in root yield to phosphorus were not observed. The yield of cassava planting material increased 75-100% with 75 kg N/ha and 100 kg K_2O/ha. As with root yield, no response to phosphorus in yield of planting material was observed.

- Alley cropping. A leuceana (Leuceana leucocephala) alley cropping system has been tested at Mvuazi on two valley bottom soils (Entisols-sandy clay loam) differing in pH and fertility level. On a soil with a pH of 5.5 and moderate fertility, leuceana appeared to make good growth. However, biomass production was only about one-half that reported at IITA, Ibadan and no yield differences have been observed between crops grown in the alley cropping system and those grown in pure stand. On a soil with a pH of 4.8 and lower fertility, leuceana growth was poor and biomass was very low. In experiments started more recently at Gandajika, on an alfisol, growth of leuceana is more vigorous and better results seem likely.

A number of tree and shrub species (and different varieties of some species) have been planted for observation for their suitability for alley cropping. Preliminary observations indicate that Acacia mangium, Flemengia congesta, and Gliricidia sepium are better adapted to the acid entisols and ultisols of Bas Zaire then leuceana. Other species are being sought.

- Mulching. Continous applications of graminaceous plant material as mulch for three years increased soil pH, soil organic carbon, total nitrogen, available phosphorus, and exchangeable cations (Ca, Mg, K). Cassava root yields were increased by 58% in the third year in comparison to the unmulched

control. (However other soil properties were also affected by mulching, such as soil tempertature and moisture content, and these may have contributed to the yield increase.) The possiblity of producing mulching material of herbaceous species (stylosanthes, penniseteum, and natural fallow) in strips between strips of crops is being investigated.

- Rotations. Rotation studies utilizing the important food legume species have been initiated. After two years, no difference in yield has been observed between yield of cassava grown in rotation and continuous cassava.

- Residue Management. Plant residues are often burned before land preparation. Alternatively they may be buried when making ridges. A common method of handling residues in Bas Zaire, called "mafuku", is to burn the residues under a covering of soil which results in incomplete combustion. In the absence of fertilizer, the mafuku method has given the highest cassava yield of these three methods of residue management. Studies of the long term effects of these various methods are called for.

b) Liming

Preliminary investigations indicate that very substantial increases in yield of cassava may be obtained with application of modest amounts of lime (500 kg/ha of oxide of lime) on entisols and ultisols in Bas Zaire. A groundnut intercrop may benefit even more. This is a particularly interesting result as lime is produced in Bas Zaire and could be available at reasonable prices.

c) Intercropping

Cassava is rarely grown in monoculture by small farmers and a number of intercropping studies have been conducted. Salient findings have been:

- Total productivity per unit area has been invariably greater with intercropping than with monocropping for cassava/groundnuts, cassava/maize

and cassava/bean systems.

- Cassava is the less competitive crop in these mixtures. Rapid establishment and good early growth and vigor are important characteristics for cassava that is grown in intercropping.

- In cassava/groundnut intercropping, cassava planting arrangement (double rows or equidistant rows) did not have a significant effect on yield of either crop. Double row planting, however facilitates planting, cultivation and harvesting of the groundnut.

- Delaying cassava planting after planting of groundnut results in decreased cassava yields.

- Yields of intercropped groundnut are higher when planted at 166,666 than at 83,333 plants/ha while cassava yield is no affected by these differences in groundnut density.

- Harvesting cassava leaves at 3 months after planting increases yields of intercropped maize but decreases cassava yields.

- In cassava/maize intercropping, these was not difference in cassava yields between densities of 10,000 and 20,000 plants/ha. However maize yields were significantly higher at the lower cassava density.

d) Land preparation

When land preparation was by hand, on a sandy clay loam, planting on ridges gave higher cassava yields than planting on the flat. When land preparation was by tractor these was no difference between planting on ridges and on the flat. The differences observed are attributed to differences in friability and tilth in the crop's rooting zone.

e) Variety x management interactions.

Variety testing by the plant breeders is carried out under a more or less standard set of conditions of crop management. However, farmers' management practices may differ in one or more important factors and it is important to determine how newly developed varieties react to different levels of these factors. Thus, newly developed varieties at an advanced level of testing are compared with a standard variety at different levels of various factors including planting date, fertility level, plant density, leaf harvesting, and cropping system (monocrop vs. intercrop). Tests of the new PRONAM varieties, Kinuani and F100, have shown that neither of these varieties displayed any undesirable interaction with the various agronomic factors tested when compared with the local variety.

f) Cultural methods to reduce pest damage.

The following findings have been made:

- Planting early in the rainy season reduced damage to cassava by the cassava green mite.

- Cassava green mite damage decreased with increasing levels of soil fertility.

- Mulching decreased damage by both cassava green mite and cassava mealybug.

g) On-farm experimentation.

During the second half of the project period, PRONAM added a farming systems research component to its research and extension program. An exploratory survey was carried out in late 1982 to describe agricultural production systems in Bas Zaire. On the basis of this survey, it was decided that the first possibility for improving production might be the introduction of

improved cassava varieties into the existing cassava-based cropping system. On-farm trials were carried out to test this hypothesis. Yields were low and, in general, the improved varieties did not yield more than the local variety. This may be attributable to the general low level of management (low fertility, less than adequate weeding) which imposed a low ceiling on yields.. At the end of the Project, trials were underway to determine the effect of improved management (application of a moderate rate of fertilizer and of lime and improved weeding practices). Yield results were not yet available but visual observations indicated a pronounced response to fertilizer and lime.

3.3. THE OUTREACH PROGRAM

3.3.1. OBJECTIVES

As PRONAM began to produce potentially useful research results, it became clear that these would not benefit the small farmer unless PRONAM, itself, played an active role in the transfer of the newly developed technology. Thus, in addition to developing the research capability of PRONAM, another primary purpose of the project was to develop the capability of PRONAM to make new cassava technology available to subsistence farmers. This involves two main activities: (1) multiplication of improved varieties and (2) demonstration and disemmination of improved varieties and production techniques.

