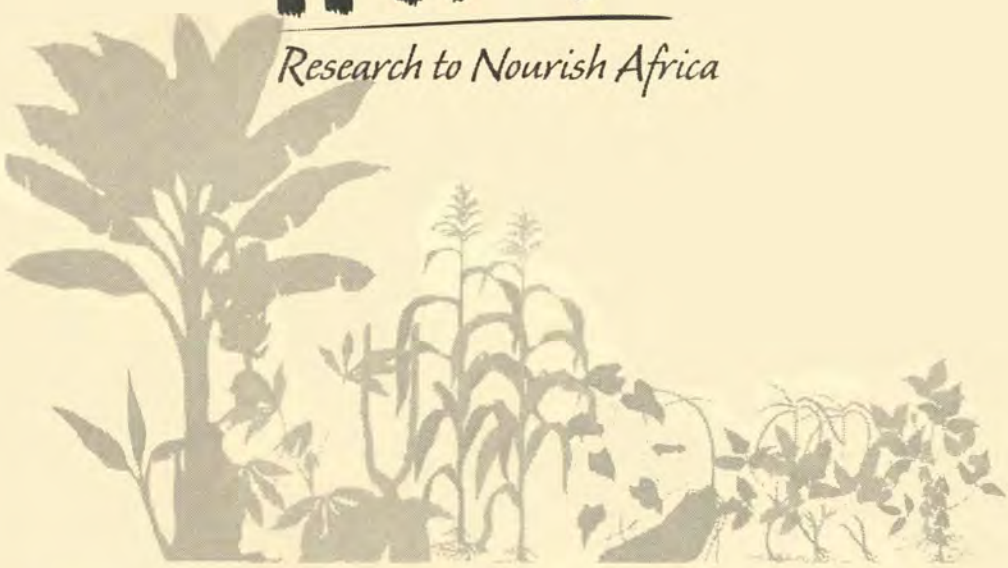
Project E

Enhancing livelihoods in the humid and subhumid zones of West and Central Africa through profitable and sustainable intensification of diverse agricultural systems

Annual Report 2003

IITA

Research to Nourish Africa



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Preface

IITA's research-for-development agenda is divided into six project themes, around which these project annual reports are prepared. These projects themes address different aspects of attaining sustainable increases in productivity of dominant farming systems and utilization practices in the various agroecologies of sub-Saharan Africa (SSA). Research and training activities carried out in the six projects are being implemented together with national program partners in order to increase the well-being of resource-poor people in SSA through higher levels of food production, better income, nutritional status, and reduced drudgery particularly for women.

Project E

Enhancing livelihoods in the humid and subhumid zones of West and Central Africa through profitable and sustainable intensification of diverse agricultural systems

by

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Project goal

Productivity and profitability of diverse agricultural systems increased and environmental services and sustainable management of natural resources improved, contributing to enhanced livelihoods in the humid and subhumid zones of West and Central Africa.

Project purpose

Productive and sustainable food (banana and plantain, cassava, and yams) and tree crop systems, as well as market-oriented peri-urban crop and livestock systems developed in partnership with farmers, NGOs, NARES, and advanced research institutions are adopted and adapted by farmers and agribusiness.

Project rationale

The landscape in the humid and subhumid zones of West and Central Africa is a mosaic of agricultural land use and forest fragments. Agriculture is dominated by traditional mixed cropping patterns that are stratified spatially (niche-specific patterns) and hierarchically (gradients in labor and input use intensity).

The dominant features are starchy crops (plantain, cassava, yam) and tree crops (cocoa, coffee, cashew). The starchy crops are produced as both staple and cash crops and are often cultivated in various combinations with leguminous crops such as groundnut and cowpea or other short season crops such as maize. As one moves closer to urban settlements, vegetable crops and livestock become important market-oriented elements of the production systems. The tree crops are essentially produced as cash crops with various levels of intensification. Tree crops account for a large share of agricultural trade in the region and can contribute substantially to sustaining biodiversity and natural resources.

Starchy crop production systems experience declines in yield due to reduced soil fertility and greater pest and disease pressures. Options for sustainable intensification based on

deploying improved varieties and pest and disease control methods that enhance yield while preventing decline in the natural resource base will be developed.

Post maturity losses occur in the handling of starchy crops before and after harvest, which affect the marketability of the products. Options for reducing losses, extending shelf life, and adding value through postharvest processing will be promoted to enhance and diversify income-generating opportunities for the farmers and the rural community.

Tree crops have traditionally been planted into fully or partially cleared forests in West and Central Africa. Options for rehabilitation or establishment of tree crop farms will be developed for fallow land to reduce pressure on forestland. Also, options for improving access to production inputs and enhancing trade opportunities for smallholder tree crop farmers, including support structures and policy environment, will be developed.

Peri-urban farming is relatively intensive with significant use of fertilizers and pesticides under short or no fallow systems where high-value horticultural crops, indigenous leafy vegetables, green maize, and other crops are frequently rotated with staple food crops and integrated with livestock production. Options for sustainable and profitable management of such systems will be developed while addressing resource use efficiency, as well as reducing environmental and health hazards associated with uninformed use of pesticides.

Thus, Project E aims to maintain and optimize the ecological and socioeconomic functions of this mosaic of agricultural land use and forest fragments, following an integrated producer-to-user approach across commodity chains, in order to enhance and sustain livelihoods by improving opportunities for smallholder farmers.

The project is subdivided into five intervention areas or outputs:

(1) Production to consumption needs, constraints, and opportunities for sustainable and competitive production of diverse crop systems in rural and peri-urban landscapes identified and prioritized.

(2) Prototype options for sustainable and competitive crop production, postharvest, and peri-urban crop–livestock systems developed and verified.

(3) Management interventions for sustainable and competitive crop production, postharvest, and peri-urban crop–livestock systems disseminated and promoted.

(4) Agroenterprise development and market linkages promoted.

(5) Dissemination and adaptation of improved management interventions monitored and their impact on farmers' livelihoods and institutional capacity evaluated.

Outputs

1 Production to consumption needs, constraints, and opportunities for sustainable and competitive production of diverse crop systems in rural and peri-urban landscapes identified and prioritized

Ongoing and future activities

1.1 Analyze production to consumption systems to identify constraints and opportunities along the continuum

1.1.1 Production constraints and opportunities

1.1.1.1 Distribution of plant parasitic nematodes on *Musa* in Nigeria

by D. Coyne and A. Tenkouano

This remains an ongoing activity to establish the geographical distribution of nematodes on *Musa* in Nigeria, and how this relates to previous studies. In neighboring countries, a shift in the community structure of nematode populations on *Musa* shows *Pratylenchus coffeae* to be more prevalent than previously, resulting in more damage to plantain by this specie. In Nigeria, results to date indicated that *P. coffeae* was present but with a relatively low prevalence in comparison to *Helicotylenchus multicinctus* the most prevalent which occurs in great densities. The species currently identified as the most common occurring on *Musa* are *P. coffeae, H. multicinctus, Meloidogyne* spp., *Radopholus similis,* and *Hoplolaimus pararobustus.*

1.1.1.2 Studies on the comparative importance of different plant parasitic nematode species of *Musa* in West Africa

by D. Coyne in collaboration with A. Tenkouano

In a plantain field experiment at Ibadan, Nigeria, the differential pathogenicity of the plant parasitic nematodes: *Pratylenchus coffeae, Helicotylenchus multicinctus, Meloidogyne* spp., *Radopholus similis,* and *Hoplolaimus pararobustus* were inoculated separately onto 25 plants per plot of plantain cv. Agbagba. Data on the mother crop got lost due to early storm damage. Mean plant heights however, were lowest in the *R. similis* and *Meloidogyne* spp. plots and highest in the non-inoculated control and *P. coffeae* plots. *P. coffeae* however, had not established well and the plots can effectively be classed as non-inoculated. Days to flowering were similar across treatments. Data collection continued for the ratoon crops and will continue until plantation exhaustion. Screenhouse pot and microplot studies have been established to support data from the field experiment.

1.1.1.3 Baseline survey of constraints to plantain production in Nigeria

by J. Lemchi and A. Tenkouano in collaboration with NARS partners

A baseline survey was carried out to assess the current status of plantain and banana production and related issues in Nigeria. The study was carried out in 11 states within the plantain producing areas of southern Nigeria namely Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ogun, Ondo, Oyo, and River. The study was located in three rural based local government areas (LGAs) in each of the states, making 33 LGAs. A total of 101 villages were surveyed involving 1010 farm households. The selection of villages and farmers were systematically random. Data collection was carried out at the village and household levels through the administration of structured interview schedules by a team of enumerators drawn from the states agricultural development programs (ADPs), universities, and national research institutes.

It was found that plantain and banana grown by the farmers were predominantly landraces, with about 73 local names for plantain and 80 for banana. Most of the names varied from village to village, with most differences in intonation. For instance, *okirima* and *okinima* for plantain are the same, so also are *ibinooh* and *obinooh;* while *okuyam* and *okuyam, obabuni* and *obagbuni,* and *ogede nigue* and *ogede nigwie,* differ only in intonation and refer

to desert banana. Distinction between plantain and banana was on the basis of finger size whereby plantain was characterized by long fingers in 88% of the villages and banana by short fingers in all the villages.

The farmers identified major factors confronting plantain and banana production in the area. These included pests and diseases, scarcity of suckers/lack of improved planting materials, decline in yield, wind damages, drought, poor soil, scarcity of land, and market related inhibitors. Some of these constraints are presented in Figure 1. As shown in the figure, the problems of pests/diseases and scarcity of planting materials topped the list, followed by transportation and market related problems, and soil infertility.

The problems of pests/diseases (and associated yields decline) can be managed by massive injection of resistant and high-yielding varieties into the farming system. Orientation of farmers on appropriate sound and sustainable crop management practices for plantain and banana will aid in curbing production problems occasioned by poor soil, drought, and lodging (wind). Scarcity of land has been a perennial problem occasioned by increasing population pressure. The problem was more in areas where production was limited to compound farms and increased demand on land for building. However, application of intensive farming approach by cultivating high- and fast-yielding varieties in addition to appropriate management input should reduce the problem induced by scarcity of land. Farmers also suffered from transportation problem due to bulkiness of fruits and suckers as well as high rate of spoilage of the fruits (when ripe). The problem can be effectively managed by processing and converting fresh fruits into other products that added value and extended the shelf life, thereby easing transportation and expanding the market. This is so because most of the processed products of high market value depended on ripe (and over ripe) fruits for their production. The adoption of a decentralized technology delivery system will reduce the distance between the source of planting materials and the farmers thereby curbing the problem associated with transporting suckers (which are bulky) over long distances. The application of rapid and cost-effective methods of producing clean and healthy suckers will greatly reduce scarcity of sucker. The technique is not complex and can easily be acquired by farmers through training.

1.1.1.4 Baseline survey of pests and diseases associated with cassava in the DR Congo

by J. Legg, R. Hanna, M. Toko, D. Coyne, and A. Dixon in collaboration with SECID

Further assessment of the samples received in 2001 showed the occurrence of cyst nematodes (*Heterodera* spp.) associated with cassava from a small number of sites in the DR Congo. Although frequency of occurrence and population density was low, it was the first record of the nematode on cassava in DR Congo and the only second record of nematode on cassava. Species of the nematode damage susceptible hosts, but at the moment, no information exists on the relationship of *Heterodera* spp. on cassava. Continued survey work in the East of DR Congo indicated that root-knot nematodes *Meloidogyne* spp. continued to be the most commonly observed plant parasitic nematodes associated with surveyed fields, with relatively high root damage recorded.

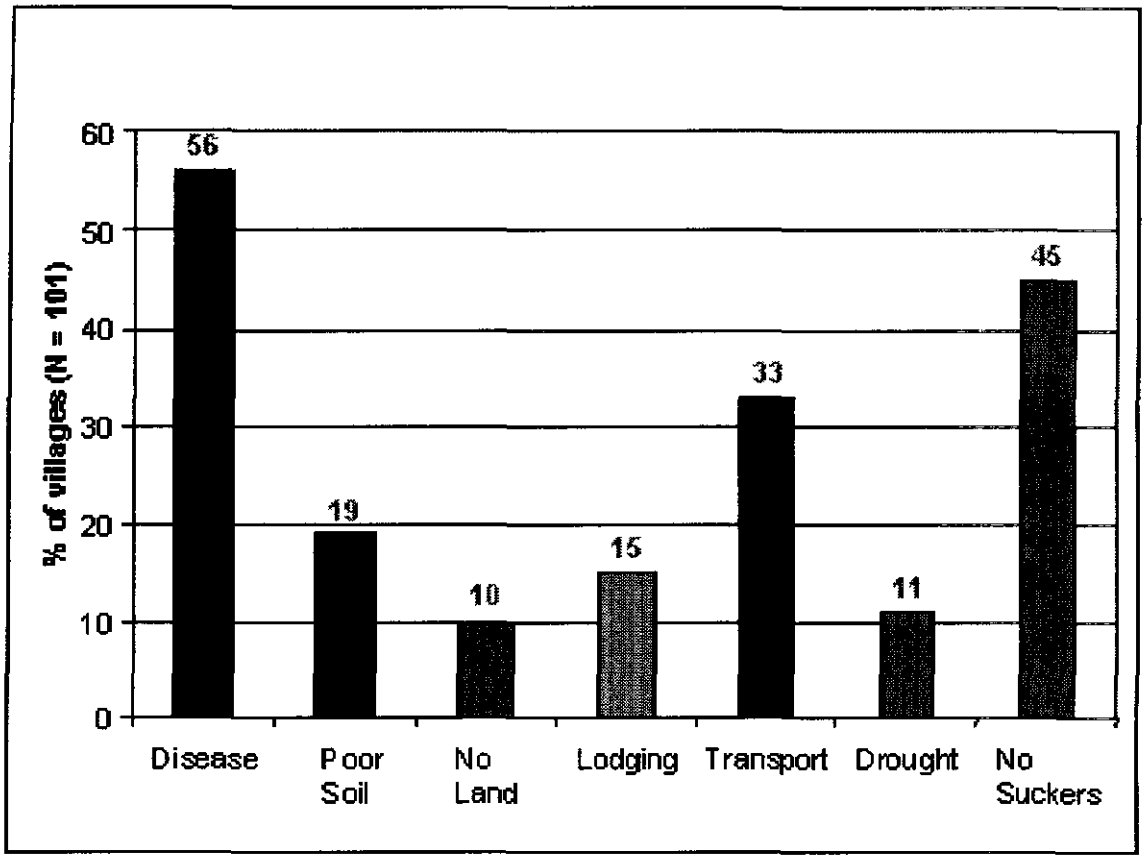

Figure 1. Farmers' perception and assessment of major constraints to the production and commercialization of banana and plantain in Nigeria.

1.1.1.5 Baseline survey of biophysical constraints associated with cassava in southern Cameroon

by C. Nolte, M. Mwangi, R. Bandiopadhyay, D. Coyne, M. Tindo, and R. Hanna

Cassava tuber yields in southern Cameroon were low. The fresh tuber yield in farmers' fields ranged from 5 to 10 Mg ha^{-1}. Such low yield hindered the intensification and commercialization of cassava production. For example, in the Pouma area, halfway between Douala and Yaoundé, UNDP and UNIFEM set up in 1993, a starch-producing factory that could not run at full capacity due to supply problems. Though these were partly due to a wrong pricing policy, the level of production was also far too low. The factory will be revived and IITA was approached to provide assistance in raising cassava production. Poorly adapted germplasm as well as pests/diseases and soil nutrient constraints are expected to limit cassava yield. This diagnostic survey will give insights into the major biophysical problems of cassava in this region. This would also be a basis for designing, together with farmers, targeted intervention trials and provide breeders with information on the kinds of plant characteristics required for intensive production.

Observation plots of 10 x 10 m were established in March/April 2003 in 62 farmers' fields in eight villages (Ngompem, Bihiang, Nkonga, Songsimout, Nkondjock, Sokele II, Pouma center, and Sibongo) around Pouma, a village 141 km southwest of Yaoundé. The villages were selected based on discussions with representatives of the farmer organization AID Cam-

eroon and the *agent de vulgarisation de zone* (AVZ), responsible for the Pouma *arrondissement*. Fields were selected based on cassava planting dates to minimize variation caused by planting date.

Men managed 18 of the 62 fields and women 44. Fallow length prior to planting cassava in 2003 was on average 6.5 years, varying from 0 to 20 years. These fields were cropped in the last 11 years on average 2.52 times, corresponding to a mean cropping frequency of 0.23 (0.09–0.55). Crops accompanying cassava in the observation plots were cocoyam (68%), groundnut (31%), yam (6%), maize (27%), and melon (35%). The average planting density of cassava was 5300 mounds ha^{-1}, ranging from 2700 to 10 900 mounds ha^{-1}, with 2.1 (2–3) cuttings per mound. Almost all cuttings were planted horizontally. Mean mound height at planting was 16 cm, ranging from 10 to 35 cm. The mean length of cuttings used by farmers was 28 cm, ranging from 20 to 35 cm. Farmers planted 1.6 cassava cultivars in these plots, ranging from 1 to 3. A total of 6 local cultivars were determined *Ngaleabomeye, Allot Bikon, Torobiko, Kolobito, Nwerembong,* and *Ndolo Mboa*. Planting was from 10 March through 16 April 2003. By 28 March 50% of the fields had been planted and one quarter between 4 and 16 April.

Root diseases

Observations for stem, root-, and tuber-rots were scheduled at 6, 9, and 12 months after planting (MAP). In each field, five plants were uprooted and inspected for superficial presence of fungi and actual rotting of the tuberous roots. Volume of roots rotted was estimated for each plant and is termed as rot severity. Samples of rotten tissue were collected for isolation and identification of the fungi in laboratory.

At 6 MAP, 41% fields were free from root-rot symptoms. Low level (less than 10% roots rotted) of root-rot was observed in 55% of the fields (Table 1). However, at this early stage of tuber development, more than 50% of root volume rotted in nearly 2% fields. Generally, superficial sign of fungal presence was high on the mother cuttings from where mycelia were seen extending to the base of the stems and to the young tuberous roots. Root-rots are assumed to be of importance only in the later stages of cassava plant growth. Their observation at 6 MAPS in this study underlines their importance in that they attack plants early causing significant yield reduction.

At 9 MAP, 24% fields were free from root-rot symptoms. In nearly 64% of the fields, the rotted roots had less than 10% of their volume spoilt while in 10% of the fields rotted, roots had up to 25% of their volume spoilt. Only about 2% of the fields had up to 50% of the root volume rotted. Complete rotting of tubers was observed in a few plants in Bihiang village (plot #12) and Pouma center (#60). Other fields with severe rotting were in Nkong Njok (#30), Sokele 1 (#39 and #40), and Sibongo (#50). Pathogens isolated from diseased plant specimens so far include *Botryodiplodia theobromae, Macrophomina phaseolina, Fusarium* spp., and *Armillaria* sp.

Preliminary results on the incidence of nematodes associated with cassava at the observation sites, 3 months after planting, indicate that *Meloidogyne* spp. are the most common parasitic nematodes, but at low population density. *Heterodera* spp. were also present at a few sites and should help provide information on the relationship of this nematode with the crop upon harvest.