3.3.2. STRATEGY

PRONAM does not have the resources to carry its'research results directly to the large population of small farmers that could benefit from them. The strategy that has been adopted to accomplish this transfer is to work through those organizations that have contact with farmers and have the capacity to pass new technology on to them. The national extension system , alone, is not capable of the task. It's effectiveness in many cases is compromised by field personnel who are frequently poorly motivated and/or poorly trained and who often must enforce unpopular government policies, such as forced production of given areas of certain crops ("Cultures Imposées"). This situation varies with the zone and collectivité. In some areas, good results can be achieved working through the Department of Agriculture agents but, in others, attempts have not been successful. Thus PRONAM works also with a wide range of non-governmental organizations such as agricultural development projects, church missions involved in agriculture, private voluntary agencies, etc. PRONAM's role is to establish liaison with these various agencies and to channel it's newly developed technology through them. This involves training personnel of these agencies in the new technology and in the methods of transfering it to farmers.

3.3.3. RESULTS

3.3.3.1. Multiplication of improved varieties

As improved varieties have been developed by PRONAM, a maximum effort has been made to make them quickly available to farmers. A very major constraint in this activity is the low rate of multiplication of cassava. Under the usual method of propogation in which the mature hardwood of the plant is cut into pieces about 25 cm long for planting, one plant will produce in one year, about ten cuttings. Compared to most crops, this is a very slow rate of multiplication. Maize, for example, has a multiplication rate of about 1:300 per generation. Where the rainy season is sufficiently long or irrigation is available, allowing two crops in one year, the rate becomes 1:90,000.

PRONAM has utilized special methods for rapid multiplication to generate planting material as quickly as possible once new improved varieties have been identified by the breeding program. One such method is propogation from two node cuttings of mature hardwood instead of using the normal 25 cm cuttings. However, special care is required to establish plants from these small cuttings. They are planted in plastic bags filled with soil, placed in shade and watered regularly. After they are established, they are hardened off by increasing exposure to sun and then transplanted in the field at about ten weeks. Another technique used to increase the rate of multiplication is to use, in addition to the mature hardwood, the stems above the hardwood for planting material. This requires still more attention in establishment. The cuttings from the tops are planted in beds filled with heat sterilized sand and covered with a polyethylene cover to make a humidity chamber to prevent the cuttings from drying out. After three weeks they are transferred to plastic bags filled with soil and then after another eight or nine weeks they are planted in the field. By using two node cuttings and all the plant tops the multiplication rate is increased from the normal rate of 1:10 to 1:60-70.

A multiplication farm of 100 ha has been established by PRONAM near the Mvuazi station. Another ten hectares for multiplication is planted each year near Kisantu to serve that area of Bas Zaire. By July 1985, 750,000 meters of cuttings of improved varieties had been produced and distributed to collaborating organizations. This is sufficient to plant 300 ha but the area now planted to improved varieties in Bas Zaire is estimated to be two to three times greater considering the continued multiplication that occurs each year as the new varieties are harvested and replanted. At the Kiyaka, 15 ha are presently planted for multiplication of F100. At Gandajika, four promising varieties at advanced levels of testing are planted on two hectares, each, for multiplication. Even with this effort in multiplication, PRONAM can supply only a nucleus of material which must be taken by other agencies and individual farmers for futher increase. PRONAM works with a number of organizations to assist them in their multiplication efforts.

3.3.3.2. Demonstration and disemmination of new technology

As previously stated, transfer of research results to farmers is achieved by working through various agricultural development agencies. The exact nature of the collaborative activity varies with the nature of the agency (it's objectives, resources, etc.) but the desired result is the same-to provide farmers with improved varieties and techniques. Following is a description of the most important collaborative activities in which PRONAM has been involved during the project.

a) Bas Zaire

- National Fertilizer Program. Since 1981, PRONAM has cooperated with the FAO supported National Fertilizer Program (P.N.E.) in Bas Zaire in an effort which has been mutually very beneficial. One hundred thirty-five demonstration/trials, comparing the local cassava variety with one or two improved PRONAM varieties at three rates of fertilizer, have been carried out in farmers'fields. With these, PNE demonstrates and obtains data on the effects of fertilizer application and PRONAM demonstrates and obtains data on

the performance of its' varieties. The data, which have confirmed the superior performance of KINUANI are presented in the discussion of the accomplishments of the breeding program. In this collaborative effort, PRONAM provides the planting material of the improved varieties, participates in monitering, especially for diseases and pests and takes part in the harvest and accompanying field day. PRONAM also provides training to the PNE staff in cassava production and extension techniques. These demonstration/trials which have been widely dispersed through much of Bas Zaire serve as foci for the diffusion of the new varieties. From each demonstration/trial approximately 3,000 meters of cuttings become available to the local farmers.

- Agricultural Project of Mbanza Ngungu. Cooperation with this French aid supported project has involved both demonstrations and distribution of improved varieties. In 1982/83 and 1983/84 crop years, the project established 26 demonstration/trials in Mbanza Ngungu Zone. In these, two PRONAM varieties were compared with the local variety with and without a moderate dose of fertilizer. The mode of collaboration was similar to that with PNE. In the 1984/85 crop year, the project shifted its' activities in cassava extension strictly to the distribution of the PRONAM variety, KINUANI. Bundles of 50 one-meter cuttings were distributed to 767 farm families dispersed through the Zone.

- OXFAM. In Bas Zaire, this organization has planted demonstration and multiplication plots with KINUANI in Madimba, Kimvula, Tshela, and Luozi Zones. Training has been given to OXFAM staff at Mvuazi.

- Integrated Agricultural Development Project of Luala. This project supported by Italian aid has been multiplying and distributing KINUANI to farmers in the Project area in Luozi Zone.