Table 1. Incidence and severity of cassava root and tuber rots at six and nine months after planting (MAP) in the Pouma area of Cameroon.

Root-rot %	6 MAP		9 MAP	
	Incidence (% no. of fields)	Severity (% no. of fields)	Incidence (% no. of fields)	Severity (% no. of fields)
0	41.4	41.4	24	24
1–10	34.5	55.2	39.7	63.8
11–25	20.7	1.7	31	10.3
26–50	1.7	0	5.2	1.7
>50	1.7	1.7	0	0

Table 2. Percentage fields with different levels of cassava mosaic disease severity at 3, 6, and 9 MAP in Pouma area of Cameroon.

Mean score	3 MAP	6 MAP	9 MAP
1 (disease-free)	0[a]	0	0
1.1–2	0	1.7	0
2.1–3	39	72	93
3.1–4	51	26	7
4.1–5 (maximum disease)	10	0	0

Foliar diseases

Observations for cassava mosaic disease (CMD), cassava bacterial blight (CBB), and cassava anthracnose disease (CAD) on the leaves and stems of plants were scheduled at 6, 9, and 12 MAP. In each field, five plants were visually examined for the presence of different disease symptoms. The severity scores for each disease were taken using a scale of 1 (no symptoms) to 5 (severe).

At 3 MAP, CMD symptoms were observed in all fields (Table 2). Plants in 39% fields were moderately infected (severity 2–3) with mild chlorotic to strong mosaic patterns observed on the leaves. Plants in 51% fields had severe infection (severity 3–4) beginning with leaf distortion and reduction in leaf sizes in some cases. Plants in 10% fields had severe mosaic disease with many distorted leaflets.

At 6 MAP, plants in 72% fields were moderately infected with only mild chlorosis. At this time, plants in 26% fields were severely infected (severity 3–4). This was a reduction when compared to 3 MAP at which time 51% fields had severe infection. At 6 MAP, the highest infection was in field #6 and #7 (Bihiang village), # 49 and #50 (Sibongo village), and # 62 (Pouma Center).

At 9 MAP, plants in 93% fields were moderately infected (severity 2–3) with mosaic symptoms not well established. Plants in the other 7% fields had severe infection. The highest infection was in field #45 (Sokele 1 village), #49 and #52 (Sibongo village) and #62 (Pouma center). In general, CMD severity decreased as the plant age increased. Possibly, as plants grew older and bigger, they became more tolerant to virus infection; hence less severe symptoms were seen on an increasingly less number of leaves.

At 3 MAP, plants in 1.6% fields did not have any symptoms of CBB while plants in 93% fields were slightly infected (severity 1–2), showing only angular leaf spots (Table 3). However, all fields had symptoms of CBB at 6 and 9 MAP. At 6 MAP, infection in 67% fields was severe (level 3–4) meaning that leaf blighting, defoliation, and wilting had started.

Field numbers 29, 30, 34, 35, and 36, all located in Nkong Njok village, had the highest infection. Plants in the other 33% fields had moderate infection (level 2–3).

At 9 MAP 55% fields had severe infection (severity 3–4) while 43% had a moderate level of CBB infection. Only 3.5% fields had plants with slight infection, which was an improvement as compared to 6 MAP. Plants with the highest infection were in field #15 and #17 (Nkonga village); #29, #30, and #31 (Nkong Njok village); and #52 and #53 (Sibongo village).

Data from the table showed that more plants were more severely infected at 6 MAP than at 9 MAP. This could be due to the fact that data for 6 MAP was recorded in October when the weather was wet and therefore favored bacterial infection. Data obtained so far indicated that CBB is still an important disease and can reduce cassava productivity.

Table 3. Percentage fields with different levels of cassava bacterial blight severity at 3, 6, and 9 MAP in Pouma area of Cameroon.

Mean score	3 MAP	6 MAP	9 MAP
1 (disease-free)	1.6[a]	0	0
1.1–2	93	0	3.5
2.1–3	5	33	43
3.1–4	0	67	55
4.1–5	0	0	0

Table 4. Percentage fields with different levels of cassava anthracnose disease severity at 3, 6 and 9 MAP in Pouma area of Cameroon.

Mean score	3 MAP	6 MAP	9 MAP
1 (disease-free)	82[a]	0	0
1.1–2	18	14	14
2.1–3	0	65	71
3.1–4	0	19	15
4.1–5	0	2	0

At 3 MAP, 82% fields had no symptoms of anthracnose infection while plants in the other 18% fields showed only slight infection with cankers mostly on the lower part of the stem (Table 4). At 6 MAP, anthracnose symptoms were observed in all fields but the severity of infection varied between fields. Plants in 65% fields had moderate infection (severity 2–3), meaning cankers were just beginning to spread from the lower to the mid part of the stem. Plants in about 20% fields had severe infection (above level 3) with cankers spreading completely to the green part of stem. Most severe infection was in field #2 in Ngompem, #46 in Sokele 1, and # 54 in Sibongo village.

At 9 MAP, plants in 71% fields had a moderate level of infection (severity 2–3) meaning that in most cases, cankers did not spread to the mid part of the stems. On average, infection appeared to be the same at 6 and 9 MAP. This was different from the significant increase in severity observed between 3 and 6 MAP.

The spread of the fungus causing anthracnose could have been increased by the wet weather experienced between 3 and 6 MAP. These data showed that anthracnose was present on cassava plants in farmers' fields, and the disease had the potential to increase to severe levels particularly under suitable weather.

The trial continued, looking at how farmers' harvesting practices related to the occurrence of fungal rots, and studying whether fungal rot incidence and severity varied with varieties. It is anticipated that data obtained at the one-year stage and thereafter when harvesting started will indicate if root-rots were a constraint to cassava production. More data of the severity of foliar diseases will be recorded so as to determine progress of the different diseases over the entire cassava-growing season and to determine if there was a relationship between cassava yield and disease severity.

1.1.1.6 Diagnostic survey of begomoviruses causing cassava mosaic disease in Nigeria

by F.O. Ogbe, A.G.O. Dixon, J. Hughes, and F. Alabi

Cassava mosaic disease (CMD) is a major biotic constraint of cassava production in Nigeria. It has so far been associated with the begomoviruses African cassava mosaic virus (ACMV) and East African cassava mosaic virus (EACMV), but threats of a more severe form of the disease are now posed by a Ugandan variant of EACMV (EACMV-Ug). Therefore, a project for preemptive management of this severe form of CMD was initiated. An aspect of the objectives of this project is to determine the present status of cassava begomoviruses in Nigeria and specifically to ascertain whether or not EACMV-Ug has already spread to Nigeria. This report presents information on the status of cassava begomoviruses and their distributions in Nigeria, and the whitefly vector populations and their distributions. Thus providing comprehensive information on suitable sites for the screening of cassava for resistance to CMD.

During the diagnostic survey, 418 farmers' fields were visited across the country from which cassava leaf samples were collected from 1397 plants (one sample per plant). Of the 1397 plants, 1106 had CMD symptoms and the remaining 291 plants were symptomless. The average population of the whitefly vector *Bemisia tabacci* per plant per farmer's field was recorded. Samples of the whitefly vectors were collected from 283 farms. The leaf and whitefly samples were tested by polymerase chain reaction using ACMV primers ACMV-AL1/F/AR0/R, EACMV primers UV-AL3/F/AL1/R2 (Zhou et al. 1997). EACMV Ugandan variant (EACMV-Ug) primers UV-AL1/F1/ACMV-CP/R3 (Harrison et al. 1997). Leaf samples that did not react with these primers were further tested using primers for the detection of Indian cassava mosaic virus (ICMV): ICMV-F1/R1 (Ogbe et al. 2003), South African cassava mosaic virus primers (SACMV): SACMV-CP 5'/ SACMP-CP 3' (Berrie et al. 1998), and a pair of universal primer that can detect some whitefly-transmitted geminiviruses: PRIMER A/B (Deng et al. 1994).

Among the 1106 symptom-bearing leaf samples, 74.1% tested positive for ACMV alone, 0.3% for EACMV alone, 24.4% for mixed infections by the two viruses, and 1.2% did not react with any of the primers. Of the 291 symptomless leaf samples, 27.2% contained ACMV alone, none tested positive to EACMV, 4.8% for mixed infections by the two viruses, and 68.0% contained no virus. The two viruses singly and in mixed infections were also detected in the whitefly vectors across the country. EACMV-Ug was not detected in any of the leaf and whitefly samples.

Mixed infections by ACMV and EACMV were almost uniformly distributed in the southeast, south south, and southwest geopolitical zones. The middle belt geopolitical zone had an appreciable number of farms with mixed infections of the two viruses while such infections were few and sparse in the northeast and northwest geopolitical zones. In the last two zones, single infection of ACMV predominates. Symptom-bearing plants in which no

virus could be identified occurred in 13 farms. Nine of such farms were in the southwest geopolitical zone, three in the middle belt, and one in northeast. The distribution of farms in which CMD was either moderately severe or severe was similar to the distribution of farms in which ACMV and mixed infections of ACMV and EACMV occurred.

Most farms in the south south, southeast, and southwest geopolitical zones had whitefly populations that ranged from 5 to 500 per plant. However, most farms in the middle belt, northeast, and northwest zones had low whitefly populations of between 0 and 4 per plant. The high proportion of plants with mixed infections by ACMV and EACMV that characterized the farms in these zones, coupled with the widely distributed moderate and high whitefly populations, made the screening of cassava for resistance to CMD in the three zones more suitable than in any other part of Nigeria.

1.1.1.7 Assessment of the importance of nematodes as constraints to cassava production

by D. Coyne in collaboration with J. Whyte, IITA; A Dixon, IITA; T. Munga, KARI, Kenya; and M. Ogunlolu, University of Ibadan, Nigeria

Trials established in East and West Africa to assess the yield difference of cassava between nematicide-treated or not treated in *Meloidogyne* spp. infested soils, provided limited insight into the relationship of the nematodes and cassava production. Initial analysis of data showed a high level of root-galling damage, at least in some sites, but also a high degree of variability of crop growth parameters within sites and between sites, and little yield differences in yields between treatments. Controlled pot and microplot experiments using inoculations of *Meloidogyne* spp. provided strong evidence of the pathogenic nature of these nematodes on cassava. However, under more natural conditions in the field, the relationship between nematode and crop was more difficult to elucidate. Analysis of the data continued, while more controlled studies under field conditions were laid down in 2003 to assess more closely the damage threshold levels of *Meloidogyne* spp. on cassava.

1.1.1.8 Assessment of the interaction between fungal root-rots and nematodes on cassava

by R. Bandhyophadhyay and D. Coyne in collaboration with A. Dixon, IITA and A. Rotimi, University of Ibadan, Nigeria

A field trial established at Ibadan and harvested in 2003 was to observe the development of fungal root-rot and nematode damage on cassava roots and tubers over 12 months through monthly destructive sampling within plots. Due to relatively low rot incidence, harvest was further delayed to provide an opportunity for rot damage to increase. Results are yet to be compiled but root-galling damage caused by *Meloidogyne* spp. was relatively severe across the trial area, increasing as time progressed. Supporting experiments carried out in pots showed that where the rot fungi *Botrodiplodia* spp. and *Meloidogyne* spp. were inoculated in combination in the same pots, either simultaneously or before or after the other, galling damage and rot incidence was greater ($P \leq 0.05$) than where either was inoculated alone. This was even though cassava infected with *Botrodiplodia* spp. reduced the development of *Meloidogyne* spp. in the roots, probably through prevention of nematode invasion.

1.1.1.9 Analysis of the pathogenic and genetic variability of *Scutellonema bradys* on yam in West Africa

by D. Coyne in collaboration with V. Williamson, UC Davis, USA; B. Hugues, University of Pretoria, RSA; and A. Tchabi, University of Lomé, Togo

During 2003 planting season, a survey was carried out on yam nematode collection across the yam-growing belt of West Africa, complimenting the collections undertaken in Nigeria and Bénin in 2002. Collections were made from Togo, Ghana, Burkina Faso, Mali, and Côte d'Ivoire to assess the extent of infestation of *Scutellonema bradys* on yam within the region. Additional information was also taken for *Meloidogyne* spp. Nematode damage was visually assessed from external symptoms at market stalls. Nematode infestation of yam collected from markets and expressing visual symptoms of nematode damage were assessed at Cotonou Station and pathogenicity studies carried out in pots for 16 geographic isolates under contained quarantine conditions. Visually observed nematode damage was greater in Ghana than in Mali, Burkina Faso or Bénin. Visual damage assessment was not undertaken in Togo or Nigeria, while it was not possible to visit Côte d'Ivoire. Samples from Côte d'Ivoire were made from limited exports found in Mali and Burkina Faso. Mean *S. bradys* population densities, across cultivars, were greater in Bénin than other countries at 397 nematodes per 5 g tuber peel, and lowest in Togo with 20 nematodes. Agroecological zone and densities were greater in the mid altitude savanna, followed by the southern Guinea savanna than other zones with 901 and 496 nematodes per 5 g tuber peel respectively. There was substantial variation in nematode density between identified cultivars within countries, although the names of cultivars varied between country and within countries, making it difficult to analyze. Reproductive fitness assessment of the different geographical isolates on yam pieces proved unsuccessful, due to contamination. Further mediums are currently being assessed to enable reproductive fitness assessment between the different isolates. Molecular assessment of individual nematodes, showed considerable DNA polymorphisms within and between populations, using the DNA from the D1 domain of 28S rDNA, IGS of rDNA, ITS of rDNA, and mitochondrial CO1 gene, with most variability appearing within the nematodes from Bénin. Assessment of nematodes from all countries has not been finalized. Data from the molecular analysis will be related to the epidemiological data and further compared with morphological measurements.

1.1.1.10 Knowledge of maize pests in the different copping systems of the humid forest zones of Cameroon

by A. Chabi-Olaye and C. Nolte (IITA), F. Schulthess (ICIPE), and C. Borgemeister (Univ. of Hannover)

Pests and diseases limited maize yields, reducing quality and quantity of pre- and post-harvest maize as well as poor soil fertility, often as a result of short fallow periods. The most notorious insect pests are stem and ear borers such as *Busseola fusca* (Fuller) and *Eldana saccharina* (Walker); and to a lesser extent, *Sesamia calamistis* Hampson (Lep.: Noctuidae) and *Mussidia nigrivenella* Ragonot (Lep.: Pyralidae). Comprehensive IPM research programs are underway in several African countries. Work focuses on host plant resistance, biological control, and habitat management technologies, such as management of soil nutrients, trap plants, and mixed cropping. The present project seeks to develop a systems-based plant protection strategy, which can respond to pest-related production constraints in maize farming systems, particularly in the humid forest margins of Central Africa. Emphasis is given to *B. fusca*, the predominant pest in the region. Major objectives

are an assessment of how intercropping and/or increased soil fertility can reduce stem borer damage and increase yields of field grown maize as well as elucidate underlying control mechanisms with particular emphasis on the role of natural enemies such as egg and larval parasitoids. A secondary objective is the assessment of the role of inland valleys, often planted with maize during the off-season, as reservoirs for pests and beneficials (mainly parasitoids). We focused attention on their role in the invasion of upland maize fields by borers and their parasitoids during the growing seasons.

Results of the surveys of mixed and fertilizer field trials provided valuable information for the control and management of stem borers in the humid forest zone of Cameroon. Forty-seven (95.9%) of the 49 inland valley maize fields visited were infested by stem borers. The percentage of field infestation ranged from 5 to 75%. During the dry season, *B. fusca* egg batches were collected in 30% of the fields visited. The average number of plants with eggs was 10% indicating that moths fly during the dry season. The egg parasitoid species *Telenomus* was found in about 80% of infested fields. Four percent of all egg batches collected were parasitized. *B. fusca* was the predominant specie and accounted for 95% of total borer species collected. *B. fusca* egg density increased significantly with season while the average *B. fusca* larvae density was highest during the second season. The analysis of *B. fusca* larvae dispersion resulted in an aggregation index greater than one for each season and across all seasons, indicating an aggregated distribution of *B. fusca* larvae in maize. Taylor's coefficients (b) did not vary significantly, indicating that *B. fusca* larvae had the same spatial distribution from one season to another. Multivariate analysis of the survey data generated hypotheses on the interactions among inland valley fields and upland fields. Although population of borers and their natural enemies in inland maize fields were low, our findings showed that *B. fusca* can be active in the area throughout the year, suggesting that inland valleys maintained carry-over populations of not only *B. fusca*, but also of its natural enemies. Hypothesized, inland valleys of Cameroon non-diapausing *B. fusca* were mainly responsible for the fast seasonal build-up of parasitoid populations on upland maize. More detailed population dynamic studies in selected inland valleys and adjacent upland maize fields are under way. Moreover, the migration pattern of *B. fusca* is being monitored in three inland valleys with pheromone traps. These investigations were a first attempt to study the flight activity of *B. fusca* in the forest zone of Cameroon, and if the results supported the migration hypothesis, more in-depth investigations would be carried out to generate a direct proof for migration, e.g., via mark-and-recapture trials.

1.1.1.11 Identification of constraints in seed yam production, farmers' perception of disease pressure, and demand for quality seeds

by K. Amegbeto

Pests and diseases on yams diminish their economic importance as food and source of income for producers. Economic losses due to damages span the production cycle and may be recorded in the form of poor germination, yield losses, rots, and/or reduced fresh tuber quality in both the field and in storage. Because seed yam is a medium for the transmission of many diseases, maintaining its quality is a major challenge in the production system. In many locations, farmers through their experiences have developed technical knowledge systems and coping strategies to deal with these issues. However, farmers' perception of pest and disease pressure and their knowledge systems have not been properly documented to develop sustainable solutions to pests and diseases control. Equally, the demand for

healthy seed has not been assessed to determine the opportunities for promoting community-based or private seed multiplication and commercialization schemes. The objective of this investigation was to document current practices of seed and yam production systems, and farmers' perception and coping strategies against disease constraints. Furthermore, this paper estimated the potential demand for quality seeds in the yam-growing areas in Kogi and Ekiti states, Nigeria.

Rapid rural appraisals (RRA) were conducted in Igalamela, Ofu, Ibaji, and Idah yam-producing zones in Kogi and eight extension blocs (Aramoko, Elawe, Efon, Ijero, Ifaki, Ipere, Igogo, and Are) in Ekiti. A formal survey followed these group assessments. Because a sampling frame listing the population of yam producers was not readily available, a stratified random sampling technique was used in the formal survey. Within each bloc that represented a stratum, yam producers were selected randomly to form the final sample that included 127 farmers from Ekiti and 100 farmers from Kogi states.

Constraints in yam production and demand for healthy seeds

Yams are produced on upland and lowland areas in Ekiti, in mixed cropping with maize, cassava, and vegetables. Farmers have two planting seasons yearly early-planting (September–November) and late-planting (March–April). Some farmers noted that early planting yields higher than late planting but disease pressure was higher and therefore, about one third of the seeds planted early did not germinate. They also indicated that less than one out of 10 farmers in a given village in Ekiti would have surplus seeds to sell to other farmers in a good year. About 10–20% of all farmers were self-sufficient in seed production, whereas majority of them had to source for additional seed yams each year. Milking of early-maturing varieties to produce a second harvest of seed tubers and cutting whole tubers into seed setts are the two methods of seed yam production in Ekiti and Kogi. Few farmers (4% only in Ekiti) mentioned seed production using the minisett technique. Low rate of seed yam germination, lack of financial capital, insufficient seed and labor were some of the constraints affecting at least 50% of yam producers in the two locations. Farmers in the two states equally enumerated financial constraint, whereas poor seed germination affected more farmers in Ekiti, nonavailability of seed affected more farmers in Kogi.

At the farm household level, the estimated demand for seed yam of the average farmer was 811 seeds in Ekiti and 1075 seeds in Idah. This corresponded to the average number of yam heaps planted, combining all species and varieties. Based on the estimated standard errors of the sample means, 95% of the effective demand by the average producer in the population of farmers was within the range of 740–880 seeds in Ekiti, and 950–1200 seeds in Kogi. These levels of effective seed demand provided evidence of the small-scale nature of yam production in the two locations where the average number of heaps planted varied between 0.15 and 0.2 hectares.

The estimated number of additional heaps farmers would like to plant if they had sufficient seed yam and under the same conditions of labor and financial resources available for farming were 8219 heaps in Ekiti and 2706 heaps in Kogi. Most farmers in the samples (median) indicated an additional 4000 heaps in Ekiti and 2000 heaps in Kogi. The most preferred yams in Ekiti (Elesu, Aro, Gbakumo, and Gambari) cost higher prices (about N 3000–5000 for a set of 200 seeds) compared to other varieties. The least demanded varieties were Oolo (*TD. cayenensis*), Ewura, and Esuru (*TD. dumetorum*). In Kogi, the Ekpe and

Ugah varieties were much appreciated and highly priced on market. Yams have been cited as one of the two most important crops for assuring households' food security. Farmers (89.5%) in Ekiti and (94%) in Kogi rated them as the most important commodity for their well-being. These results showed the importance of quantitative and qualitative availability of seed yam as a constraint in production. The potential demand for seed yam in the two states is at least twice as much as the quantities currently planted.

Farmers' perceptions of disease constraints

Farmers recognized during the focus group discussions the symptoms of attack on yams caused by nematodes, insects, viruses, fungus, and bacteria. They reported additional symptoms such as multiple shoots that did not develop any vine, leaf beetle, die-back caused by a larvae that feeds on the vine pit and latter kills the plant, and small millipedes that feed on tuber flesh. In Effon village, Ekiti, the virus symptom that caused yellowing of the leaf similar to plant senescence was not recognized as a disease.

Farmers made a difference between high-grade quality seed and low grade ones through visual inspection; the acceptable seed yam tuber must be neat. Most farmers in Ekiti indicated that larger seeds commanded higher prices and that appearance was an important factor that determined the price level. A lower number of producers in Kogi (68%) agreed on the positive correlation between size and price but equally (99%) indicated the importance of seed yam appearance. Beside the use of appearance as selection criterion that is mostly appreciated through the smoothness of the skin, absence of cracks, disease attacks, and physical damages, farmers looked for parameters such as weight, symptoms of dormancy breakage or ability to germinate, and size. The preference was for a whole seed that was neither too small nor too big. Seed availability in quantity and quality was a major problem in the zones. In Ekiti, farmers were able to differentiate between planting seasons with respect to disease incidence. Accordingly, the seed health issue was more acute during early planting (September–November). Results of a quantitative assessment of differential impacts of seed quality on yields showed that 41% of farmers in Ekiti and 50% in Kogi, thought a top grade seed would yield two times more than a low grade seed; while 32% of farmers in Ekiti and 40% in Kogi believed it would be three times higher.

In addition to the combination of traditional and modern techniques of crop protection, farmers exploited the genetic diversity of yams to manage or reduce the risk of crop failure, insufficient food production, or income generation on their farms. At the village level in Ekiti, the number of yam varieties grown ranged from 10 to 23 varieties, while more than 80% of farmers interviewed planted simultaneously the Aro, Gbakumo, Elesu, and Adjimokun varieties. The extent of varietal diversification on farm was lower in Kogi compared to Ekiti.

Farmers' assessment of the vulnerability of yam varieties to diseases

The process of growth in yams could be easily suppressed depending on the genetic material or if the seed was not properly stored, protected from physical damage, or from pests and diseases. Lack of germination represents the first stage of economic losses that occur in yam production. Estimated, 90.2% of farmers interviewed in Ekiti and 50% in Kogi indicated they had had a problem with seed germination during the 2003 growing season. The prevalence of this problem varied across the study zones as well as across yam varieties. Among seven yam varieties that were planted by at least two third of the farmers interviewed in

Ekiti, seed lost resulting from lack of germination was highest for Madurodojo and Elesu (17–19%), followed by Aro, Gbakumo, Dagidagi, and Ajimokun. While the resistance of a particular variety could not be assessed though these results, they indicated that varieties widely cultivated by farmers were also subject to greater losses due to nongermination of seed. On average, 30% of the Olegbe seeds planted did not germinate and to a lesser extent the Opoko variety in Kogi.

Conclusion

The results showed that farmers had knowledge about most yam pests and diseases, their impact on production, therefore, were looking for solutions. Most farmers believed they could improve crop yields through the use of quality seeds but effectiveness of the traditional methods used in treating diseases was questionable and needed serious collaborative evaluations. Madurodojo and Elesu varieties in Ekiti and Olegede variety in Kogi had the highest rates of poor germination. They qualified for technical testing against different pest and disease control methods, for ease of breaking dormancy, and the economic viability of these tests need to be assessed. Beside the application of indigenous and conventional knowledge, varietal diversification was also used to reduce disease pressure and the risk of insufficient food production in yam cultivation. The demand for the quality seed yams was at least twice the level of current demand in both Ekiti and Kogi states. Farmers increased the scale of yam production when healthy seeds were available, promoting healthy seed multiplication schemes in the two locations.

1.1.1.12 Evaluating potentials for crop–livestock integration in urban and peri-urban agriculture of Yaoundé

by C. Nolte in collaboration with T. Dongmo (IRAD), J. Tchakounté (IRAD), J.M. Fotso (IRAD), R. Meffeja (IRAD), A. Zoyuim (IRAD), H. Lekané (Univ. of Dschang), and R. Brummett (ICLARM)

The integration of agriculture and livestock production is one of the oldest agricultural practices in rural areas, yet at present, this has not been achieved to large extent in the UPA of Yaoundé. Rearing small livestock in the backyards is a common and supplementary activity, constituting an important source of animal protein for human nutrition. Equally, livestock is often used as a gift or for religious purposes (sacrifice). Manure, used in crop production, notably intensive production of traditional leafy vegetables and other horticultural crops, entails the application of chicken and pig manure, applied at rates ranging from 7 to 20 tonnes per hectare per year. Farmers preferred manure purchased from the market because of its high cost of mineral fertilizers. A 35–40 kg bag of chicken manure sold for between FCFA500 and 1500 in the Yaoundé market, compared to FCFA12 500 for a 50 kg bag of N-P-K fertilizer (20-10-10). The total production of chicken manure in the urban area of Yaoundé was estimated at 7000 tonnes per year (Gockowski et al. 2000). However, the largest part was transported towards the western province, because there, a bag sold for between FCFA2000 and 2500. Total amount and price indicated the potential and economical value of animal manure around Yaoundé. Apart from manure, industrial by-products such as brewery wastes were used as animal feed in poultry, piggery, and fishery, for which 1000 producers registered with the brewery in Yaoundé. Total production was estimated at 15 000 t/yr.

Up to date, little information is available about the extent, function, and constraints of crop–livestock integration. Furthermore, farmers' interest on such integration at the farm level was misunderstood. The objective of this study was to characterize the swine and chicken production and their potential for integration with agricultural production in the urban and peri-urban areas of Yaoundé. Urban Yaoundé comprised six agglomerations (Yaoundé I–VI), including Ngoulemekong, Afanayo, and Abom, hence nine agglomerations, divided into 51 quarters, correspond to old villages.

Peri-urban Yaoundé covered Soa, Esse, Afanloum, Edzendouan, Nkolafamba, Mfou, Awae, Assamba, and Olembe. Urban and peri-urban Yaoundé falls within the Mfoundi Division covering an area of 297 km^2. Data were collected from agricultural census, export statistics, interviews with key informants, and published and unpublished reports. In addition, survey data were also collected from 150 chicken and swine producers, 75 for each category in all 11 quarters of the 16 subdivisions *(arrondissements)* of Yaoundé, as well as four peripheral zones. Producers' were selected based on a stratified random sample along seven major axes crossing Yaoundé from the central post office.

According to national statistics, 70% of chicken and 50% of pigs of the Center province were produced in the Mfoundi division. This heavy concentration of animal production around Yaoundé was due to insufficient and decrepit road network in rural areas as well as better access to vaccines.

Within urban Yaoundé, intensive animal production was concentrated in Ahala, Mimboman, Etoug-Ebe, Biye-Massi, Mendong, and Simbock quarters. Quarters with medium intensity of animal production were Messa–Carrière, Nkolbisson, and Oyom Abang. Thus, the more one approached the center of Yaoundé, the less found animal production.

More than 80% of animal production in these areas was geared towards chicken (broilers and hens) and pigs, with almost equal distribution between urban and peri-urban areas for all three categories. However, small production units with < 500 broilers/hens per production cycle were found in the urban areas, whereas big production units (> 500) were located in the peri-urban zone. Small production units accounted for > 90% of the broiler and around 10% of the hen production. About 5% of the broiler producers accounted for 45% of the total broiler production. Women, 80% of which were between 20 and 50 years, produced 65% of chickens. Men produced 78% of pigs, 55% of them were over 50 years, hence retired. The total number of pigs in the Mfoundi division was estimated at 50 000 $year^{-1}$, broilers at 710 000 $year^{-1}$ and hens at 200 000 $year^{-1}$. These data provided an estimate for manure production. A pig, mainly fed with food leftovers, supplemented by chaff, produced 600–700 kg fresh excrements $year^{-1}$. Hence, 50 000 pigs produce 4320 tonnes of dry manure. Broiler and hens, fed mainly with maize and soybean, supplemented by fishmeal, produced 157 g and 173 g of fresh excrements day^{-1}, respectively. Thus 710 000 broilers produced 2006 tonnes of dry manure $year^{-1}$ and 200 000 hens produced 3780 tonnes of dry manure $year^{-1}$. The total manure production in Mfoundi was estimated at 10 100 tonnes of dry matter $year^{-1}$.

Vegetable growers in this region used one part, sold another part to the northwest province, notably Bamenda, where chicken manure fetched a higher price (between CFA1500 and 2500 per bag "Bandjock" and CFA700–1200 per bag in the Yaoundé market), and dumped the other part into the environment. Temple et al. (2003) estimated that vegetable growers in Yaoundé used 228 hectares of inland valleys while Damesse et al. (2003) estimated 245 hectares. Dongmo and Hernandez (1999) stated that vegetable growers used 40 kg of

manure for 12m² of vegetable land, whereas Gockowski et al. (2003) stated 35 kg for 15m². Thus for 245 hectares, 4084 tonnes of manure was used with an estimated two cycles per crop and 50% of farmers cropping and using manure. A total of 6125 tonnes of manure was used for vegetable production in Mfoundi, equalled 61% of the total production. About 10% of the manure was sold off to the northwest province while 71% was used for agricultural production, and 29% or about 3000 tonnes dumped into the environment. Calculating the average nutrient contents used for these manures were 180 tonnes of N, 48.5 tonnes of P, and 45 tonnes of K.

1.1.2 Consumption constraints and opportunities

1.1.2.1 Household food consumption, malnutrition, and micronutrient deficiencies in children under-five, women of childbearing age, and pregnant women in Nigeria: results of the Nigeria Food Consumption and Nutrition Survey

by B. Maziya-Dixon in collaboration with I.O. Akinyele, R.A. Sanusi, E.B. Oguntona, and E. Harris

Paucity of data available was the first problem encountered in attempts to assess the prevalence of malnutrition globally, regionally, or nationally. The data currently used in nutrition circles in Nigeria were fairly old and drawn from different surveys of diverse or different methodologies and techniques, or notably focused on specific aspects of nutrition. IITA therefore conducted a Food Consumption and Nutrition Survey in collaboration with the Federal Government of Nigeria (FGN), the United States Department of Agriculture (USDA), and various universities and institutions in the country nationwide. The survey was national in scope. Data on the nature and extent of food security, food and nutrient intake, and anthropometric and biochemical parameters were collected and used to determine the nutritional status of women and children in rural and urban areas in Nigeria. The survey design targeted the whole of Nigeria. Nigeria was initially stratified according to major AEZ and predominant food crops within AEZ, because of the obvious and documented relationships between (a) the agroecological zone (AEZ) and type of farming systems; (b) crops grown and foods consumed; and (c) type of food consumed (intake) and micronutrient deficiencies. A total 12 states, 72 local government areas, 216 enumeration areas, 6480 households including a mother and child pair were sampled.

Nationally, most households indicated that staple foods were available to them for 9–12 months (Table 5). It was observed that especially within the 9–12 months range, the percentage of households that could afford the foods was usually lower than the percentage that indicated availability.

The most available staple foods that are major sources of energy (calories) were rice (14.8%), cassava (12.9%), maize (10.6%), and yam (10.1%). Cowpea, groundnut, and soybean are major sources of plant proteins. Cowpea was the most available, followed by groundnut, and soybean.

Table 6 shows that, overall, maize was the most consumed staple with 20% of the studied population consuming it at various numbers of times in a week, either as maize grain that had been processed to flour or as green maize. Other staples with a high frequency of consumption included cassava (16.5%), rice (14.9%), cowpea grain (11.8%), groundnut (11.1%), and yam (10.4%). The staples with relatively lower frequencies of consumption were sorghum (6.6%), plantain (5.9%), and soybean (2.6%).

Table 5. Percentage distribution: availability and affordability of major staple foods at the national level.

	1–4 months		5–8 months		9–12 months	
Staple food	Available	Affordable	Available	Affordable	Available	Affordable
Cassava	1.58	2.87	2.09	2.30	12.90	11.04
Cowpea	0.08	0.68	0.16	1.14	10.75	9.47
Groundnut	0.31	1.12	0.77	1.39	9.31	8.11
Maize	6.11	7.81	2.62	3.00	10.62	8.66
Plantain	0.21	1.01	0.98	1.33	4.74	3.50
Rice	0.16	1.45	0.21	1.19	14.83	12.30
Sorghum	0.06	0.57	0.19	0.94	6.03	4.80
Soybean	0.02	0.31	0.18	0.28	2.87	2.12
Yam	0.50	2.14	1.52	3.10	10.13	6.80

Table 6. Frequency of consumption of staple food crops at the national level.

Staple food	N[1]	0 × week	1–2 × week	3–4 × week	Over 4 × week	Overall percentage
Cassava	6708	0.63	6.85	4.61	4.45	16.5
Cowpea grain	4805	0.31	4.31	4.45	2.77	11.8
Groundnut	4520	0.18	4.07	3.58	3.31	11.1
Maize	8170	0.68	6.15	6.35	6.96	20.1
Plantain	2402	0.63	3.45	1.29	0.55	5.9
Rice	6048	0.52	5.89	5.26	3.24	14.9
Sorghum	2682	0.08	1.22	2.19	3.12	6.6
Soybean	1036	0.25	1.48	0.47	0.35	2.6
Yam	4209	0.45	4.92	3.29	1.72	10.4

[1]Number of observations

Consumption over four times in a week which could indicate that foods were consumed almost daily in a week substantially reflected foods most preferred by households or those that were available to them and affordable and of the utmost importance for their food security and nutrition. The frequency of maize consumption was consistently high as 7% of the studied population consumed it almost daily. The wide range of maize consumption, especially as green maize, a major component of complementary foods in most Nigerian households and as a common beverage in the two-major AEZ might have accounted for the indicated frequency of consumption. After maize, the most frequently consumed food was cassava, followed by rice and sorghum. Among the staple legumes, groundnut had the highest frequency of consumption followed by cowpea. A considerable amount of yam was consumed once or twice a week. Although yam is another major source of energy for most Nigerian households, it was consumed less often than cassava.

Differences in the pattern of food consumption were observed across the AEZ (Table 7), indicating that availability of food and the agroecological zones determined the levels of food consumption. Maize was consistently the most frequently consumed staple as 18.8% of households in the dry savanna, 21.9% in the moist savanna, and 19.8% in the humid forest consumed it at various times within the week (Table 7). The proportion of the overall respondents that consumed cassava increased as one moved from the dry savanna zone (14.3%), through the moist savanna (15.7%), to the humid forest (18.3%). Rice was most

frequently consumed in the dry savanna zone (16.3%) while 11.9% of households consumed sorghum at various times within the week, 9.6% in the moist savanna, and 1.6% in the humid forest.

Results obtained indicate that: (a) nationally, 42% of children under-five surveyed were stunted due to long-standing dietary inadequacy or malnutrition; (b) more children under-five were stunted in the dry savanna (58%), which is more than twice the rate in the humid forest (27%). Stunting was equally high (46%) in the moist savanna; (c) nationally, 11.6% of women suffered from chronic undernutrition. The condition was more prevalent in the dry savanna (16.4%) than in the moist (9.9%) savanna and humid (9%) forest zone. Within the different sectors, chronic undernutrition ranged from 10.3 to 12.7%.

At the national level, 24.8% of children under five suffered from marginal deficiency and therefore were vitamin A deficient while 4.7% suffered from severe vitamin A deficiency (clinical deficiency). Merging those who were deficient marginally and clinically showed that 29.5% of children-under five were vitamin A deficient. The level of vitamin A deficiency was high in the dry savanna at 31.3%, 24.0% in the moist savanna, and 29.9% in the humid forest. More children with clinical deficiency lived in the humid forest (7.1%) than in the dry savanna (3.1%) and moist savanna (2.4%).

Table 7. Frequency of consumption of staple food crops by AEZ.

Dry savanna						
Staple food	No[1]	0 × week	1–2 × week	3–4 × week	Over 4 × week	Overall percentage
Cassava	1552	0.25	9.61	4.01	0.4	14.3
Cowpea grain	1541	0.09	4.39	5.27	4.41	14.2
Groundnut	1373	0.13	5.48	4.62	2.39	12.6
Maize	2045	0.16	7.1	5.83	5.71	18.8
Plantain	59	0.01	0.33	0.14	0.06	0.5
Rice	1768	0.28	7.09	5.11	3.78	16.3
Sorghum	1291	0.08	1.84	3.57	6.37	11.9
Soybean	310	0.27	1.72	0.52	0.34	2.9
Yam	943	0.28	6.37	1.73	0.28	8.7
Moist savanna						
Staple food	N[1]	0 × week	1–2 × week	3–4 × week	Over 4 × week	Overall percentage
Cassava	1801	0.31	7.76	4.26	3.41	15.7
Cowpea grain	1207	0	3.62	4.07	2.86	10.6
Groundnut	1209	0.08	3.62	3.42	3.45	10.6
Maize	2511	0.03	4.56	7.77	9.59	21.9
Plantain	423	0.18	2.53	0.75	0.23	3.7
Rice	1498	0.23	4.68	4.9	3.28	13.1
Sorghum	1095	0.03	2.04	3.78	3.72	9.6
Soybean	461	0.22	2.39	0.77	0.66	4.0
Yam	1238	0.06	4.49	4.14	2.12	10.8
Humid forest						
Staple food	N[1]	0 × week	1–2 × week	3–4 × week	Over 4 × week	Overall percentage
Cassava	3355	1.06	4.63	5.18	7.51	18.4
Cowpea grain	2057	0.62	4.69	4.21	1.75	11.3
Groundnut	1938	0.27	3.51	3.05	3.78	10.6
Maize	3614	1.39	6.57	5.78	6.06	19.8
Plantain	1920	1.28	5.89	2.31	1.04	10.5
Rice	2782	0.84	5.93	5.58	2.89	15.2
Sorghum	296	0.12	0.35	0.36	0.80	1.6
Soybean	265	0.25	0.77	0.26	0.17	1.5
Yam	2028	0.79	4.32	3.69	2.31	11.1

[1]Number of observations

In conclusion, staple foods were available almost all the year round, however, not all the survey respondents could afford it. Nationally, 42% of the children in this study were stunted (chronic, longer standing malnutrition), while about 10% were wasted (acute, ongoing malnutrition). Underweight was 25%.