- Zairean Army. To feed the troops stationed at Mbanza Ngungu, the Zairean Army has entered into contracts with local farmers to produce cassava. Under these contracts, the Army prepares their land and supplies

them with cuttings of PRONAM varieties. Twenty-five thousand meters of cuttings were distributed in 1984/85. At harvest, the planting material is retained by the farmers.

- Church mission projects. Catholic missions at Kolo, Sonabata, and Luvaka, CEDECO at Kimpese and the Salvation Army at Mbanza Ndundu have taken planting material for multiplication and distribution. These groups took 31,250 meters of cuttings in 1984/85.

- Two large industrial enterprises, the cement factory at Lukala and ONATRA (railroad) at Lufu-toto are multiplying KINUANI for distribution of planting material to their workers.

- The Department of Agriculture Sub-Regional Offices at Kisantu and Mbanza Ngungu obtained enough planting material of KINUANI in 1984/85 to plant six and a half hectares.

- The Agriculturral Technical Schools at Gombe Matadi and Kimpese have been receiving cuttings of KINUANI and serving as sources for dispersal.

a) Bandundu

- Extension Service of the Department of Agriculture. In its' outreach activities in Bandundu region, PRONAM has concentrated on working with the extension service of the Department of Agriculture. Capable and well motivated agents have been identified and given training at Kiyaka. The PRONAM extension agronomists at Kiyaka have worked side by side with them in the field giving them supervision and support throughout the cropping cycle. This effort has paid good rewards. Each year multiplication plots are being established at different locations to cover the Subregions of Kwilu and Kwango. The individual plots are one-half hectare in area. They are planted adjacent to a planting of the local variety so they serve demonstration as well as multiplication/distribution purposes. The plots are pre-

pared, planted, tended, and harvested by the local farmers under the supervision of the local extension agent who, in turn, receives close back-up from the PRONAM extension agronomists. Forty-seven such plots were established in the 1984/85 crop year.

- CODAIK. This World Bank supported agricultural development Project serves a large part of Kwilu subregion. In this area, PRONAM channels its' research results through the project. CODAIK has been multiplying and distributing PRONAM varieties, especially F100, widely through the project area.

- Other agencies. PRONAM is collaborating with OXFAM and several church missions in multiplication and distribution activities.

c) Kasai

- The breeding program at Gandajika and, thus, the outreach effort are not as advanced as at Mvuazi and Kiyaka. Collaboration has, however, begun with Project Maïs, Kasai Oriental (a World Bank supported regional Maize production project), the Christain Health Center and several catholic missions to multiply promising PRONAM varieties.

3.4. ESTABLISHMENT OF A TRAINING COMPONENT

A stated objective of the Project was to establish a training facility and program at Mvuazi to support and complement the outreach activity. Intermediate level extension personnel and research workers were to be trained in the basics of cassava technology and to be made aware of the latest results of cassava research. These individuals would return to their jobs and train others in the techniques they learned. To accomplish this, a facility capable of accomodating the trainees was to be constructed and a training officer was included on the technical assistance team. It was planned that there would be two 10 week training courses given each year.

As mentioned in the section on the development of facilities, there was a long delay before construction of the training center commenced. Construction did not begin until early 1984 and was completed one year later. A training officer was not engaged until it could be determined when a training center would be provided. He arrived in Zaire in January, 1985. Although there were only a few months of the Project remaining, the position was filled as a similar position would exist in the successor project. Soon after arrival, he developed specifications for equipment and furnishings for the training center and submitted them for procurement. These had not yet been received at the completion of the Project. However development of training courses has begun and it is anticipated that the training activities prescribed in the project paper will commence in 1986 when equipment and furnishings are in place.

In an effort to, at least, partially meet the need for training of technicians of several agencies collaborating in PRONAM outreach activities, several one week courses were conducted at Mvuazi and Kiyaka (or Kilwit). These were organized by the extension agronomists who called upon various specialists in PRONAM to participate in deliverying the courses. The courses given are shown in Table 3.

Table 3. One week training sessions conducted by PRONAM during period of Project.

Region	Year	No. of trainees	Name of organization
Bas Zaire	1982	8	Agricultural Project of Mbanza-Ngungu
	1983	31	National Fertilizer Program, Mbanza-Ngungu
	1983	18	Agricultural Project of Mbanza-Ngungu
	1983	7	OXFAM, Mbanza-Ngungu
Bandundu	1982	15	National extension service
	1983	23	Several non-governmental organizations
	1984	16	National extension service
	1985	17	National extension service

3.5. STAFF DEVELOPMENT

3.5.1. TRAINING

A key element of the Project was training of PRONAM personnel with the objective of developing a staff that would take full responsibility for operation of the Program at the earliest possible date. To accomplish this goal, non-degree technical training and advanced degree training, which are currently not available in Zaire, were provided.

3.5.1.1. Non-degree technical training

Sixteen PRONAM technicians completed the IITA Tropical Root and Tuber Crop Production Course during the period of the Project. This brings to 39, the number of PRONAM staff that have received this training since 1975. This nine week course provides training in improved methods of tropical root and tuber crop production and focuses on identification of various field problems and pratical solutions to them. It also teaches participants how to perform applied research trials on experiment stations and in farmers' fields and how to demonstrate new technology.

PRONAM staff also participated in two other IITA courses. A plant pathology technician attended the three week course in Tissue Culture for Root and Tuber Crops. Three MSc level agronomists participated in a three week course on Alley Cropping.

Individualized training at IITA was provided for three PRONAM staff members. The physical plant services foreman spent three months at IITA and received on-the-job training in vehicle and farm equipment repair and maintenance and operation and maintenance of physical plant facilities. An agronomist (Msc) spent six weeks working on soil microbiology and nitrogen fixation to learn techniques applicable to his work on alley cropping. An entomologist (MSc) spent three weeks learning methodology for assessing effectiveness of biological control of cassava mealybug.