With these malnutrition indicators, protein energy malnutrition was still the major problem of public health importance in Nigeria. These magnitudes of malnutrition deserved urgent attention knowing the consequences of malnutrition as it affects health and survival, education, and the economy of the nation. About 12% of nursing mothers nationally, suffered from undernutrition, threatening public health magnitude especially in the dry savanna and rural settings. There is therefore a need for nutrition intervention actions targeted at under-five children, and lactating mothers.

1.1.2.2 Socioeconomic determinants of households' food insecurity across agroecological zones and sectors in Nigeria

by K. Amegbeto and B. Maziya-Dixon

Food security is defined as "peoples' access to enough food at all times for active and healthy life" (World Bank 1986)[1]. How to measure this had been the subject of debate within the scientific community. There was no simple formula for constructing valid measures because of the difficulties in defining the concept, including quantitative, qualitative, cognitive and affective components of certainty, acceptability, and sustainability. Methods such as ethnography, rapid rural appraisal (RRA), coping strategies, food economy approach, expert systems, and livelihood security have been used in developing countries to gain understanding of food insecurity and to develop measures (Wolfe et al. 2000). Matching various demographic characteristics of households with food consumption data is vital to policymakers and program designers who plan to reduce food insecurity. Household food consumption surveys were a source of multiple, policy-relevant, and valid measures of food security. They allowed multilevel monitoring and targeting, which can be used to identify the food insecure people for appropriate interventions. The objective of this section is to identify the socioeconomic and demographic factors that determine households' food insecurity level in Nigeria. A quantitative measure of food availability and its access by households was defined and compared across three sectors (rural, medium, and urban), three agroecological zones (dry savanna, moist savanna, and humid forest), and with respect to households' socioeconomic characteristics in Nigeria.

A detailed food consumption and nutrition survey was conducted in 2002 in Nigeria. Information was collected on, among other variables, food availability and affordability from 6000 households. A measure of food insecurity at the household level was defined based on the availability and affordability of food items over 12 months. First, the multiplicative law of probability was applied to derive the joint probability of a given food item being available and affordable at the household level. An index of food insecurity was then constructed by aggregating the joint probabilities over the basket of food items consumed by each household. The approach used in the aggregation was similar to the construction of consumer price index (CPI) in economics that employs expenditure proportions instead of fixed quantity shares of food items as weights. It is believed that expenditure weights estimator would better reflect the substitution effects of price changes in consumer spending than the quantity weighted formula (US Bureau of Labor Statistics 1998). Moreover,

expenditure weights were uniform for all food items and more convenient to estimate than quantity weights.

The constructed food insecurity index (FSI_h) is comprised within the interval [0,1], and the closer the index was to zero for a given household, the better it was for the households' food security level in terms of joint availability and affordability. Tobit model provided a good framework and was used in the analysis to identify the socioeconomic determinants of the variability in the index across households because its formulation was based on a censored distribution of the dependent variable. The model measured both the probability and the extent of food insecurity across the households (Adesina and Zinnah 1993), and had been extensively applied in economic analysis of consumer demand for food (Yen and Jones 1997; Angulo et al. 2001). Empirically, the food insecurity index regressed against a set of variables that described the socioeconomic characteristics of households. Depending on households' primary source of energy, drinking water, methods of refuse disposal, and toilet systems, households were also classified into low, medium, and high standard of living. The low standard corresponds to an environment without electricity and where pond, lake, spring, river or harvesting rain water was the main source of drinking water, bush was used for toilet or refuse disposal. The medium standard refers to access to rural electrification, well or bore hole for drinking water, and refuse dump and VIP latrine for waste disposal. The high level includes households that possessed their own electricity generator or had access to NEPA (National Electrical Power Authority), to organized refuse disposal services, having water-flushing toilets. The regression model was run on Limdep 7.0.

Preliminary results can be summarized as:

1. Across the sectors, households in the rural sector in Nigeria were relatively more food insecure than those in the medium and urban sectors. Similarly, households in the moist savanna agroecological zone were more food insecure compared to those in the dry savanna and the humid forest respectively.
2. On the basis of the primary occupation of household heads, families headed by farmers were the most severely affected by food insecurity. The level of insecurity decreased as one moved from households headed by farmers to those of traders, artisans, civil servants, and fishermen. At the same time, male-headed households showed higher food insecurity compared to female-headed ones.
3. There was a negative relationship between household incomes and the food insecurity index, as one would expect.
4. Food insecurity was relatively more severe within households in the low-living standard category, followed by those in the medium and high categories. This suggests positive correlation between food security and living standards as measured in this study.

The work progressed to refine model specification. Full report and policy implications will be provided thereafter.

1.1.2.3 Contribution of perishable products to the nutrition of households in Yaoundé

by S. Dury in collaboration with C. Kana (ISSEA), R. Ngonthe (ISSEA), and E. Fokou (Univ. of Yaoundé)

Perishable commodities, such as fresh cassava and traditional leafy vegetables, are particularly important for the nutrition of the urban poor. Studies revealed that the leafy

vegetables were a principal source of calcium, iron, vitamin B, and protein. Supply, however was seasonal and the poor had to modify their consumption habits in the dry season, because prices tripled from January through April.

Several economical data are available, either from DSCN (national statistical division) or from a consumption survey conducted by IITA/CIRAD from June 1999 to December 2000. These data provide information on the source of consumed products (purchase, self-production) and on their prices. For this proposed activity, data on perishable commodities had to be processed, and additional information gathered (e.g., a nutritional database).

There were three hypotheses for this research: the first supposed that "poor" households depended more on perishable commodities than richer households for food consumption and to meet their daily nutritional intake. The second hypothesis presumed that poor households did not have many substitutes, while the third hypothesis was that poor households suffered more from seasonal variations in supply and price of perishable commodities.

The purpose of this activity was to assess the importance of perishable products in the diet of urban households, with respect to their standard of living. Work based on secondary data was reported. The data documented the contribution of urban and peri-urban agriculture (UPA) to the nutrition of urban dwellers. The average nutritional intake per person was estimated with data collected seven times during one year in 1999–2000, within 183 households, representing the Yaoundé population.

On average, the macro nutriment requirements for the Yaoundé population were met. However, about 10% of the population seemed to be deficient in carbohydrate and protein. The available data did not provide information on the spatial origin (urban/peri-urban/other) of the food consumed. However, it assumed that leafy vegetables from the urban/peri-urban areas were highly perishable. Three leafy vegetables (cassava leaves, Vernonia, and Amaranthus) provide about 8% of the protein and 40% of the calcium intake. The bioresorption of these nutrients would be confirmed. Fresh cassava root a perishable commodity usually came from areas close to Yaoundé. The fresh roots consumption contributed 6% of the total energy intake.

The data distinguished between food purchased and food produced by the household. The urban consumers produced 10% of the fresh cassava roots and leaves consumed. They also produced between 5 and 8% of the plantain, Amaranthus, cocoyam (taro), banana, processed cassava products (bâton), and papaya. The study therefore showed that urban and peri-urban products included perishable products, as well as plantain, taro, and banana. Finally, the analysis showed that the caloric contribution of peri-urban products was more important for poor than for rich households.

1.1.3 Policy and institution analysis for increased competitiveness of the tree crops sector in West Africa

by G.B. Nkamleu, J. Gockowski, S. Weise in collaboration with E. Wood (USGS), and P. Abbott (Purdue University)

1.1.3.1 Baseline surveys

Among the first activities of STCP was the implementation of baseline surveys in the major cocoa-producing regions of Cameroon, Côte d'Ivoire, Ghana, and Nigeria and the major cashew areas in Guinea. To date, the country baseline report for Côte d'Ivoire has been

completed, and others will follow. Using the baseline survey data, this activity merged administrative divisions in the baseline database with those available in existing GIS layers, and calculated descriptive statistics for selected variables. The spatial representation of Côte d'Ivoire is completed whereas that of other countries is in process of completion.

Child labor has been a conspicuous theme in the production of tree crops, which has been addressed through a series of studies. Using descriptive and econometric analysis of survey data and focusing on the extent and role of child labor in the cocoa sectors of Nigeria, Cameroon, Côte d'Ivoire, and Ghana, attempts were made to formulate recommendations for addressing the developmental issues surrounding child labor in the cocoa sector of West Africa. STCP monographs for Cameroon, Ghana, and Nigeria are in press at IITA, and the synthesis report on child labor findings have been posted on the STCP website. The relationship between child labor and child schooling in the cocoa sector of Cote d'Ivoire was examined to identify determinant factors that could help to design a multiangle policy approach towards eliminating child labor. To date, the econometric analysis has been completed and a draft article for peer-reviewed journals is being prepared. Data on labor markets from baseline surveys and child labor surveys in Côte d'Ivoire were also used to arrive at policy recommendations for alleviating pressure on labor and land institutions. A completed and revised draft paper from this research has been submitted for publication.

1.1.3.2 Descriptive assessment of cocoa marketing chains in West Africa

This activity consisted of gathering information on the cocoa marketing chain, the role of West African governments, and changes since market liberalization. Analysis of the cocoa marketing systems in Cameroon, Côte d'Ivoire, and Ghana showed three quite different degrees of government intervention in the cocoa sector of these countries, as well as similarities, with significant implications for the role of external actors such as USAID and STCP. The two key challenges were difficulty in creating and maintaining farmer organizations, and critical campaign financing problems. Another product of this effort was the creation of diagrammatic representations of the cocoa marketing chain in each country.

1.1.3.3 Integrating social objectives into cocoa market outcomes

Another important theme of STCP activities has been the extent to which firms engaged in cocoa trade address social concerns, including fostering better labor practices, protecting the environment, and insuring fair outcomes for farmers. STCP and Fair Trade initiatives focus on the potential for poverty alleviation and on achieving sustainable development for poor African farmers. A conceptual examination of marketing systems between the African cocoa farm and the chocolate manufacturer, emphasizing institutional arrangements, was used to assess the likely success of these initiatives in achieving their social goals. Application of the concept of decoupling suggested that direct aid was preferred than market-based approaches, especially when imperfect market linkages along the supply chain dissipated consumers' willingness to pay for poverty alleviation.

1.1 Assessing farmers' perception and the profitability of planted legume fallows and preplanting treatments against pests and diseases

by J. Gockowksi and C. Nolte

For long, agricultural development has been accompanied by shifts in assets especially capital assets. The agricultural sectors of most developing countries are characterized in relative terms by large shares for labor, low levels of physical and human capital, and a reliance on natural capital for maintaining cropping system productivity. With development, physical and human capital increase in relative terms, while labor inputs and natural capital declined. Natural capital (defined for the purposes of this paper as the combination of plant biomass accumulated in the fallow period and inherent soil fertility) is a critical input for many farmers in the humid forest region of West and Central Africa. However with growth in population and the commercialization of agriculture, natural capital was gradually used as fallow periods diminished and use of purchased soil amendments replaced natural capital. One of the focuses of tropical agricultural research for this region in the last 30 years had been the integration of leguminous nitrogen fixing plant species into smallholder farming systems. The underlying rational was that these innovations increased productivity by augmenting the quality and quantity of natural capital of the cropping system without placing any demand on the limited financial resources of small-scale agriculturalists. Such systems have shown farmer acceptability and were increasingly adopted in eastern Africa. However, the labor demands of such systems have been highlighted as an important consideration in their adoption.

The focus of the study is the effect of planted leguminous fallow interventions on the labor requirements of the traditional *Beti* mixed food crop system (known by the local appellation as *afub owondo*). This annual cropping system is the most widespread in the humid forest zone of southern Cameroon and guarantees the sustenance of the rural household while generating small market surpluses for a variety of crops.

The mixed food crop system of southern Cameroon has been described as a "subsistence masterpiece". The cropping system contains 4–15 crop species, the most important being groundnut, which is reflected in its local *Beti* appellation *afub owondo*—meaning groundnut field. Cassava is the other principal crop in the system. The field is cropped after a fallow period of 2–10 years depending on land and labor availability. The cropping system does not use external inputs and the only capital inputs are simple hand tools (hoe and machete).

Labor was the chief factor of production, mostly supplied by household members. Scarcity of labor in southern Cameroon was a major concern to farmers in labor productivity. Under the relative factor endowments of southern Cameroon, if an innovation did not increase labor productivity, then its adoption was likely to be low.

An on-farm researcher-managed trial compared two-year fallows planted to nitrogen fixing *Calliandra* with two-year and a four-year natural fallows on the productivity of the traditional mixed groundnut–cassava cropping system of southern Cameroon. Four planting arrays of *Calliandra* were examined to see if the introduction of a nitrogen-fixing tree during the fallow period of the cropping system could increase crop productivity. One of the factors that varied in the design was the spatial planting layout of the trees to see the effect of planting design on the labor required for managing the system. These layouts were arranged in alley cropping, a clustering of trees in groups, a planting of trees along the plot borders, and the uniform equidistant planting of trees. Observations were made

Table 8. Variables included in a regression model of labor requirements for the afub owondo mixed food crop field.

Variable	Variable type	Hyp. sign	Variable description
ALLEY	0,1 binary	+ -	*Calliandra* plot planted in alleys
EQUIDIST	0,1 binary	+ -	*Calliandra* plot planted in equidistant pattern
CLUSTER	0,1 binary	+ -	*Calliandra* plot planted in cluster pattern
BORDER	0,1 binary	+ -	*Calliandra* plot planted as border around plot
FALLOW2	0,1 binary	+ -	Two-year natural fallow control plot
FALLOW4	0,1 binary	+ -	Four-year natural fallow control plot
MANAGE	0,1 binary	+ -	Indicates management by farmer (=1) versus research (=0)
CLEAR	0,1 binary	+ -	Manual clearing of field with machetes
CLEARB	t ha^{-1}	+	The interaction of CLEAR and the total biomass of the fallow cleared
CLEAN	0,1 binary	+ -	Burning of biomass and removal of surface debris prior to planting
CLEANB	t ha^{-1}	+	The interaction of CLEAN and the biomass of the fallow cleared
PLANT	0,1 binary	+ -	Simultaneous tillage/seeding of field
WEED	0,1 binary	+ -	Weeding of field
HARVG	0,1 binary	+ -	Harvesting of groundnut production
HARVGYLD	t ha^{-1}	+	The interaction of HARVG and the yield of fresh groundnut per ha
NWORKER	Count	+ -	The number of workers effectuating the labor task
NW2	Count	+ -	The square of NWORKER
PWOM	Proportion	[a]	The proportion of NWORKER over the age of 15 and female
PCHILD	Proportion	[a]	The proportion of NWORKER under the age of 15
PMEN	Proportion	[a]	The proportion of NWORKER over the age of 15 and male
F1 to F18	0,1 binary	+ -	Dummy variables for each of 18 field sites

[a] The hypothesized relationships among the three coefficients are PMEN > PWOM > PCHILD.

on each of the six labor tasks described above with the cooperation of the 18 participating farmers over the range of *Calliandra* and control treatments. A total of completed 880 tasks were measured chronometrically.

Tables 8 and 9 summarized the statistics for the variables in the model. In addition to the model variables, the mean proportions of the workforce experiencing stomach illness (PSTOM) and malaria (PMAL) in the two weeks prior to their employment were reported. The relatively high proportion reporting indicated the importance of malaria morbidity and stomach illnesses on labor supply. However when included in the regression model, there was no effect on the labor effort required and the variables were dropped.

Table 9. Summary statistics for labor demand regression model.

	Mean	Std. Dev.	Minimum	Maximum	No. cases
ALLEY	0.187	0.390	0	1	902
EQUIDIST	0.188	0.391	0	1	902
CLUSTER	0.173	0.378	0	1	902
BORDER	0.174	0.379	0	1	902
FALLOW2	0.139	0.346	0	1	902
FALLOW4	0.139	0.346	0	1	902
MANAGE	0.454	0.498	0	1	901
CLEAR	0.210	0.408	0	1	900
CLEARB	4.06	8.85	0	48.3	900
CLEAN	0.202	0.402	0	1	900
CLEANB	4.027	8.953	0	48.3	901
WEED	0.162	0.369	0	1	900
PLANT	0.211	0.408	0	1	900
HARVG	0.143	0.351	0	1	900
HARVGYLD	168	496	0	3770	893
PRUNE	0.071	0.257	0	1	900
NWORKER	2.86	2.27	1	14	894
NW2	13.2	22.2	1	196	900
LTIME	5.460	1.103	1.946	8.105	893
PWOM	0.514	0.436	0	1	894
PMEN	0.458	0.441	0	1	894
PKID	0.029	0.130	0	1	893
PMAL	0.169	0.335	0	1	665
PSTOM	0.171	0.338	0	1	665
TOTALBIO	20.6	8.75	2.79	48.3	899
F1 to F17	.043–.070	0.20–0.26	0.000	1.000	902

The most likely explanation for this lack of significance was sample self-selection; persons currently experiencing malaria or with serious stomach disorders were unlikely to seek farm employment. Those who did, indicated not to accept employment if they had malaria or still felt the effects. As such, 17% of the worker population reporting was most likely an underestimate of the overall population mean.

Due to linear dependencies, the variables *PRUNE, FALLOW2,* and *PMEN* were dropped from the model. The estimated model explained approximately three-fifths of the variation in labor time (adjusted R squared = 0.61).

Excluding the site-specific field dummies, 11 of the 18 variables were significant at $P < .001$ (two-tail test) level, and additional three variables were significant at $P < 0.05$ level (two tail test) (Table 10).

The coefficients for the three variables *CLEANB, CLEARP,* and *HARVGYLD* were positive as predicted but significantly different from zero only in the case of *HARVGYLD*. The hypothesized relationship between the sizes of the coefficients on *PMEN >PWOM > PCHILD* was not rejected. Overall, the site-location dummy variables were significant; individually 8 of the 17 variables had coefficients significantly different from zero.

The model was used to predict the amount of labor per ha required for the various cropping tasks by experimental treatment holding the other variables constant at their means.

The results in Table 11 highlight the high labor demands for this traditional cropping system, which given an almost exclusive reliance on household labor sources limits its

Table 10. Model estimates.