3.5.1.2. Advanced degree training.

At the start of the Project, one PRONAM staff member had completed the MSc degree and ten were in MSc training. The Project was to train 16 MSc's (including the 10 already in training) and, from these, 6 PhD's. Table 4 shows the academic training programmed in the Project Paper and the training actuall accomplished. MSc training fell somewhat short of what was programmed and this can be attributed to the fact that the full number of qualified candidates did not become available. Targets for PhD training were rather unrealistic considering the time required to complete MSc training and the desirability of work experience before continuing on for the PhD degree.

With the exception of one individual who was in training at Michigan State University when the Project began and the candidate for a MSc in agricultural economics, who is at the University of Georgia, all training was done at the University of Ibadan. For these participants, all thesis research was done at IITA except in one case where the PhD thesis research was done back on the job in Zaire. Thesis research was jointly supervised by University of Ibadan and IITA scientists.

Some students were encouraged by the University of Ibadan to continue for a Master of Philosophy (M Phil) degree after completing requirements for the MSc. This involved more in-depth research on their thesis topic. However, it was found that, because of much more complicated administrative procedures involved for this degree, one to two and a half additional years were required to complete the program and training at this level was eventually discontinued. Instead, participants remained at IITA for another six months after completion of the MSc degree to gain additional research experience.

A policy was followed for advanced degree training whereby an individual worked within PRONAM for approximately one year before being considered for training for a higher degree. Thus a BSc entering PRONAM would have the opportunity to obtain pratical experience and be evaluated for selec-

Table 4. Status of participant training for advanced degrees at completion of project

Degree and discipline	Programmed in Project Paper	Completed	In process
MSc			
Plant breeding	3	5[a]	0
Agronomy	6	5[b]	0
Entomology	2	4[c]	0
Plant pathology	2	2	0
Agricultural economics	1	0	1
Food technology	1	0	0
Agricultural education	1	0	0
Ph.D.			
Plant breeding	2	1	0
Agronomy	2	0	1
Entomology	1	0	1
Plant pathology	1	0	0

[a] Two left project
[b] One left project
[c] One left project

tion for MSc study. Similarly, after the Msc, participants were expected to return to Zaire for futher experience and evaluation before possibly proceeding on to PhD studies. Table 5 gives assignment of staff who have received advanced degree training.

3.5.2 OTHER ASPECTS OF STAFF DEVELOPMENT

It has been recognized in the implementation of the Project, that staff development does not end with formal academic training but that professional and career development is an on-going process that also must be given attention. One important element in professional development is participation in conferences, workshops, and seminars which provide the opportunity to interact with scientists from other institutions. The Project has sought to provide opportunities for such participation. Eleven PRONAM staff have taken part in one or more of 12 international meetings. A list of these conferences and numbers of staff attening is appended.

Another very important aspect of professional development is the publication of papers in scientific journals and presentation of papers at scientific meetings. A considerable number of papers reporting PRONAM work have appeared during the project period in which national staff are authors or co-authors. Appended is a list which includes these publications.

Table 5. PRONAM personnel receiving advanced degree training and their assignment as of Project completion date.

Name	Position/Duty station
Lutaladio ne Bambi, MSc	Co-Director, pursuing doctoral studies in agronomy
Kasele Idumbo, MPhil	Agronomist/Kiyaka
Kasu Tombo, MSc	Entomologist/Mvuazi
Kiala Kilusi, MPhil	Regional Coordinator, Breeder/Gandajika
Landu Kalemba, MSc	Agronomist/Mvuazi
Mahungu Nzola Meso, PhD	Head, Breeding section/Mvuazi
Mbulu Ntoto, MSc	Agronomist, Farming Systems/Kisantu (Mvuazi)
Muaka Toko, MPhil	Regional Coordinator, Entomologist/Kiyaka
Muimba Kankolongo, MPhil	Head, Pathology section/Mvuazi
Muyolo Gilumba, MPhil	Pathologist/Mvuazi
Ndombo Delo, MSc	Plant Breeder/Mvuazi
Nsiama She Hatalman, MSc	Pursuing doctoral studies in entomology
Simba Lianabo	Pursuing MSc studies in agricultural economics

3.6. DEVELOPMENT OF FACILITIES

Mvuazi, Kiyaka and Gandajika had, at one time, been well developed and equipped research stations. However, over the twenty years preceding the Project, there had been a general deterioration of station facilities due to inadequate maintenance. The little field equipment and few vehicles which belonged to the Project were in need of replacement. Basic laboratory equipment and library reference materials were missing. There were virtually no tools or shop equipment for repair and maintenance of machinery. Thus it was necessary to rehabilitate or improve and to equip station facilities.

3.6.1. PHYSICAL PLANT

At the start of the Project, laboratory research activities were hindered and living conditions were difficult due to inadequate electrical and water systems at Mvuazi. Electricity was supplied by a diesel generator which was inadequate to meet station needs, expensive to operate and unreliable. At best, electricity could only be provided for a few hours in the evening for lighting senior staff housing. The water supply for senior staff housing was rainwater which was collected from the roof in a cistern an pumped by hand to an overhead tank. The capacity of the cistern was not sufficient to provide water during the dry season. During most of the dry season, it was necessary to replenish them with water carried from a stream in a tractor drawn water tank. The office and laboratory building did not have a functional water supply. There was thus an urgent need for new electrical and water systems.

Initially, numerous efforts were made to obtain cooperation from Zairean Government entities (SNEL - the electric company and REGIDESO - the water company) in installing the electric and water systems but results were essentially nil. Progress was finally made when a private engineering firm was engaged for the design, preparation of bid documents, appraisal of bids and supervision of the work. A contract for the installation of the two systems was signed at the end of 1983. The contract also included the renovation

and conversion of a building for a training center dormitory facility to accomodate up to 21 trainees and the installation of a dispensary in another building. The funds, being the equivalent of approximately US$ 1,000,000 were made available from counterpart funds. Electricity was brought a distance of 16 km from the national hydroelectric grid high tension system. Buildings were rewired and electrical applicances provided for senior staff housing. The water system installation involved drilling a well, constructing a water tower and laying pipelines. The work was completed in early 1985. The importance of these improvements cannot be exaggerated. Laboratory and workshop equipment were put into operation and the quality of life for the staff was vastly improved.

Under the Project, a small diesel generator was installed at the Kiyaka substation to provide household lighting.

Other improvements of the physical plant at Mvuazi were made during the project. The main office/laboratory building and houses were brought back into a good state of repair. Simply as an exemple of the extent of repairs required, more than 50 panes of glass were used to replace broken windows in the main building. Station roads and grounds around housing and office areas which had been badly neglected were improved and are now being maintained. A garage workshop was set-up with equipment to perform maintenance and basic repairs. A climate controlled insectary for insect rearing and studies was installed with twelve cages ventilated by a forced air system. A large room in the main building was remodeled and equipped to serve as a social and recreation center, a conference hall and a training classroom. Screen houses, specially designed by IITA for conditions of the lowland humid tropics, were being erected at the completion of the Project. Also under construction were a machinery shed and several storehouses.

3.6.2. LAND

As PRONAM's activities grew, limitations on the amount of suitable land for research and multiplication needs became an increasingly serious pro-

blem. Mvuazi station has only about 40 ha which can be used for annual crops and this had to be shared between PRONAM and INERA. Much of the land which lies between the Nkokozi and Mvuazi rivers had a history of flooding problems. At one time, an extensive system of dikes had been constructed to protect the area. However, over the years, these had been eroded and broken down. In 1982, the dikes were rebuilt. Two bulldozers and a motor grader were rented and the work was directed by the Assistant Farm Manager and the Heavy Equipment Specialist from IITA, Ibadan. Access roads and drains were also laid out. However, even with these improvements, flooding still occurred. The problem was futhur studied by an IITA Water Management Engineer. It was determined that a very major investment in a water control system would be required to provide full protection from flooding necessary for proper conduct of research trials. In view of this and of problems involved in sharing Mvuazi facilities with INERA, PRONAM together with USAID and the Department of Agriculture investigated the possibility of establishing the headquarters at another location. However, no suitable site was found and efforts were shifted to finding other land close to Mvuazi. Ultimately, PRONAM was able to conclude long term leases with local authorities for 96 ha adjacent to Mvuazi to be used for research plots and 100 ha about 10 km from Mvuazi for a multiplication farm. The research farm is being developed with access roads, soil and water conservation structures and drainage systems. The land has been surveyed and a plan prepared (Fig.10). A portion of the farm that could be developed with existing equipment has been improved. Equipment (bulldozer and scraper) have been ordered which will allow complete development of the entire area. A plan has also been prepared for the development of another 10 ha of land at Mvuazi for irrigation.

3.6.3. EQUIPMENT AND VEHICLES

Funds were included in the Project for procurement of vehicles and farm, workshop, laboratory and radio communication equipment. A fleet of 11 pickup trucks, two jeeps, three twelve-ton trucks and five motorcycles were purchased. These were later supplemented by a gift from the British Government of seven landrovers. The IITA Biological Control Program provided