	Coeff.	Std. Err.	t-ratio	P-value
CONSTANT	3.291	0.172	19.116	<0.001
ALLEY	-0.182	0.086	-2.120	0.034
EQUIDIST	-0.082	0.085	-0.958	0.338
CLUSTER	-0.215	0.086	-2.510	0.012
BORDER	-0.135	0.085	-1.583	0.113
FALLOW4	0.009	0.090	0.103	0.918
MANAGE	0.233	0.052	4.482	<0.001
CLEAR	0.872	0.168	5.185	<0.001
CLEARB	0.008	0.007	1.165	0.244
CLEAN	1.930	0.169	11.402	<0.001
CLEANB	0.002	0.006	0.330	0.742
PLANT	1.910	0.115	16.662	<0.001
WEED	1.866	0.115	16.256	<0.001
HARVG	1.300	0.164	7.913	<0.001
HARVGYLD	0.000	0.000	4.677	<0.001
NWORKER	0.199	0.037	5.336	<0.001
NW2	-0.007	0.004	-2.034	0.042
PWOM	0.490	0.080	6.158	<0.001
PKID	1.034	0.212	4.870	<0.001
F1	0.124	0.156	0.797	0.426
F2	-0.372	0.159	-2.341	0.019
F3	-0.407	0.146	-2.786	0.005
F4	-0.104	0.156	-0.671	0.502
F5	0.207	0.145	1.430	0.153
F6	-0.005	0.152	-0.033	0.973
F7	-0.093	0.150	-0.624	0.533
F8	-0.622	0.148	-4.213	<0.001
F9	-0.258	0.142	-1.822	0.068
F10	-0.302	0.139	-2.176	0.030
F11	-0.863	0.154	-5.609	<0.001
F12	-0.461	0.153	-3.004	0.003
F13	0.090	0.145	0.618	0.537
F14	0.241	0.152	1.588	0.112
F15	-0.356	0.146	-2.448	0.014
F16	0.473	0.157	3.001	0.003
F17	0.018	0.147	0.124	0.902

Table 11. Predicted labor requirements of various fallow treatments by labor task for first season traditional mixed food crop field (120 day production cycle).

Tasks	Days* of labor ha^{-1}					
	Alley	Equidist	Cluster	Border	2-year fallow	4-year fallow
Clearing	33	36	32	34	39	39
Cleaning	84	93	81	88	101	102
Planting	79	87	76	83	94	95
Weeding	75	83	73	79	90	91
Harvesting	67	75	65	71	81	82
Pruning	12	13	11	12	0	0
Total	350	387	338	367	406	409

effective size which averages approximately 1300 m^2 in southern Cameroon. Groundnuts yields had a significant positive effect on the labor time required for harvesting. Doubling the average yield of groundnuts from 1 to 2 tonnes requires 55% increase in harvest labor equal to an additional 160 labor days per ha. If labor was scarce, even high-yielding improved varieties may not be accepted among farmers.

1.1 Determine the importance of crop characteristics and consumers' quality criteria on market value

*1.3.1 Implicit market values of fresh yam (*Dioscorea *species) tuber attributes in two urban centers in Togo*

by K. Amegbeto in collaboration with the University of Lomé, Togo

The diversity of yams across and within species provides alternatives in terms of agronomic, morphological, and end-use characteristics to producers and consumers. These characteristics also provide flexibility to the timing of harvesting, tuber storage, and marketing. In the context of enhancing producers' food security, income generation capacity and at the same time reduce poverty, recent research efforts at IITA aimed at developing nutritious and highly marketable yam varieties. Information about the implicit market values of these characteristics would be critical in guiding decision-making by farmers as well as demand-oriented breeding programs. However, this information is not available in the literature on yams even though the framework for evaluating consumer demand as a function of the good and its characteristics is well established in economic theory. It is deemed imperative to fill the knowledge gap by simultaneously taking into account varietal characteristics, spatial production, and seasonal marketing factors. This study applied a flexible-form hedonic pricing model to derive the implicit market valuation of yam characteristics in two consumption centers in Togo.

Rosen (1974)[2] formulated the theory of hedonic prices as a problem in the economics of spatial equilibrium in which an entire set of implicit prices guides both production and consumption decisions. This concept was used to determine the market value attributable to product characteristics for agricultural goods (Buccola and Iizuka 1997; Nimon and Beghin 1999; Langyintuo et al. 2000; and McConnell et al. 2000). Following Rosen (1974), a yam retailer was assumed to maximize profits (□) in a competitive market where he/she could not influence prices. The retailer incurred some costs that depend on the quantity offered on the market, the characteristics of the tubers, and other factors. It follows from the first order condition for profit maximization that the retailer's offer price for the ith characteristic must equal the per unit marginal cost of that characteristic, which determines the offer function for fresh tubers with specific bundle of characteristics (C). Empirically, the valuation of fresh yam tuber attributes, as is the case for any other good, would be sensitive to the specification of the offer function. However, there is no *a priori* information from economic theory on the functional form and many authors resorted to the unrestricted quadratic Box-Cox transformation (Richards and Jeffrey 1996; Chattopadhyay 1999). The same approach was used in the current study.

In collaboration with the University of Lomé, Togo, data on yam tuber prices and physical characteristics were collected in two cities, Lomé and Sokodé, the major yam consumption areas. Two enumerators were recruited and trained for fresh tuber description and data collection. An average of 48 and 24 tubers were randomly selected, calibrated, and priced

per market day on each site resulting in a total of 6407 tubers sampled in Lomé and 3341 tubers sampled in Sokodé. These data were collected from August 2001 to July 2002. In order to estimate the hedonic price model for fresh yam tubers, the nominal tuber prices were deflated to obtain real prices. The consumer price index (CPI) obtained from the International Monetary Fund (2003) was used and all prices expressed in constant term (i.e., CFAF2000). A general form specification of heteroscedasticity was specified in the model. The marginal value or implicit price of each characteristic was derived from the expression for elasticity using the logarithm transformation. The Box-Cox regressions were run on Limdep 7.0 based on the Maximum Likelihood method and values of the transformation parameters searched for numerically.

Results of the price model for Lomé markets showed high level of price differentiation based on the yam species and varieties. Compared to the *D. rotundata* late-maturing varieties, estimated average premium for early-maturing varieties equaled approximately CFAF3, while *D. alata* species were discounted for about CFAF20.5. Price variations were significantly and positively explained by the size variables namely, tuber length and width as expected. The marginal value is about CFAF2 for tuber length, CFAF0.34 for the width at the head portion, and CFAF0.24 for the width at the middle section of the tuber. There is a marginal increase in tuber price as the size increased, implying that larger sizes of fresh tuber commanded higher unit values in the markets.

White and light yellow colorings were identified on tuber flesh during the market survey. The former carried a discount of CFAF11 over the latter. The yellow pigmentation of tuber flesh was due to the presence of carotenoids (Degras 1993) that have nutritional value, as precursors of vitamin A. Tubers having this pigmentation were common but less popular than white yams in terms of volumes supplied in the markets. Thus, a combination of demand and supply factors explained the additional valuation of yellowish tuber flesh. Among tuber shape variables, cylindrical, conical, and flat tubers were less valued in the market compared to irregular shaped or branched tubers. Average discounts varied between CFAF2 and 10 depending on the shape. This finding is surprising as one thought that city dwellers were more inclined towards nice and uniformly shaped tubers for convenience and ease of processing. However, irregular and branched shapes may be typical of some varieties that were preferred for specific reasons. In situations where consumers linked physical attributes of tuber-specific varieties and end-use quality, or where the marginal cost of processing was low, preferences and demand were high for such characteristics as seen in the current study.

The real price of yam tuber decreased due to the presence of necrotic spots and symptoms of rot, which contributed to an average discount of CFAF2–3 per unit. Among 25 supply sources identified for the three markets in Lomé, yam tubers that originated from Bassar, Kpalime, Atakpame, and Agbavi, in decreasing order of importance, were valued above those from other origins. Tubers from Bassar carried the highest premium of CFAF11.2 per unit compared to CFAF3.2 per unit of those supplied from Agbavi. With respect to market location within the city, tuber prices were relatively lower in the Akodessewa market with an average of CFAF4 per unit. Compared to the base month (September), yam producers and retailers could derive a premium for storing yam toward sales in later months. The potential market window remained the period of April through July where the implicit value of time was high and varied between CFAF11 and 23 per unit (Fig. 2).

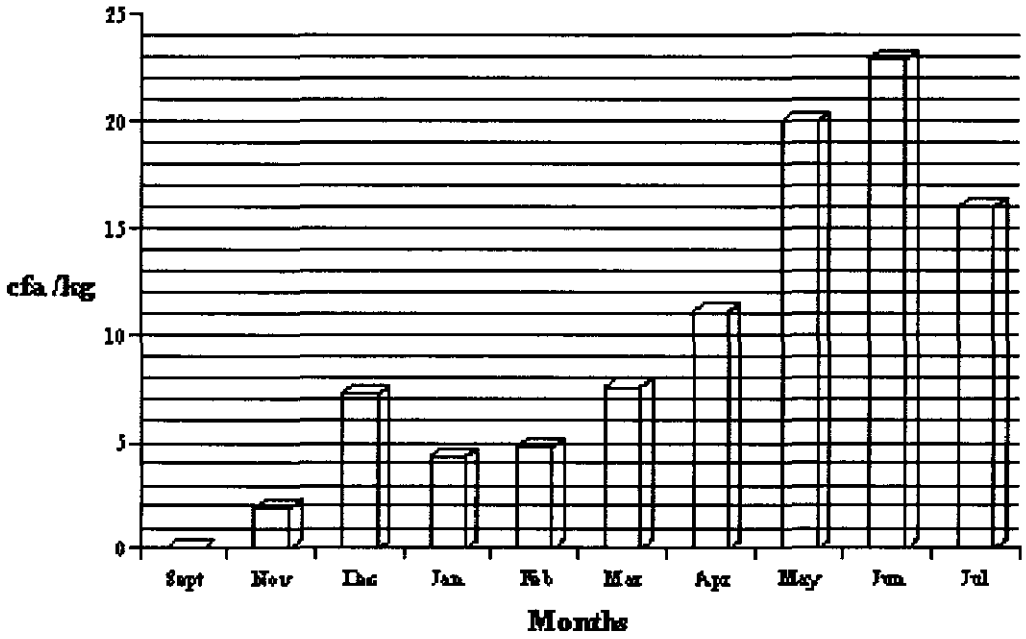

Figure 2. Implicit market value for time of fresh tuber sales.

Table 12. Partial enterprise budget results for selected secondary products and cocoa in the shaded cocoa agroforests of southern Cameroon.

Secondary product	Net returns to mgt and land (FCFA per ha)
African plum (*D. edulis*)	96 913
Ndjanssang (*R. heudelotii)*	20 939
Palm oil (*E. guinensis)*	4771
Palm wine (*E. guinensis*)	13 250
Avocado *(Persea americanus)*	2795
Orange (*Citrus sinsensis*)	16 698
Mandarin (*C. reticulata*)	62 700
Cocoa (*Theobroma cacao*)	164 000

In conclusion, fresh yam tuber prices were differentiated across species and varieties within species because of differential characteristics that reflected end-use qualities and food value attributes. The existence of market premiums for short growth cycle, tuber size, shape, flesh color, and time factors provided opportunities for some farmers to use cultivar selection, planting, harvesting, and marketing decisions that can be controlled from supply side to tap into the market and effectively increase farm benefits. Early harvest of varieties that have short growth cycle gave flexibility to the producer to tap into high price markets for early harvests. The differential valuation for tuber shape observed suggests that market participants made an association between varieties that have typical shapes and their specific end-uses. The presence of premium on the yellow coloring of tuber flesh was a market opportunity for product differentiation.

These findings have implications for the development of new yam technologies. Tuber shape could be used effectively as product differentiation. Methods of producing distinctive and desired tuber shapes are well known and practiced in some Asian countries. Similarly, genetic improvement of yams should consider the development of hybrids that combine

the yellowish color with short growth cycle, as well as high yields, resistance to diseases, and suitability to alternative end uses. Popularization of such varieties should benefit producers and consumers. The implicit market valuation for big tubers, which reflected consumers' preferences could be detrimental on natural resources if producers did not adopt or intensify better crop management technologies or resorted to natural fallows to increase tuber size and yields. Therefore, resource and crop management technologies should be jointly promoted to yam producers to achieve sustainability in the production systems.

1.1 Elucidate the ecological functioning and environmental services of crop systems to identify factors of sustainability

1.4.1 Conservation because it pays: shaded cocoa agroforests in West Africa

by J. Gockowski, S. Weise in collaboration with D. Sonwa, M. Tchtat, and M. Ngobo

The shaded cocoa cropping system found throughout West Africa but particularly well represented in Cameroon and Nigeria is a sustainable agricultural land use system that provides relatively high values of environmental services. The non-cocoa economic and environmental values are partially quantified and the economic logic underlying smallholder management examined. Estimates of these values are developed from field surveys and on-farm research conducted with cocoa producers in West Africa over the last four years (Table 12). The secondary products evaluated include the fruits of shade trees commonly associated and occupying the mid and upper canopy such as the African plum (*Dacryodes edulis*) and ndjassang (*Ricinodendron heudolotii*) along with introduced fruit species such as mandarin and avocado.

On a regional basis, approximately 5.6 million hectares of what was once moist tropical forest in the Nigeria, Côte d'Ivoire and Ghana has been converted to cocoa production systems. By comparison, the World Resource Institute (http://www.wri.org/earthtrends/) estimated that approximately 2.4 million ha, 1.2 million, and 2.6 million ha of tropical forest (i.e., > 75% canopy coverage) remained in Côte d'Ivoire, Ghana, and Nigeria, roughly equivalent to the area in cocoa production systems. Clearly, the ecosystem functions and natural resources of the cocoa production system are important at the macro level for the moist humid tropics of West Africa. The environmental and ecological effects include habitat conservation, climate change mitigation, hydrological cycling, and watershed protection. The degree to which these services were provided depended largely on the type and degree of shade maintained as well as spatial coverage of the landscape.

Regionally, the frequency of no shade farms expressed as a proportion of all farms varied from as low as 3% in Ondo State, Nigeria to as high as 51% in the Lagune region of Côte d'Ivoire. At the country level, Ghana and Côte d'Ivoire had the highest frequency of no shade cocoa farms with 28% of the cocoa farms indicating full sun systems. Cameroon had the highest frequency of densely shaded farms. In Nigeria and Cameroon, shade levels were significantly higher than in Ghana and Côte d'Ivoire. Farmers in Nigeria and Cameroon also maintained native fruit, timber, and medicinal tree species. The conservation of these indigenous forest species is particularly important for wildlife habitat and ecosystem functionality. Cocoa agroforests are a livelihood for local communities surrounding the Dja Reserve in southern Cameroon working with the ECOFAC Project. The maintenance of indigenous forest species such as *Dacryodes edulis* and others are important food sources

for monkeys and avian seed dispersers such as hornbills and parrots. The cocoa agroforest provides vital habitat for these seed dispersers, which in the case of the hornbills (estimated to account for 35% of forest seed dispersal) leave the Dja reserve at certain periods of the year in search of other food sources (Tom Smith, UCLA Center for Tropical Research, personal communication). The forest-like nature of shaded cocoa systems effectively provides a buffer and helps maintain the ecological functioning needed to maintain the biodiversity of the reserve.

An ordered probit econometric model of the determinants of shade level explores some of the driving forces behind shade management in Côte d'Ivoire, Ghana, Nigeria, and Cameroon. The model was estimated separately for Ghana, Nigeria, Côte d'Ivoire, and Cameroon using information gathered from producer interviews on a total of 6430 spatially distinct cocoa cropping systems. The analysis of the factors motivating the choice of shade level on cocoa farms suggests that the processes of cocoa intensification and specialization contributed to lower levels of shade as producers seek to maximize cocoa production. Where farms were large in size and labor was relatively scarce, producers opted for low risk extensive production strategy. As part of this strategy, shade was encouraged as a means of stabilizing production and providing a reliable albeit low level of production. Johns (1999)[3] described a similar low risk shade strategy for the cocoa producers of Bahia, Brazil.

Most cocoa producers in West Africa maintained shade on their cocoa farms and majority in Cameroon, Nigeria, and Ghana planted fruit trees. The secondary products generated from this shade contribute significantly to household revenues and nutrition. The environmental services provided by over 5 million ha of shaded cocoa are beneficial. These include habitat conservation and hydrological functions ranging from sediment control to in-situ conservation of indigenous fruit-tree species. Given the positive externalities of shade, we agreed that resources for the promotion and development of shaded cocoa systems were under allocated.

The environmental services provided by shaded systems and the tradeoffs between cocoa productivity and shade needed better information (if any). There was also a research gap in the development of improved varieties adapted to shaded systems. Finally, we advocated for promotion of shaded biologically-diverse cocoa production systems by national extension services and NGOs.

1.4.2 Effects of shading, soil water content, soil type on germination, and growth of local cacao

by L. Norgrove and S. Hauser

In recent trials in Cameroon, we found no relationship between shade level and cacao growth. Therefore a microcosm experiment started at Mbalmayo to assess the effects of various shade levels and their interaction with soil water content and soil type on cacao germination and early growth under controlled conditions. The experiment was a three-factorial design in five replicates. Shade levels were 0–67% established with shade cloth. Soil water contents were 100% and 50% saturation. Soil types were from forest and *Chromolaena* systems. The second experiment used soils from adjacent *Chromolaena* and forest systems in Mbalmayo and was a three-factorial design, as above but on 10 replicates. Shade levels were 0–67% established with shade cloth. Soil water contents were field capacity (f.c.) and 50% f.c. replenished on a weekly basis. Microcosms were covered by moveable clear plastic tents during rain showers and at night but left open at other times. Plants

were sprayed with insecticide to avoid experimental artefacts of differential insect pressure due to covering with shade cloth. Variables, measured weekly, were leaf and flush leaf number count, height, and diameter. At termination, dry matter, leaf area, and the nutrient content of plants were assessed, permitting full nutrient budget calculation. Pots were harvested at 6 MAP. Data were analyzed in the Proc GLM procedure in Sasv8 in a three-factorial fully randomized design and all two- and three-way interaction terms were included in the model. The effects of soil type were related to the chemical status of the soil and not to whether it was derived from the forest or from a *Chromolaena* fallow. In Nkometou, where the *Chromolaena* soil was poorer in N, Ca, and Mg, performance was better on forest soil. In Mbalmayo, the reverse was true and thus cacao performed better on *Chromolaena* soil.

Shade had a positive effect on plant height and diameter, however interacted with water level (Table 13). The benefit of shade on plant height and diameter was greater under low water conditions and differences were less pronounced at field capacity. After harvesting the plants, the buckets were maintained under the same conditions and the water evaporation loss per day was calculated. In the treatments where f.c. was imposed, losses were estimated as the equivalent of 4 mm rainfall per day, whereas in the shaded treatment, losses were 3 mm per day thus this might partially explain the positive effect of shade.

However, clearly shaded plants had other positive effects that were independent of water treatment with shaded plants having more than 50% more leaf area and aboveground biomass at harvest (Table 14). Leaf turnover rates, however, were higher in full light treatment, while cacao had low light saturation point. Positive effects of shade, which maintained lower soil temperatures and data are currently being analyzed to determine this.