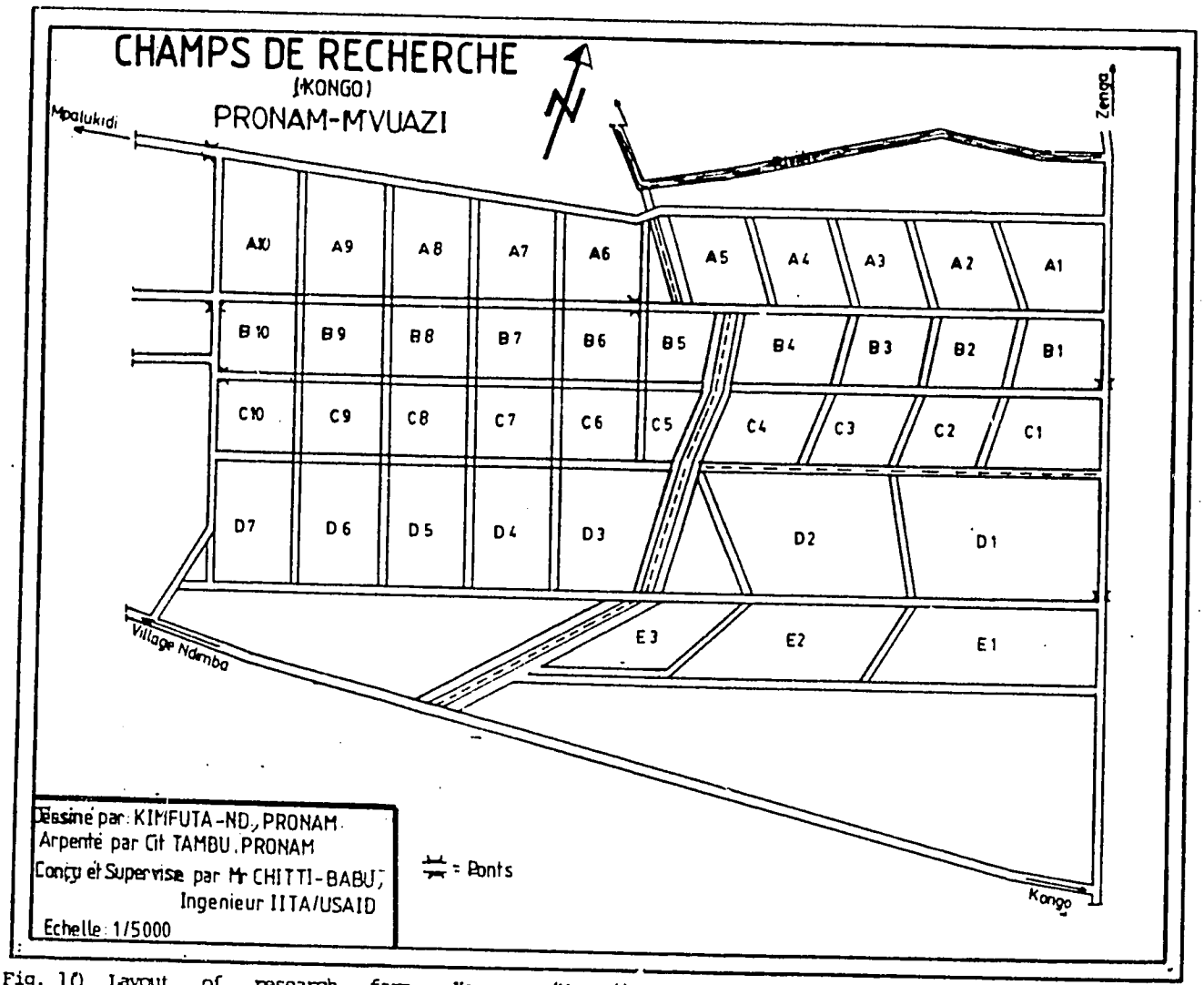

Fig. 10 Layout of research farm, Kongo (Mvuazi)

another landrover and three additional motorcycles. Five 65 horsepower tractors, each with disc plow, disc harrow, ridger, rotary mower and trailer were purchased. At a later date, the Department of Agriculture allocated to PRONAM two 80 horsepower tractors, with disc plows and disc harrows, which were part of a gift from the government of Japan. Other farm implements purchased included fertilizer spreader, herbicide sprayer, tipping trailer and front end loader. A motor grader was bought for road maintenance and land development. Major laboratory equipment acquired included spectrophotometer, laminar flow transfer chamber, large capacity drying oven, five laboratory ovens, Kjeldahl appartus, analytical balance, two dissecting microscopes, water bath shaker and incubator. The workshop was equipped with air compressor, electric arc welder, hydraulic press, drill press, bench grinder, hydraulic hoist, heavy duty hydraulic jack and hand tools. Single side band radio transceivers were purchased and installed at the three stations and the administrative support office in Kinshasa. This provides a communications network essential for proper operation of the Program. Office equipment and furniture were also provided. Thus by the completion of the project, PRONAM had the equipment necessary for transport, all normal farm operations, repair and maintenance of machinery, essential laboratory procedures and office functions.

3.6.4. LIBRARY

Basic reference books and subscriptions to the major scientific journals relating to crop research were requistioned and a library reestablished at Mvuazi

3.7. MAINTENANCE OF MACHINERY AND PHYSICAL PLANT

A problem which had constantly plagued PRONAM in it's first years was lack of trained manpower and equipment to maintain and repair farm machinery, vehicles and physical plant. Finally, in 1979, virtuallly all PRONAM vehicles and equipment were out of order and a physical plant services officer had been hired as a consultant to put them back in operation. The need for such a position in the Project had been evident and a long term position for a physical plant services officer was included in the technical assistance team. When the Project commenced, the consultant assumed this position. As previously mentioned, tools and equipment were purchased to equip a workshop facility. Spare parts were requistioned and a storeroom set up. This provided PRONAM with a full repair and maintenance service at Mvuazi. Staff received day to day on-the-job training in proper repair and maintenance procedures. PRONAM has, in fact, provided an apprenticeship service, training people over and above the Project's needs. At any one time, there may be as many as five trainees who work for PRONAM for several months to obtain practical experience in garage mechanics, etc. As stated earlier, the Zairian Deputy Physical Plant Services Officer spent three months at IITA in on-the-job training in vehicle and farm equipment repair and maintenance and operation and maintenance of physical plant facilities. The effectiveness of the repair and maintenance service which was established is illustrated by the fact that, with only one exception, all vehicle and tractors purchased for the project were in operation at the completion of the project (except for one vehicle put out of service due to a major accident). This included vehicles five years old which had been driven over 200,000 km under very rough conditions and tractors with well over 600 hours of operation.

4. PROBLEMS ENCOUNTERED

The Cassava Outreach Project provided support for an existing program (PRONAM) and incorporated into the design of the Project were measures to alleviate problems which had been interfering with PRONAM's operation and output. However, as could be expected, not all these measures were entirely successful and certain other unforseen problems developed during the course of the Project.

Several of the problems encountered have been previously mentioned. These were:

(a) Long delay in Mvuazi station rehabilitation and it's effect on laboratory and workshop operations, on establishment of a training component and on living conditions of staff. After two years of fruitless attempts to work through government entities for the realization of this work, the problem was resolved by entering into a contract with a private architectural and engineering firm for design, preparation of bid documents, appraisal of bids and supervision of the work and, subsequently, by contracting with private electrical and civil engineering firms for the actual work. (Discussed in Section 3.6.1.).

(b) Insufficient numbers of qualified candidates available for M. Sc. training and unrealistic targets for Ph.D. training. Because of this, advanced degree training quotas were not completely met (Section 3.5.1.) .

(c) Flooding problems on research farm. This was resolved by leasing land outside the station for research and multiplication farms. (Section 3.6.2.) .

Other problems were:

(a) Inadequate budgetary support from the Government of Zaire. Obviously, for the long term sustainability of PRONAM, the Government must assume financial support for the Program. To date this support has been minimal and, in recent years, the share of operating expenses covered by the

Government's contribution has been decreasing. In 1985, Department of Agricul ture funds covered only 5.4% of operating costs. A long term continued effor must be made to demonstrate the value of agricultural research and to influence policy makers to give it a higher priority in the national budget. A noteworthy effort was made in this respect with the U.S. Presidential Agricultural Task Force Mission to Zaire in January 1985. A primary point that was emphasized by the Task Force was the need for proper support for agricultural research.