Table 13. Interaction of shade level and water effects on cacao sapling height and diameter (SE mean in brackets). Treatment with different letters is significantly different at P □ 0.01.

Treatment factors		Response variables	
Relative water	Relative light	Height (mm)	Diameter (mm)
50% f.c.	Full light	148(14)a	6.2(0.3)
50% f.c.	67% shade	268 (11)b	8.7(0.2)
f.c.	Full light	357 (12)c	11.7(0.2)
f.c.	67% shade	424 (11)d	12.7(0.2)

Table 14. Effects of shade and water level on leaf number, total leaf production, leaf area, and aboveground mass of cacao per plant at 6 MAP (SE mean in brackets).

	Number of green leaves	Total leaf production	Leaf area (cm^2)	Aboveground mass (DWT) g
Field capacity (f.c.)	12.4 (0.4)	20.5 (0.5)	1002 (41)	11.9 (0.4)
50% f.c.	10.7 (0.5)	12.4 (0.5)	487 (46)	4.0 (0.5)
P (water)	**	***	***	***
Full light	10.3 (0.5)	17.2 (0.5)	544 (47)	6.1 (0.5)
67% shade	12.8 (0.5)	15.7 (0.5)	946 (41)	9.8 (0.4)
P (shade)	***	*	***	***

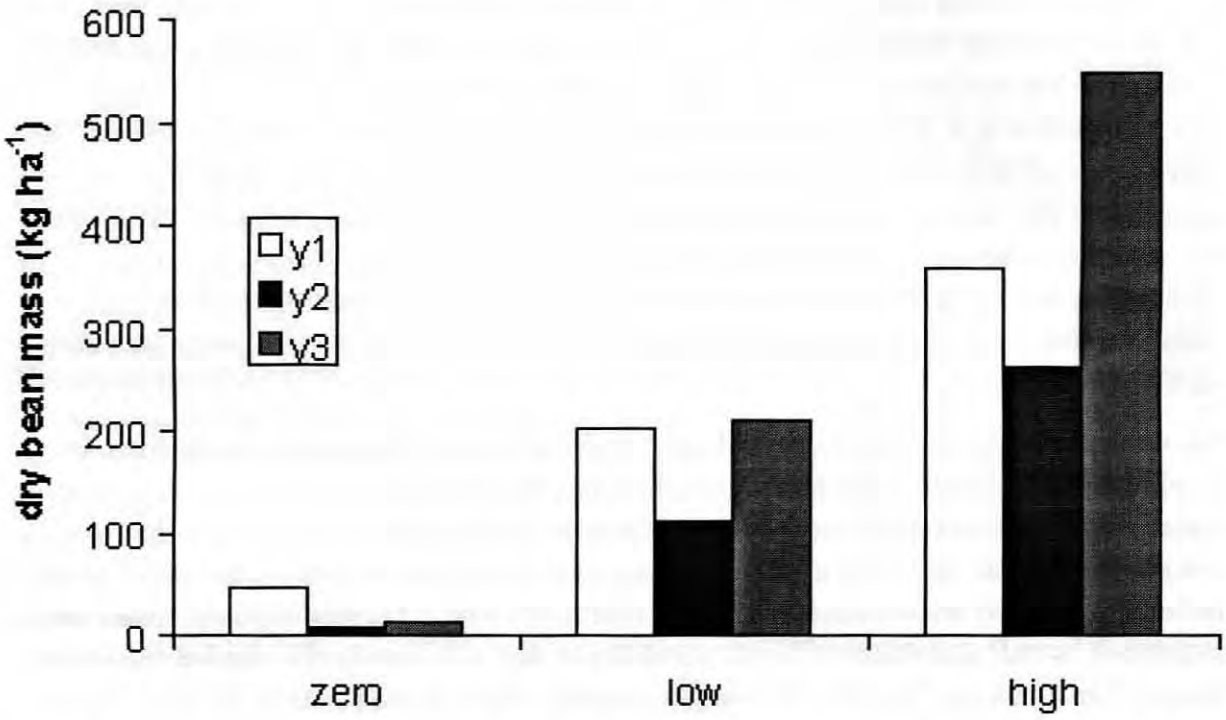

Figure 3. Mean yields of cocoa (kg ha^{-1}) in 35-38 year old previously abandoned cocoa farms as affected by fungicide treatment.

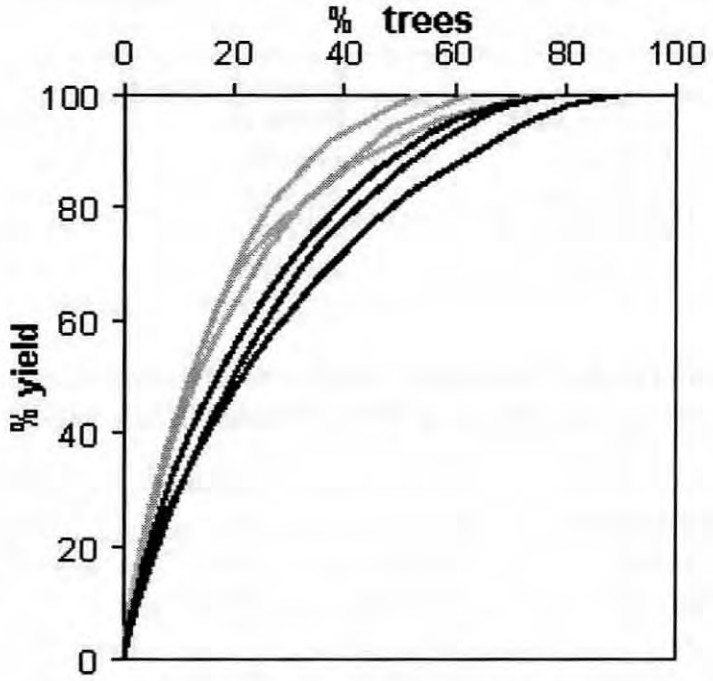

Figure 4. Distribution of yield between individual trees in low (yellow–left 3) and high (red-right 3) fungicide treated plots.

1.4.3 Effects of fungicide application upon yield and sustainability indicators

by L. Norgrove and S. Hauser

Given increased interest in cacao production due to higher market prices, it was important to know yields that were possible from previously abandoned fields, the incidence of the fungal disease blackpod in these fields, and the yield response to fungicide. In 2001, an experiment was established in farmers' cacao farms that had been abandoned for three years. The effects of high and low fungicide applications, zero-spray control on blackpod incidence, cacao yield, bean quality, and various environmental parameters and nutrient cycling were assessed.

In 2003, flowering, cherelle, and pod production per tree were monitored to identify trees with the highest yield as well as those that did not produce over a three-year period. Four canopy cover estimates were made per plot (48 images in total) by digital photography and are currently being analyzed. Phytosanitary harvests were made and a biweekly observation of soil faunal activity continued.

Yields in 2003 in sprayed plots exceeded those of previous years with yields in the high fungicide treatment exceeding 550 kg ha^{-1} (Fig. 3).

Between 10 and 25% of trees produced 50% of yield (Fig. 4). There were differences between fungicide treatments in the percentage of trees contributing to yield with a greater proportion of trees producing in high fungicide plots. These data were compared with data from previous years to assess whether there was an inter-year correlation between yields per tree.

There were no differences between treatments in flowering and cherelle production at the beginning of the season. Thus, there were no differences in yield potential. Conservative estimates of losses to blackpod from April to early September 2003, based on mass of diseased pods of mature size only, converted to dry bean mass, were 189 kg ha^{-1} in control plots, 71 kg ha^{-1} in low, and 37 kg ha^{-1} in high.

Evidently, without spraying, yield losses to blackpod disease approach 100%, even with weekly phytosanitary harvests and complete removal of infected material from the cocoa field. This confirms data from previous years. Therefore, phytosanitary harvest was not recommended because it could not prevent complete yield loss. Consequently, "'organic"cocoa is not an option in shaded cocoa fields. In addition, removal of diseased pods, a significant nutrient export, may have negative long-term consequences on sustainability.

1.4.4 Environmental pollution affecting and caused by urban agriculture in Yaoundé

by C. Nolte in collaboration with S. Foto-Menbohan (Univ. of Yaoundé), E. Tanawa (ENSP), E. Ngikam (ENSP), and R. Brummett (ICLARM)

The urban area of Yaoundé has increased tremendously in agricultural activities over the last 15 years due to an annual increase in population of 5–7%, as well as major economic crisis since 1985. Agricultural production takes place mainly in the wetland areas (inland valleys or *bas-fonds*), unsuitable and prohibited by law for construction purposes, and because it allowed off-season production which generates important revenues, especially for the urban poor. Since these bas-fonds are the run-off areas for excess water, problems

arise with respect to water quality. Polluted water used for irrigating crops or heavy-metal polluted water flows into fishponds, as well as other water users, affect agricultural production, because farmers use substantial amounts of pesticides and fertilizers in these systems. In addition to widespread small-scale production (non-point sources of pollution), large animal production units for chicken and pigs (point sources) have been set up in urban areas with no facilities for water purification. Excrements of these units are partly sold as manure on the market, giving rise to opportunities for crop–livestock integration, but the extent of such appropriate use vis-à-vis dumping them with subsequent pollution potential is not known. Hence, public health is affected by these activities but the extent of the problem is not known.

The purpose of this activity is to highlight and quantify (as much as possible) environmental problems associated with urban agricultural activities and to explore possibilities for better use of inputs and outputs. The Yaoundé topography, with its seven mountains and surrounding undulating surface, is made up of a network of inland valleys.

Table 15. Effluent production of industrial plants in Yaoundé.

Type of industrial plant	Total number	Number Surveyed	Effluents in m^3	
Animal production	17	3	258	0.1%
Manufacturing	224	44	171 192	57.8%
Water, electricity, and gaz supply	24	3	1690	0.6%
Construction	62	7	4156	1.4%
Car and repair workshops	712	71	13 809	4.7%
Hotels and restaurants	152	15	27 686	9.4%
Transport and communication	90	10	888	0.3%
Banks and insurances	161	16	2046	0.7%
Furniture manufacturing and other services	459	46	4764	1.6%
Economic and social administration	232	24	10 512	3.6%
Education	152	15	20 594	7.0%
Health and social action	150	30	24 368	8.2%
Collective and personal activities	141	14	10 037	3.4%
Extraterritorial organizations	111	5	4029	1.4%
Total	2687	303	296 029	100.0%

Table 16. Mean water pollution levels of 12 Yaoundé surface waters.

		Mean	S.E.	CV	Min	Max.
PH		7.1	0.80	0.11	6.5	9.9
Temperature	°C	26.0	0.81	0.03	24.3	27.4
Conductivity	$\mu s\ cm^{-1}$	321.2	158.58	0.49	127.0	716.5
MES	$mg\ l^{-1}$	115.2	234.32	2.03	7.0	956.0
O_2	$mg\ l^{-1}$	2.7	0.76	0.29	1.1	3.5
DBO_5	$mg\ l^{-1}$	48.7	66.73	1.37	7.4	271.0
DCO	$mg\ l^{-1}$	95.2	182.11	1.91	5.3	739.0
NO_3	$mg\ l^{-1}$	1.9	2.19	1.14	0.6	8.9
NH_4	$mg\ l^{-1}$	10.4	14.78	1.42	1.0	59.4
PO_4	$mg\ l^{-1}$	9.8	12.46	1.27	1.7	50.0
Faecal coliforme	CFU $100ml^{-1}$	1.7E + 06	2.5E +06	1.44	1500	8.2E + 06
Faecal streptococci	CFU $100ml^{-1}$	9.7E + 05	3.3E + 06	3.42	100	1.3E + 07
Quality class		4.5				

Note: Class 4 = strongly polluted; class 5 = very strongly polluted

Farmers involved in urban and peri-urban agriculture (UPA) often use the land at the bottom and at the fringes of these inland valleys to grow crops, mainly vegetables. These lands belong to the state and agricultural exploitation as well as construction work is officially prohibited. However, due to the "availability" of land, urban dwellers often cultivate these lands. Surface, run-off, and sub-surface water from 14 small watersheds in and around Yaoundé converge in these inland valleys, the largest of which is in the watershed of the river Mfoundi. The waters are polluted by:

a) Point polluters (e.g., industrial plants, fuel stations, septic tanks, non-functional sewers, and markets).
b) Non-point or diffuse polluters (e.g., dumped household refuse and latrines and agricultural inputs such as pesticides, organic and inorganic fertilizers, informal small animal production units and soil erosion).

Complete data for all watersheds were not available. However, pilot studies looked at pollution levels of specific small watersheds and point polluters.

Yaoundé has 2687 known industrial units, which are mostly located in the south, north, and center of the city. Most of these plants discharge their liquid effluents and solid wastes untreated directly into surface waters. They are estimated to produce monthly 4600 tonnes of solid waste and 296 000 m^3 of effluents (Table 15).

Six larger manufacturing plants, such as breweries, slaughterhouses, and dairy plants were responsible for more than half of all liquid industrial effluents discharged into Yaoundé 's surface waters. The load of each effluent with specific chemical compounds or biological substances is known for some but not all such plants.

For example, 2080 mg/l DCO, 259 mg/l MES, 1650 mg/l DBO_5, 41.5 mg/l PO_4, and 71.5 mg/l NH_4 were found along with 1000 CFU $100ml^{-1}$ faecal coliforms and 50 CFU $100ml^{-1}$ faecal streptococci in effluents from breweries.

An analysis of microbiological and physicochemical quality of surface waters in the Mfoundi watershed revealed up to 27 x 10^9 CFU 100 ml^{-1} of *Pseudomonas aeruginosa* due to faecal contamination. This bacterium a common fatal genetic disorders in the US, infects individuals with cystic fibrosis, affecting the respiratory tract. Unlike many other environmental bacteria, *P. aeruginosa* has a remarkable capacity to cause disease in susceptible hosts, i.e., individuals with immune system deficiencies. Often, pollution levels were higher in lower parts (*en aval*) of the watershed than in the upper parts (*en amont*). For example, in the Abiergué watershed, it was found that DBO_5 levels were 150 mg/l in the lower part and 35 mg/l in the upper part. This was a result of increasing numbers of polluters along the rivers, which had an important bearing on water quality of small lakes, often used for fishing. Thus, high levels of faecal contamination were found in two major lakes of Yaoundé. A study in the Mingoa watershed, covering the Melen and Ellig Effa quarters, revealed that 65% of households were "equipped" with *latrines à fonds perdu*, 15% had septic tanks, and 18% had *latrines à canon*. *Latrines à fonds perdu* are in direct contact with the uppermost groundwater level, causing the bulk of surface water pollution with biological substances. This was a major reason why the quality of water from all streams flowing into Yaoundé was rated from strongly to very strongly polluted, with faecal bacteria (Table 16).

The World Health Organization (WHO) recommended a maximum concentration of faecal coliformes of 0.0 CFU $100ml^{-1}$ for drinking water. Fresh fruits and vegetables of 10–1000 CFU 100 ml^{-1} *Escherichia coli* (one of the most common *Faecal coliforms*) were known to

cause bloody diarrhoea and abdominal pain. In children and the elderly, 100–1000 CFU could cause *Haemolytic uremic* syndrome and kidney failure. WHO also recommended that water, coming into direct contact with people, should contain less than 1.0E + 04 CFU 100 ml^{-1} of total *Faecal coliform* bacteria. The mean of 12 surface waters exceeded the thresholds, as did the values of 10 out of the 12 rivers—the two exceptions were the Ebama and Ekozoa rivers in Yaoundé, 5 and 4 respectively. The same was found for the waters of Lac Central and Lac Melen, the two major lakes in central Yaoundé.

Due to these pollution levels, contact with surface water is dangerous. Contamination occurs by direct contact when fetching irrigation water or bathing, as well as consumption of fresh vegetables that had been irrigated with surface water. Apart from the health problems mentioned above, germs in the water become vectors for illnesses, such as cholera and dysentery, malaria, bilharzia, and schistosomiasis. In a survey of 60 urban farmers, Elong (2004) found, that farmers, who cultivated the bottomlands complained more often (>50%) about health problems and spent more money on health than farmers who cultivated the slopes and uplands (20%). Most (87%) commercial farmers cultivated the bottomlands, whereas most (80%) food producers cultivated the uplands.

Therefore, urban farmers were not only affected by water pollution, they also contributed to it by using excessive or wrong application of fertilizers and pesticides. The average intensive vegetable grower in Yaoundé uses 20 bags of chicken manure on 393 m^2 of land, corresponding to 18 t/ha and 10 t/ha used by the average extensive vegetable grower. These are not excessive levels, but a previous survey of 296 urban and peri-urban farmers showed that small landholders used relatively more fertilizers than larger landholders. The same applied to pesticide use (Fig. 5).

They also determined, that 51% of urban/peri-urban inland valley farmers applying pesticides used Methyl-Parathion, a highly toxic insecticide, 16% used Maneb, a nontoxic fungicide, 16% used Deltamethrin, a pyrethroid, 6% Benomyl, a nontoxic fungicide, and 2% Carbofuran, a highly to moderately toxic insecticide. No data were available about the impact of pesticide use on water quality.

The current level of water pollution affecting agricultural activities in Yaoundé and its impact on human health raises the question whether or not such agriculture should be promoted. It is clear that this could only be responsibly done in conjunction with measures to inform and educate both, producers and consumers about the risks involved.

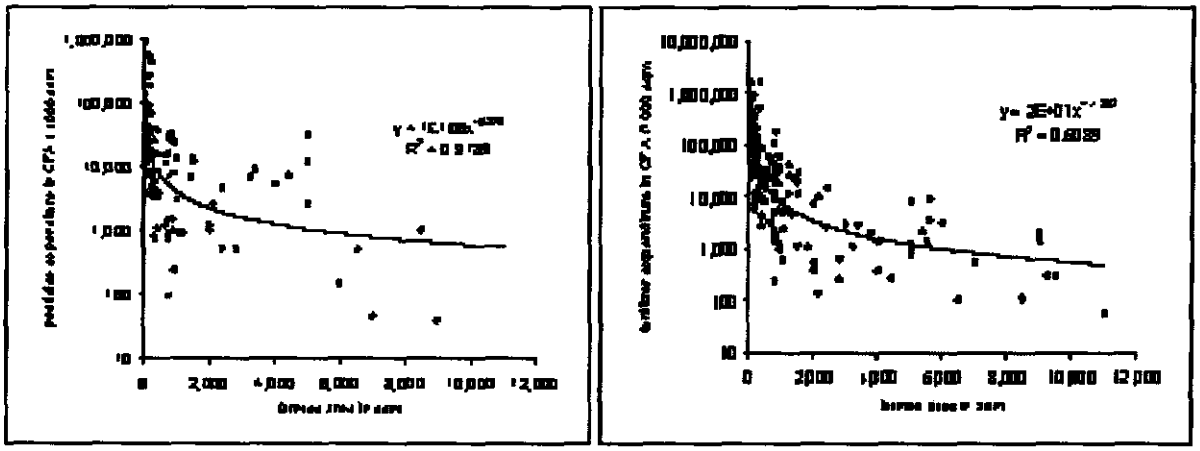

Figure 5. Biocide use of UPA farmer in relation to the farmed area.