(b) PRONAM/INERA relationship. From the beginning and until present, PRONAM activities have been carried out on stations that fall under the National Institute for Agricultural Research (INERA). PRONAM was purposely never absorbed into the INERA structure to avoid being ensnared in the cumbersome INERA administration and to avoid the dissipation of funds that would be very difficult to prevent in view of the magnitude of INERA's long-standing budgetary problems. However, there have been a number of problems inherent in this cohabitation with INERA. A primary problem has centered around the question of what facilities (land, laboratories, offices, houses, etc) can be made available for PRONAM's needs. Another problem is that PRONAM is much better equipped and supported than INERA and, as is natural INERA frequently makes demands on PRONAM for certain services. PRONAM feels an obligation to attempt to meet some of these requests but this is often at the expense of efficiency in PRONAM's operations. An attempt is being made to resolve these problems through dialogue with INERA. A convention was signed with INERA in November, 1984 which provides broad guidelines governing the sharing of station facilities. In May, 1985, a series of discussions were held to work out the specific details as they would apply to each station At the completion of the Project, it appeared that the substance of these discussions would be incorporated in an annexe to the general convention that would be acceptable to both parties.

(c) Inadequate salaries of national staff. PRONAM salaries at all staff levels have been undeniably inadequate when viewed against the cost of living and expected work output. In order to retain the trained and dedicated professional staff that has been developed under the Project, it is

necessary to provide a level of compensation commensurate with their training and responsibilities. At the completion of the Project, USAID had reached the conclusion that salary supplements should be paid from counterpart funds and was in the process of formulating a policy to cover this.

d) Inadequate social services. The social services available to staff posted at the research stations have been less than satisfactory. This pertains to health, educational and recreational services and facilities. An attempt has been made to improve health services by upgrading station dispensaries and by working out well defined arrangements with hospitals in the area for treatment of staff and providing necessary transport to these hospitals. The families of most professional staff are still young. However, when their children reach school age they will be faced with a problem of making suitable arrangements for their education because of the relative isolation of the research stations. Efforts have been made to provide some recreational outlets. A social center has been created at Mvuazi and equipped for audio and video entertainment. Arrangements have been made to have video films on a regular basis. Some sports equipment has been obtained. Furthur expansion of recreational facilities (e.g. tennis court) would be desirable.

e) Inferior quality of some equipment. The procedure used for procurement resulted in receiving some farm equipment of poor quality. Equipment specifications were furnished to a purchasing agent who bought the lowest priced equipment with those specifications. The problem lies in the fact that it is difficult to give all the specifications that fully determine the quality of a piece of farm equipment. It is felt that this type of procurement could be best handled if the contractor's recommendations of make and model could be followed.

5. RECOMMENDATIONS FOR ON-GOING ACTIVITIES

The Cassava Outreach Project is being succeeded by a more comprehensive project, the Applied Agricultural Research and Outreach Project which incorporates PRONAM, the National Maize Program, and the National Grain Legume Program. IITA was intimately involved in the planning of the successor project. It's recommendations for the future development of PRONAM, within the Project, are reflected in the Project design and need not be repeated here. However, suggested guidelines for future research efforts are given below.

5.1 GENERAL

a) PRONAM activities at Mvuazi, Gandajika and Kiyaka should be continued and expanded, pursuing the established broad objectives and using the same basic strategy. However, in order to fulfill it's mandate as a national program, PRONAM should extend it's activities to other important ecological zones. It is planned that PRONAM will begin operations next growing season at Kaniameshi station near Lubumbashi in southern Shaba region. Within the limits that financial and personnel resources permit, activities should also be extended to Mulungu representing the higher elevation area of eastern Zaire and to a site in the high rainfall forest area. Within the broad ecological zones, furthur attention should be given to identification of testing sites necessary to represent soil and climatic variability.

b) PRONAM should define the procedures to be followed for release of varieties for widespread multiplication and distribution.

c) PRONAM should attempt to evaluate it's contribution to cassava production. This could be done by the FSR and Outreach elements of the successor project.

5.2. BREEEDING

a) Continue work on breeding for increased levels of resistance to Bacterial Blight, Mosaic and Anthracnose.

b) Intensify efforts to identify sources of resistance to green mite and utilize them in the breeding program.

c) Expand hybridization program for incorporation of mealybug resistance of the clone 70453 into locally adapted high yielding varieties. After sel tion from seedling nursery at Mvuazi,evaluation should also be carried out in Shaba under high mealybug pressure.

d) Develop varieties adapted to intercropping. Rapid early growth and early vigor appear to be important characteristics. If this is verified, it should be taken as an important selection criterion.

e) With the arrival of equipment on order for enzymatic assay for cyanide content, breeding for low cyanide is to be furthur intensified.

5.3. PATHOLOGY

a) Continue to collaborate with the Breeding Section in screening for resistance to Bacterial Blight, Mosaic and Anthracnose.

b) Continue work to determine etiology of stem-tip dieback disorder and develop a method for screening for resistance to the disorder.

c) Continue collaboration with IITA, Ibadan and the University of Wageningen in studies to determine if different strains of cassava mosaic virus exist.

d) Determine factors involved in post harvest deterioration and quantify losses incurred.

e) Make follow-up observations on concentric leaf spot symptoms seen at Gimbi.

f) Investigate the mechanism of resistance to anthracnose and develop a method for screening for resistance to this disease.

g) Investigate factors involved in root rot and develop method for screening for resistance.