On the other hand, there are no studies available that would establish the relative effect of this risk vis-à-vis all the other factors affecting human health in an African city like Yaoundé (e.g., air pollution by leaded exhausts).

Cleaning up the surface waters of Yaoundé will be a huge task that is not likely to be achieved in the future. As a first immediate step, urban agriculturalists should be educated about the dangers of using and getting into contact with urban river water. Furthermore, consumers should be informed that the use of fresh vegetables without bacteriological decontamination is dangerous. Washing fresh vegetables prior to consumption and treating them with small amounts of household bleach can easily and cheaply achieve this. Alternatively, cooking vegetables before consumption kills off the germs that might affect human health.

1.1 Establishing scale relationships in biophysical and socioeconomic context to delineate appropriate intervention domains and define actions for targeting experimentation and dissemination

1.5.1 Livelihoods study of urban agriculturalists in Yaoundé

by J. Gockowski in collaboration with N.N. Soua Mboo, P.A. Elong (Univ. of Dschang), and O. David (IRAD)

The importance of urban and peri-urban agriculture (UPA) in the overall livelihood strategies of its practitioners is not well understood and consequently policymakers have little basis for making informed decisions. The typical urban agricultural enterprise focused on the production of leafy vegetables generates revenues which exceeds the legal minimum wage in Yaoundé, using production cycles, which are short (4–6 weeks) and potentially allow households flexibility in terms of entry and exit from this activity (Gockowski et al. in review). However, we did not have a clear picture on the integration of this type of activity into the overall household livelihood strategy.

In the outlying urban periphery (20–45 kilometers), market proximity encourages the production of perishable commodities that are difficult to bring to market from the more distant hinterlands (these include leafy vegetables, fresh fruits, fresh cassava, and bananas). The locational advantages for households in the peri-urban periphery were likely to have different implications for intra-household welfare, as there is a clear division in the cropping systems managed by men and women. These differences and their implications for poverty reduction are not clear. There is similarly a lack of knowledge on the evolution of intensification strategies among men and women producers and their choice of technology. Data from the ASB4 program for instance showed a clear increase in cassava density (up to 85% increase) for households producing within 30 kilometers of Yaoundé, relative to villages too far to market fresh cassava to Yaoundé consumers (IITA unpublished data). Other results indicated that in this area, cassava was the most important commercial food crop for a majority of households in this periphery (IITA unpublished data). However, the integration of commercial cassava production into the women's overall set of responsibilities was also not well understood.

To answer these types of research questions, a study targeting the role and impact of urban and peri-urban production and its marketing channels on the livelihood strategies of the poor is proposed.

The objectives of the study included:

1. Describing and diagnosing the diversity of socioeconomic roles played by peri urban and urban agriculture and their relationship with other livelihood activities of the poor.
2. Describing livelihood system models among the poor and the role and interactions of urban and peri-urban agriculture within these systems.
3. Conducting a focused participatory appraisal to identify means of ameliorating the contribution of UPA for the principal livelihood systems incorporating a significant role for urban and peri-urban agriculture.
4. Providing quantitative evidence of the contribution of UPA in the livelihood strategies of the poor.

Casual observation of urban agriculture in Yaoundé revealed three main types of cropping systems: (1) mixed crop systems dominated by open-pollinated varieties (OPVs) of improved maize in the upland areas (vacant lots, unused municipal lands), (2) monocrop systems of OPVs of improved maize grown in valley bottoms, and (3) intensive horticultural systems in valley bottoms. Other manifestations of urban agriculture, evident in Yaoundé, included stands of plantains and bananas around households, small beds of leafy vegetables and commonly used herbs, grown adjacent to households, numerous avocado, African plum (*Dacryodes edulis*), mango, and guava trees around households and in the case of mangos as line plantings along streets, small animal husbandry (guinea pigs, rabbits, chickens, pigs). A prioritization of these types of agriculture based on the economic importance, numbers of persons involved, importance to urban market supply, and potential for successful innovation (agronomic, marketing, institutional, or policy) in support of urban agriculture led to our focus on the three principal cropping systems described above.

The activity began in March 2003 with a qualitative evaluation of the livelihoods of urban agriculturalists (defined as those agriculturalists cultivating within the boundaries of at least one of the six *sous-prefectures* which comprise Yaoundé). Semi-structured interviews were conducted with 28 urban agriculturalists located in six different sites in the city. These agriculturalists were chosen opportunistically while working in their fields by a team of two interviewers. A checklist of discussion subjects aided the interview. The purpose of the qualitative interviews was to develop a clearer understanding of the motivations for urban agriculture and its importance in their overall livelihood strategies and on the basis of the findings to develop a focused survey instrument for the second phase of the study. The first phase of the study was completed at the end of May 2003.

Given the limited resources available for the study (US$1800), it was not possible to do a large systematic random sample of urban households, which would have established the overall importance of urban agriculture relative to the population as a whole.[5] Instead, a purposive stratified sampling strategy was pursued based on the findings from the qualitative study.

The qualitative study uncovered two strategic household objectives in pursuing urban agriculture: contribute to the household food supply and generate cash income.

Furthermore, there was a high correlation between where a producer operated his or her enterprise, the visual nature of the enterprise and the nature of the household's objective vis-à-vis urban agriculture. Producers pursuing urban agriculture on raised beds in the valley bottoms, or those growing monoculture maize were much more likely to pursue a

commercial objective than those agriculturalists who cultivated mixed crop associations on upland fields to augment household food supplies.

The preceding information was used to classify the population of urban agriculturalists for commercial and household food production. These objectives are not mutually exclusive. Even the most commercially-oriented producer of traditional leafy vegetables was likely to consume at least some of his or her produce (unless perhaps it was produced using grey water from urban Yaoundé's open sewage system), necessitating a clear definition of a commercial producer. Producers were classified as commercial if they sold at least half of one of their products in the market; but if they did not, they were classified as household food producers. In the final count, a total of 121 urban agriculturalists were purposively chosen and interviewed with both commercial and food producers in roughly equal proportions (Ncommercial = 61 and NHFOOD = 60).

To summarize, the sampling procedure did not allow us to extrapolate our results in a statistical sense, as the exact population of urban agriculturists was unknown. It however allowed us to make meaningful comparisons concerning the impact and nature of urban agriculture on the well-being of producer's households.

Among some of the more interesting findings of the study were:

- High prevalence of women producers, accounting for 87% of the total sample
- Greater tendency for men to be involved in commercial agriculture (81% of men interviewed were producing for commercial objectives).
- Lower proportion of commercial producers with secondary education as compared to household food producers (25% versus 42%).
- Majority of urban agriculturalists were from the densely populated and impoverished western highlands (55% of total).
- Abnormally large size of the average household (7.9 persons).[6]
- Unstable and transitory nature of urban agriculture evidenced by the high frequency of producers (55%) indicating that they had been forced to abandon fields because of various tenurial issues.
- More secure tenure arrangements among commercial producers relative to household food producers (e.g., two thirds of commercial producers had inherited customary tenure rights in contrast to only one third of food producers).
- Concentration of commercial production in valley bottoms (87% of producers) and of household food production on the uplands (80% of producers).
- Small size of the typical urban plot (approximately 400 m^2) and the greater number of plots among commercial producers (4.1 plots) and household food producers (1.8 plots).
- High employment of child labor (57% of all producers), some engaged in potentially hazardous activities (e.g., application of pesticides).
- Focus on traditional leafy vegetables and green maize production among commercial producers (85% and 75% of interviewees) and household food producers (63% and 88% of interviewees respectively).

- Greater frequency of commercial producers relative to household food producers using purchased inputs (chicken manure 87% versus 28%, inorganic fertilizer 87% versus 37%, insecticides 80% versus 23%, and fungicides 29% versus 10%).
- 70% of commercial producers indicated agriculture as their principal source of income, 21% formal sector, while 9% petty commerce.
- 67% of household food producers indicated formal sector job as their principal source of income, 20% petty commerce, while 13% pension. None indicated agriculture as their principal source of income, approximately half indicated it was their second most important source of revenue.
- Much higher reported rate of morbidity and greater health care expense among commercial producers probably related to the unhealthy septic environment of Yaoundé's valley bottoms.
- Enterprise budgets developed for commercial TLV production gave an estimated monthly income of FCFA36 000, which was above the minimum wage.

1.5.2 Institutional aspects and policies of urban agricultural management at Yaoundé

by C. Nolte in collaboration with A. Bopda (Institut National de Cartographie), and L. Awono (Commune Urbaine de Yaoundé)

The context of UPA offered a virtual front line where the "rural" met the "urban" right from the farmed plot to the city quarter or the market. It was a meeting point around food security, where the nutritional requirements of citizens called out for production capacities of rural people while at the same time, the food production of rural people give rose to the commercial activities of city-dwellers.

However, the relationship between the two parties was not always cordial. The urban people exploited the rural people because they (urban) were richer, better educated, and better at decision-making. The rural people therefore resorted to occult practices against the city-dwellers.

The uncordial relationship led to anarchy. The urban dwellers saw the rural people as anarchic, transposed by neo-urbans, who still retained their traditional views of the world, thought caught up in "urbanization". By contrast, villagers did not accept the anarchy that came along with modernization in the process of urbanization. If they had the means, they would have settled their dispute if the citizens had withdrawn to the village (witchcraft, etc.).

Conflicts of legitimacy and indecision of the legislators caused uncertainty in the environment. This finally led to conjecture where wanted and unconscious confusion could not help to calm the relationship between city and agriculture. However, a calm approach imposes itself daily. Innovation or perishing is inevitable.

UPA finally changed between natural agriculture and artificial environment. The study obliged us to think about our relationship in interactive and interdependent terms. The complexities of things and people, complicated matters were taken into account. We advocated that agriculture should not be considered as a plan for urban improvement, but as an intrinsic dimension of the life of men, women, and children, be they in villages or in the city. Even at night? (*contre jour*) and totally isolated in a universe of invading stones,

a tree, a flower, a lettuce or tomato bed, gives more tranquillity and human quality for the environment. Thus reintegrated into the priorities since the conception phase and appropriated by concerned actors in the creation of a normative synergy, built thanks to a concerted approach, agriculture in bygone days excluded from the conception of our cities, UPA could serve as a leverage for an efficient and effective renaissance, in a contextual and adjusted way, for entering general urbanization, which today is triumphant in our societies.

We have to use urban agricultural rehabilitation in order to re-initialize the conscience of our open and prospective integration into the living world. All that imposes openness, flexibility, availability, entrepreneurship, and responsibility in the perpetual effort of modernization. An inspiring task of conception, experimentation, and validation of adjusted norms and standards awaits us. It includes one suspects and a vast institutional component in which dissociating agricultural utility and urban pleasantly would be risky and painful.

UPA presents itself as a vast working program for present or future institutional actors, because of its spontaneous activity, with or without proper training, across Yaoundé's agglomeration like in other Third World countries. Institutional interest for UPA appeared weak or insufficient, in spite of the fact that multiple functions of UPA in Yaoundé had impact on a number of economic and social activities. There was a wide gap between possible interventions of existing institutions and real interventions on the ground.

The possibilities for reinforcement of institutional capacity in UPA and its environment were numerous and sometimes urgent. These reinforcements could be in terms of promoting food production or employment of the urban poor and encouraging leisure activities that were spontaneously adopted; in defence of an urban environment, which was greener, richer in oxygen, more protected against land slides; or development of bush land in inland valleys.

The aspects of land tenure and property rights deserve special attention, because they are sensitive issues often put forward. In addition, UPA activities led to multiple conflicts in these last years. The facts once established, it is important to understand how these conflicts come about, how they are managed, and what are the consequences. How to improve urban policies vis-à-vis UPA? Should they or can they be stabilized in the long run so that, by establishing longed-for employment, in the medium and long run a good quality of life can be guaranteed through defending, protecting and reproducing a viable environment? How to better attract attention for this vast field of activities so that all possibilities for charity are promoted, while those for nuisance are suppressed? Such could be the formulation of a topic for stimulating a first brainstorming workshop. Mobilizing all potential institutional structures, which were identified by this study, would permit to establish a status quo and at the same time to outline a road map for all potential stakeholders of a quality UPA in cities like Yaoundé at the beginning of this millennium.

2 Prototype options for sustainable and competitive crop production, postharvest, and peri-urban crop–livestock systems developed and verified

2.1 Develop and test soil, weed, disease and pest management options, and integrate required components adapted to farmer circumstances

2.1.1 *Evaluation of improved* Musa *(plantain) production techniques through pest management and mulching with* Tithonia diversifolia *on farms in Nigeria*

by D. Coyne in collaboration with S. Hauser and A. Tenkouano

On-farm demonstration plots were established at 15 sites in Nigeria in 2003 to promote the use of clean-planting material in combination with mulch, for improved nematode management, increased longevity of plantain plantations, and increased production per crop cycle. Treatments included: farmers' traditional planting style (using suckers without removing the roots or treatment and without mulching); using suckers that have had their roots removed to the corm and the corm dipped in boiling water for 30 seconds; and treated suckers (roots removed and dipped in boiling water), plus *Tithonia diversifolia* mulch added at a recommended rate of one handful per plant per month when possible. Removal of roots and dipping in boiling water was for the purpose of disinfesting the suckers of plant parasitic nematodes, which currently cause severe losses to plantain in West Africa. Farmers added mulch at varying rates according to the availability of mulch material and their other demands, but were willing to mulch. Treatment of farmers' planting material was infested with nematodes to varying degrees, mainly with *Helicotylenchus multicinctus* and *Meloidogyne* spp. and some with *Radopholus similis*. At 6 MAP, plants in the treated sucker and mulch were higher ($P \leq 0.01$) than plants in the other treatments, while plant girth at 1 m from the ground was less ($P \leq 0.001$) in the farmers' practice than the other treatments. Data collection continues.

2.1.2 *Evaluation of the comparative efficiency of* Tithonia diversifolia *mulch for pest management and improved Musa (plantain) production*

by D. Coyne in collaboration A. Tenkouano

Use of *Tithonia diversifolia* applied as fresh mulch, was assessed for its affect on plantain crop growth and production and on nematode activity, in both a microplots and field experiment. In microplots, the experiment had been repeated, but was terminated after nine months. The application of mulch at the equivalent of 2 t/ha dry weight gave higher plantain leaf dry weight ($P \leq 0.001$) compared with no mulch and higher stem ($P \leq 0.01$) and leaf ($P \leq 0.001$) dry weight at 4 t/ha dry weight application. No differences in root weight were observed between the treatments ($P \leq 0.05$) at nine months. Nematode densities of *Helicotylenchus multicinctus* and *Radopholus similis* appear to be suppressed at high application rates of mulch (> 8 t/ha dry weight application) and resulting in lower root damage indices. In the field experiment, mulch was applied annually at 0, 6 (in one application), 6 (in 2 x split application) and 6 t/ha dry weight application (split in between 5 x monthly application). In all mulched plots, plant height was greater than without mulch ($P \leq 0.01$) but increased the number of days to flowering ($P \leq 0.05$). Yields were higher in the single application and 5 x split application ($P \leq 0.05$) than the remaining two treatments to date, although harvests continued for the mother crop and therefore not finalized. The effect of mulching with *T. diversifolia* on plantain nematode activity and multiplication has not been concluded, but appears to have a suppressive effect. Both microplot and field trials are continuing.

2.1.3 *Integrated crop management for plantain in the humid forest zone of Cameroon*

by S. Hauser in collaboration with B. Banful and A. Tenkouano

Integrated crop management for plantain comprises of activities on integrated pest and disease management; improved soil and biomass management; including the use of cover crops, testing agronomical practices such as planting arrangements and density and fertilizer use, and testing of new or non-conventional varieties and *Musa* types.

Integrated pest and disease management addresses nematode control, largely *Radopholus similes*, the banana weevil (*Cosmopolites sordidus*) and unspecified diseases attached to conventional planting material (suckers). The efficiency and yield responses of local plantain to paring and several methods of sucker cleaning with and without previous paring were reported last year and it appears that paring was not beneficial, yet any of the two thermal control methods (hot water and boiling-water treatment) out-performed all other methods including nematicide application. Therefore, other experiments were conducted with the most simple boiling-water treatment. Further, the use of corm-fragment-generated plants was tested and despite low establishment, the surviving plants produced early and heavy bunches.

Improved soil and biomass management has so far produced results unsuitable for firm recommendations. Retaining the biomass after clearing rather than burning did not contribute to consistent yield increases. In one experiment, burning biomass, in combination with hot water treatment increased bunch yield significantly. Thus, burning and mulching was regarded as an issue of labor requirement for plantation establishment and maintenance, rather than soil management. The introduction of leguminous cover crops of lines of shrubs is being tested in a multilocation experiment with differently treated planting material and an IITA hybrid. Fertilizer use has been successful in previous experiments. Yet, firm recommendations could not be given, because there were no fertilizer response curves for any of the major nutrients, nor information on the requirements for the other essential elements available. Agronomic measures such as planting pattern and density have not been tested in Cameroon or another Congo basin country. Activities in 2003 started to test the effects of increased planting densities on plantain yield. However, as the wide range of local cultivars varied considerably in plant size and duration to flowering, density effects were likely to be cultivar-dependent. Further, with inherently low soil nutrient status, changes in plant density may require nutrient addition. Plant density, cultivar, and soil nutrient supply are expected to be interdependent. The introduction or promulgation of uncommon or new cultivars was a success. Cooking banana to shade cocoa outlasted plantain and continued with production for five years, with no significant sign of decline. A multihanded-true-horn cultivar used in an experiment on pest and disease and nutrient management and produced more bunches and fetched higher prices per kg than a French type. Weed control in plantain is yet to be a subject of research activities. Highlights of 2003 results are provided.

2.1.3.1 Effects of land type, cultivar, sucker treatment, and fertilizer application on plantain bunch yields

An experiment on the effects of hot water treatment, fertilizer application, soil, and cultivar conducted near Yaoundé on a degraded land and after forest clearing, revealed the overwhelming importance of the land type. The forest sites out-yielded the degraded sites, even without fertilizer application and nematode-infected suckers. In both land types and cultivars, the pattern of yield increase was the same: fertilizer alone increased yields less than cleaning alone, while cleaning plus fertilizer application produced the highest yields.