5.4. ENTOMOLOGY

a) Conduct controlled field experiments to determine effectivenes of E. lopezi and Diomus sp. in biological control of the mealybug.

b) Continue to import and release new exotic natural enemies of the mealybug and green mite. Check release sites for establishment. Determine effectiveness if established.

c) Continue collaboration with Breeding Section in evaluation of mealybug resistance of progeny of clone 70453.

d) Collaborate with Breeding Section in screening for resistance to green mite.

e) Conduct nation-wide survey for distribution of mealybug and green mite and their introduced and natural enemies.

f) Conduct studies on mechnanism of resistance to mealybug (clone 70453) and green mite (several clones with demonstrated resistance).

5.5. AGRONOMY

a) Implement the FSR program together with the agricultural economists in the new project. This will involve both on-farm and on-station work. On-farm activities will be to identify constraints and to test proposed ways of relieving these constraints. On-station work will be to develop new production techniques to relieve those constraints for which ready solutions are not apparent.

b) Intensify work on alley-cropping. In the Gandajika area, it would appear that work could proceed using tree/shrub species such as leuceana and gliricidia which have been tested and proven elsewhere on soils which are

only moderately acid. For Bas Zaire and Bandundu, species adapted to more acid soils must be sought for evaluation.

c) Follow-up on preliminary indications that moderate rates of lime can result in substantial yield increase of cassava and groundnut, with which it is commonly associated, on the acid soils of western Zaire.

d) Continue to determine the effect of various agronomic factors on the performance of new varieties as they are developed.

APPENDIX A

Theses and Dissertations

Kasele, I.N. 1983. Studies on the Effects of Some Environmental Factors on Cassava (Manihot esculenta Crantz) Tuberization. M.Phil. thesis, University of Ibadan, Nigeria. 152 pp.

Kasu, T. 1984. Effects of Pubescence on the Behavior, Reproduction, and Post-Embryonic Development of the Cassava Mealybug, Phenacoccus manihoti Matile-Ferrero. M.Sc. thesis, University of Ibadan, Nigeria. 72 pp.

Kiala, K. 1982. Screening Cassava for Resistance to Cassava green Spider Mite. M.Sc. thesis. 42 pp.

Kiala, K. 1983. Mechanism and Inheritance of Resistance to the Green Spider Mite of Cassava. M.Phil. thesis. 105 pp.

Landu, B.K. 1981 Timing of Nitrogen Fertilizer Application on Cassava (Manihot esculenta Crantz). M.Sc. thesis, University of Ibadan, Nigeria. 55 pp.

Mahungu, N.M. 1983. elationships among Selected Agronomic Characters and Their Effect on Tuberous Root Yield of Cassava (Manihot esculenta Crantz) Ph.D. dissertation, University of Ibadan, Nigeria.

Muaka, T. 1981. Aspects of the Biology of Mononychellus tanajoa (Bondar) Infesting Manihot esculenta Crantz in Southern Nigeria. M. Phil. Thesis, University of Ibadan, Nigeria.

Mbulu, N. 1981. Residual Effetcts of Different Mulch Materials on Growth of Cassava (Manihot esculenta Crantz) and Maize (Zea mays L.) in the Greenhouse. M.Sc. thesis, University of Ibadan, Nigeria. 60 pp.

Muimba, K.A. 1980. Some Factors Affecting the Susceptibility of Cassava (Manihot esculenta Crantz) to Infection by Colletotrichum manihotis Henn. M.Sc. thesis, University of Ibadan, Nigeria. 80 pp.

Muimba K.A. 1982. Predisposition of Cassava Plants to Infection by Colletochum manihotis Henn. And Some Factors Involved in the Initiation of Anthracnose Disease. M.Phil. thesis, University of Ibadan, Nigeria. 242 pp.

Muyolo, G. 1981. Studies on the Synergistic Relationship between Xanthomonas campestris manihotis (Arthaud-Berthet) Maraite and Meyer and Colletotrichum manihotis Henn. on Cassava. M.Sc. thesis, University of Ibadan, Nigeria. 56 pp.

Muyolo, G. 1984. Studies on the Interaction between Xanthomonas campestris campestris manihotis (Berthet and Bondar, 1915) Dye and Colletotrichum gloeosporoides f. sp. manihotis (Chevaugeon) on Cassava and Its Effect on Yield. M.Phil. thesis, University of Ibadan, Nigeria 229 pp.

Ndombo, D. 1984. Improvement of Cassava (Manihot esculenta Crantz) by Clonal Mass Selection. M.Sc. thesis, University of Ibadan, Nigeria., 92 pp.

APPENDIX B

Scientific Publications and Reports

Ezumah, H.C. and N.B. Lutaladio (1980). Organization and conducting of multilocational cassava evaluation including cultural practices. In: Cassava Production and Extension in Central Africa. Proceedings series Nº 4, IITA, Ibadan, pp. 25-31.

Hennessey, R.D. Rates of parasitization of the cassava mealybug, Phenacoccus manihoti (Homoptera: Pseudococcidae), by Epidinocarsis lopezi (Hymenoptera: Encyrtidae) in western Zaire. Submitted for peer review prior to publication.

Hennessey, R.D., P. Neuenschwander, and T. Muaka. Spread, current distribution and damage of the cassava mealybug, Phenacoccus manihoti (Homoptera: Pseudococcidae), in Zaire. Submitted for peer review prior to publication.

Herren, H.R., P. Neuenschwander, J.S. Yaninek, T. Haug, F. Schulthess, B. Loer, A.M. Varela, and R.D. Hennessey. In press. Cassava mealybug (Phenacoccus manihoti) and green spider mites (Mononychellus spp.) biological control: an example of classical biological control for Africa. In, Proc. Inter. Soc. Tropical Root Crops, Guadeloupe, July 1-5, 1985.

Herren, H.R., R.D. Hennessey, and R. Bitterli (eds.). 1985. Proc. Inter. Workshop on Biological Control and Host Plant Resistance to Control the Cassava Mealybug and the Green Spider Mite in Africa. International Institute of Tropical Agriculture, Ibadan, Nigeria, December 6-10, 1982.

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APPENDIX C

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* Numbers in parentheses indicate participants from PRONAM.