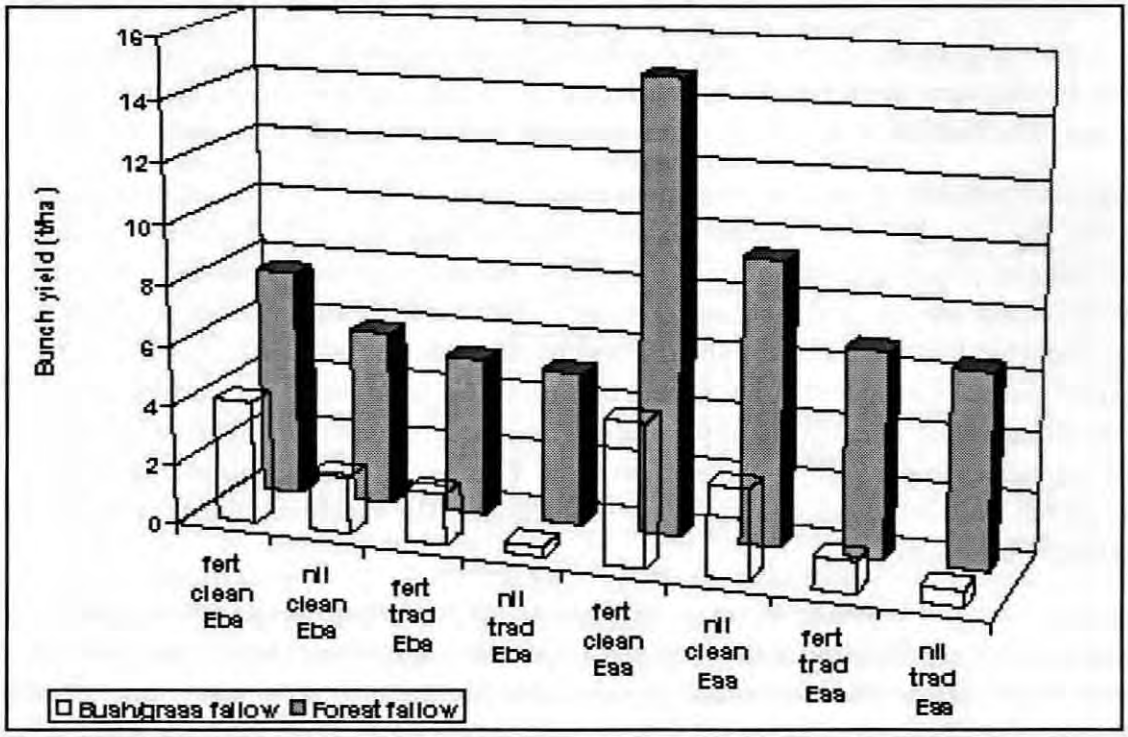

Figure 6. Plantain fresh bunch yields of a false horn (Ebang [Eba]) and a French (Essong [Ess]) plantain after hot water treatment (clean) with traditional (trad) planting and with (fert) and without (nil) fertilizer application in degraded grass/bush fallow and after forest clearing.

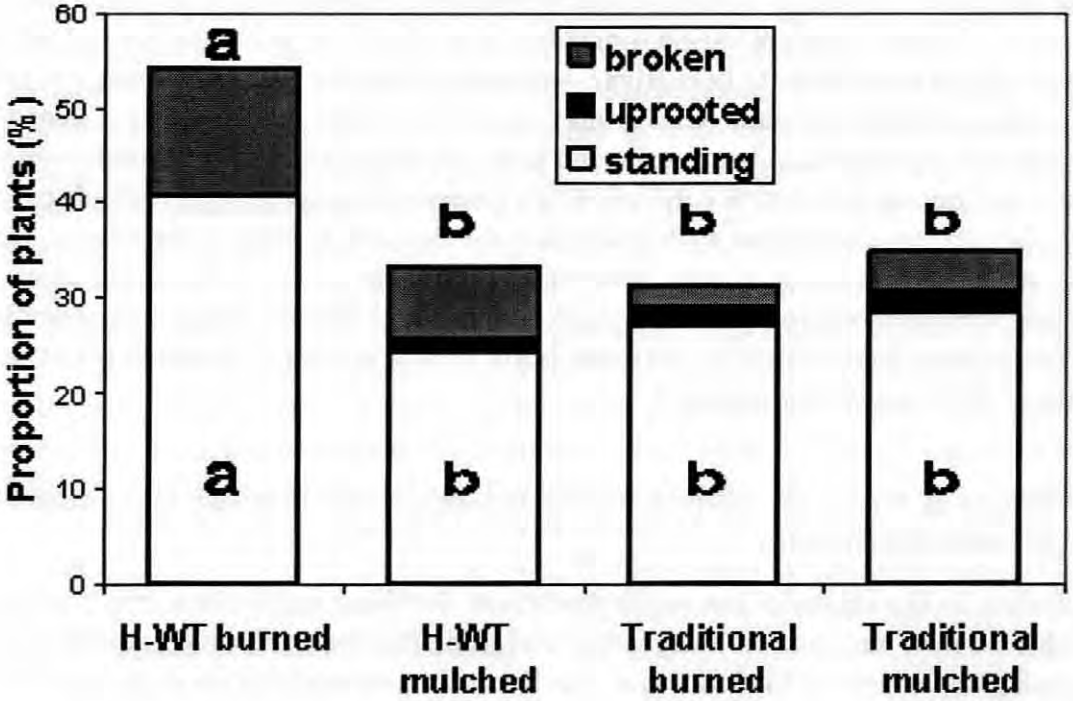

Figure 7. The proportion of false horn plantain plants that produced edible bunches after hot water treatment (H-WT) of suckers and forest biomass burning, at Ngoumbou.

Relative yield increments were higher in the degraded grass/bush fallow, due to extremely low yield in untreated and unfertilized plots (Fig. 6).

Under forest conditions, the advantage of French plantain was more pronounced than in the grass/bush fallow. Thus, if farmers were to intensify plantain production, the first measure would be to clean the suckers, as this is less cost intensive than fertilizer application. Furthermore, as fertilizer alone had a less positive effect than treatment, a second step would be to use treatment and fertilizer rather than fertilizer alone. The reintroduction of profitable plantain production to grass/bush fallows required more than nutrient (N, P, K) addition and the elimination of nematodes. However, in this experiment, no other soil related factors were modified or measured. There was no correlation between soil chemical properties such as pH, organic C, total N, available P, and exchangeable cations, determined by standard chemical procedures and the plantain bunch yields. Probably, other properties, either biological or physical had more influence on plantain growth and yield.

2.1.3.2 Effects of biomass management and sucker treatment on bunch yield of a false horn plantain after forest clearing

The experiment was conducted in a farmer's field 28 km south of Mbalmayo, after clearing a 17-year old secondary forest. Biomass was either burned or retained. The false horn cultivar Ebang was planted either after hot water treatment (20 minutes in 52°C) or after traditional preparation, (i.e., crude removal of rotten tissue). The proportion of plants that produced (Fig. 7) was highest in plots planted to hot water treated suckers after biomass was burned.

There was virtually no uprooting of plants, yet about 15% of the edible bunches were recovered from plants with pseudo stem breakage. The bunch yield followed the same pattern as the proportion of producing plants (Fig. 8), with the highest yield in the hot water treated, plots after burning.

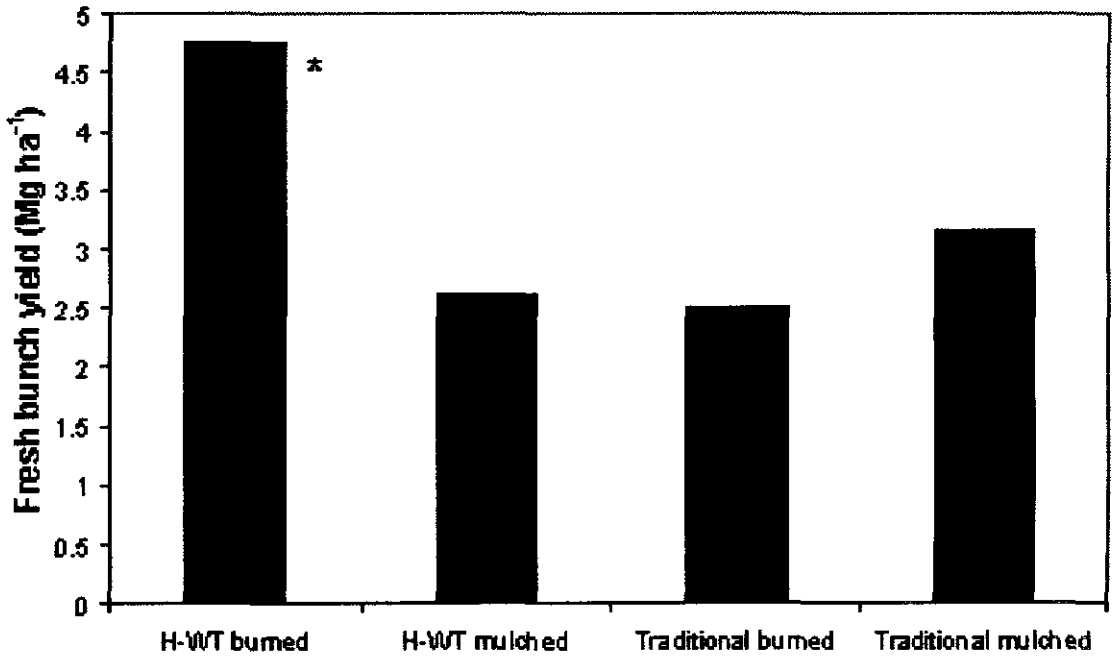

Figure 6. Fresh bunch yield of a false horn plantain cultivar after hot water treatment (H-WT) of suckers and forest biomass burning, Ngoumbou (* significantly different from all other treatments).

Burning had no negative effect and under these conditions, could attain higher yields. The site may have been strongly nutrient deficient. Burning releases P and cations into the soil faster than decomposition of mulched biomass. Therefore, plantain with a clean root system could benefit from such nutrient release while in the mulched plots, lack of nutrients may have prevented a higher yield.

2.1.3.3 Effects of boiling-water treatment, cultivar, and fertilizer application on bunch yield of local plantain

The experiment is conducted in a farmer's field at Awae village near Yaoundé. The land was cleared from 12- to 15-year old secondary forest and the biomass burned, however, not completely. Large logs remained while smaller branches were burned completely. A French and a multihanded-true-horn variety were planted either after traditional sucker treatment or submergence in boiling water after 30 seconds. A third treatment was planting of corm fragment generated plants (CFP), purchased from a farmer group which had picked up the technology to produce planting material and generate income through plant sales. Establishment was low in the CFP plots, about 50% of the level attained by boiling water treated and traditionally planted suckers. At flowering, CFP plants were not of the expected cultivar but largely of a third cultivar, a French type locally called Elat and rather dissimilar to the intended French type locally called Essong. The treatment was thus discarded from further analysis. Bunch yield at 18 MAP was affected by treatment with boiling water-treated plots yielding 11.56 t ha^{-1} and 7.9 t ha^{-1} in traditionally planted plots ($P = 0.072$). The cultivar and fertilizer application had no effects. However, earlier in the production phase, there was an advantage to the true-horn cultivar as more plants had flowered and produced earlier than in the French cultivar. The bunch mass per plant that produced an edible bunch was 13.0 kg in the true horn cv. and 18.3 kg in the French cv. ($P < 0.0001$), with a slight, yet insignificant advantage of the plots with boiling water treatment. The experiment was not sufficient (less tan 50% of plants have produced) to make firm conclusions. However, the absence of a fertilizer effect confirmed the results of previous experiments on hot water treatment, indicating that the most important and profitable intervention is sucker cleaning.

2.1.3.4 Effects of sucker cleaning, cropping system, land type on local plantain yield, and performance of an IITA hybrid (PITA 14) in southern Cameroon

A multilocation experiment was established in three villages. Within each village, land was cleared in *Chromolaena odorata* dominated bush fallow and in about 15–22-year old secondary forest. In each land type, four cropping systems: natural regrowth, *Pueraria phaseoloides* cover crop, *Flemingia macrophylla* shrub lines, and hot pepper intensive intercropping. In each of these systems, the local French plantain cv. Essong was planted from conventional suckers either after boiling-water treatment or traditional preparation, and from corm fragment generated plants (CFP), as a comparison PITA 14 CFPs were planted. The cropping systems were imposed one year before plantain planting. At systems implementation, soil samples were taken to establish the chemical and physical properties and nematode composition and abundance. Nematode abundance was determined one year later for a second time just before planting the plantains. In both systems planted to the leguminous species, nematode abundance was significantly lower than in natural regrowth and the intercrop. Weed biomass and composition was determined 11 MAP the legumes (Table 17). There was a significant land type by cropping system interaction, with total broadleaf weeds in the *F. macrophylla* and *P. phaseoloides* systems producing the

same amount of biomass after bush and forest clearing, while there were fewer weeds in the forest clearings than the bush clearings when natural regrowth was allowed. In both land types, all three systems were significantly different with *P. phaseoloides* reducing weeds the strongest.

Plantain establishment was affected by the type and treatment of the planting material (Table 18). The local cv. and PITA 14 CFPs had significantly higher establishment rates than the untreated and boiling-water treated suckers. There were some differences in establishment between villages (not shown)—untreated suckers, followed by boiling water-treated suckers, attained lowest establishment. The experiment was not sufficiently advanced to report further data plants flowering.

Table 17. Effect of 11 months of growth of *Flemingia macrophylla*, *Pueraria phaseoloides* and natural fallow on broadleaved weeds biomass in bush and forest natural fallows.

	Bush fallow	Forest	Mean	P w comp
F. macrophylla (Fm)	2.30	2.26	2.28	ns
P. phaseoloides (Pp)	0.49	0.90	0.70	0.10
Natural regrowth (NR)	5.77	4.12	4.95	<0.0001
Mean	2.85	2.43		0.005
Pairwise comparison				
Fm vs Pp	<0.0001	<0.001	<0.0001	
Fm vs NR	<0.0001	<0.001	<0.0001	
Pp vs NR	<0.0001	<0.001	<0.0001	

Fm = *F. macrophylla*, Pp = *P. phaseoloides*, NR = natural regrowth

Table 18. Percent establishment of a local French plantain cultivar Essong and PITA 14, as a function of the type and treatment of the planting material.

	Ngoumou	Mfou	Nkometou	Mean
Untreated	65.6	89.8	70.8	75.4
Boiling water	96.3	85.4	86.1	86.1
CFP Essong	95.2	95.4	97.2	95.9
CFP PITA 14	100.0	99.4	98.3	99.3
Pairwise comparison				
Untreated vs boiling	<0.0001	0.034	0.0067	<0.0001
Boiling vs CFP Essong	ns	<0.0001	<0.0001	<0.0001

CFP = corm fragment-generated plant.

2.1.4 Evaluation of the interaction between fertilizer application and nematode damage on yam

by D. Coyne in collaboration with H. Baimey, University of Pretoria, RSA

Field trials were conducted in Ibadan, Nigeria (NPK) and at Cotonou, Bénin (NPK, DAP, and KCl) to assess the interaction between fertilizer application and *Scutellonema bradys* nematode damage on yam cv. Td131. Results showed that in Bénin, there was no difference in nematode densities on yams at harvest between treatments (inoculated). But at 3 months through 5 months after harvest, nematode densities increased to higher levels ($P \leq 0.05$) in the nonfertilized treatments than in fertilizer treatments, for inoculated plants, and densities increased in NPK treatments more ($P \leq 0.05$) than in either the KCl or DAP treatments. Infested (inoculated) tubers lost weight to a greater extent than noninfested tubers during storage, which became more pronounced during storage. Tubers from either inoculated or non-inoculated treatments that received no fertilizer lost less weight ($P \leq 0.05$) during storage than those that received fertilizer.

2.1.5 *Integrated management of maize stem borers in the humid forest margins of Cameroon*

by A. Chabi-Olaye and C. Nolte (IITA), F. Schulthess (ICIPE) and C. Borgemeister (Univ. of Hannover)

2.1.5.1 The effect of nitrogen/potassium combinations and damage by *Busseola fusca* on maize yield in the humid forest zone of Cameroon

This experiment is part of the large study that investigates the effect of fertilizer on the incidence of stem borer and maize yield. Thus, a field trial was designed to investigate the effect of different N x K combinations on maize yield and stem borer attacks with particular reference to *B. fusca*. Three levels of nitrogen (N0 = 0, N1 = 60, and N2 = 120 kg/ha) combined with three levels of potassium (K0 = 0, K1 = 80, and K2 = 160kg/ha), giving a total of nine treatments by two insect levels (infested plot and carbofuran treatment plot) were tested.

B. fusca infestation varied significantly between number of days after planting (DAP). Increase in the nitrogen level increased *B. fusca* populations as seen in the percentage of plants with egg batches and the percentage of infested plants. Infestation reached a peak of 1.5 and 3.5 larvae per plant at 49 DAPS, in the first and second season, respectively. Thereafter, the average number of larvae per plant decreased significantly with the level of K applied. At 63 DAP, the larval mortality rate in plots with no N and with K = 80 or 160 kg/ha was 1.5 higher than those with no N and no K application. But, the overall mortalities were not different among treatments. Thus, the effect of K and N were likely to be more important at the early instars larvae.

The total dry matter and grain yield were significantly affected by both N/K application and borer activity. Hence, increasing the rates of N increased the total dry matter and grain yield.

The total dry matter and grain yield at 120 kg N/ha was 2 and 1.8 times higher than that of the control. The application of K increased significantly the total dry matter and grain yield, particularly when no N was applied. By contrast, at a given level of N and with insecticide application, the total dry matter and grain yield of simple effects of K were not significantly different, indicating that K did not have a direct effect on yield. However, its contribution to yield increase was due to the reduction in borer population and their damage as indicated by lower grain yield losses at higher rates of N and K.

The percentage of grain yield loss was 45.6% when no N was applied. It decreased significantly to 2.7% when a rate of 120 kg N and 160 kg K ha^{-1} was applied (Fig. 9). The findings so far indicated that N and K had a significant effect on *B. fusca* and thereby increased the grain yield. A more detailed life table study is ongoing to elucidate the possible control mechanisms.

2.1.5.2 Effects of intercropping maize with cassava, cowpea, and soybean on the incidence and severity of *Busseola fusca* damage of maize

Field experiments were designed, comparing insecticide-treated and untreated maize monocrops with the respective maize/legume or maize/cassava intercrops in two spatial arrangements, i.e., maize on alternate hills (Ah) or in alternative rows (Ar). Destructive and nondestructive sampling procedures were used to identify the factors leading to reductions in pest densities. During both, the longer first and the shorter second season, egg batches and larval densities varied significantly with DAP (significant linear trends, $P < 0.0001$).

During both seasons, the temporal fluctuation of egg and larval infestations in intercrops more or less followed that of the monocrop, but densities were considerably and significantly lower in mixed cropping treatments. Young *B. fusca* larvae moved from the oviposition site between the leaf sheath and the stem, to the whorl from where they either penetrated into the stem or dispersed to other plants. It was theorized that in mixed cropping migration-related mortality was higher as a result of reduced host finding. However, since differences in egg-to-larva mortality between cropping systems were small (1.5–5), suggested that most of the differences in larval densities were due to differences in oviposition rates rather than migration-related mortality, corroborating our previous findings in 2002.

Depending on crop association and planting pattern and compared to monocropped maize, intercropping maize with a nonhost reduced egg densities by 30–60% and plant damage (stem tunneled, grain damage) by 50–75%. Depending on crop mixture and season, intercropped maize had significantly higher per plant yield than monocropped maize.

A stepwise multiple regression analysis of data, collected during the first and second seasons, between stem borer density and attack and variables of plant damage on maize grain yield, showed that the only significant plant damage variables, that entered the multiple regression equation, were percentage plant bored and percentage ear damage, both negatively related (b= -1.6, -1.2 and F= 19, 78.4 respectively) to the grain yield. Number of *B. fusca* at harvest was not significantly related to grain yield. This was probably due to migration (dispersal and immigration) of immatures and immatures reaching adulthood. Land equivalent ratios (LER) varied between 1.15 and 189. They were higher during the first than the second season.

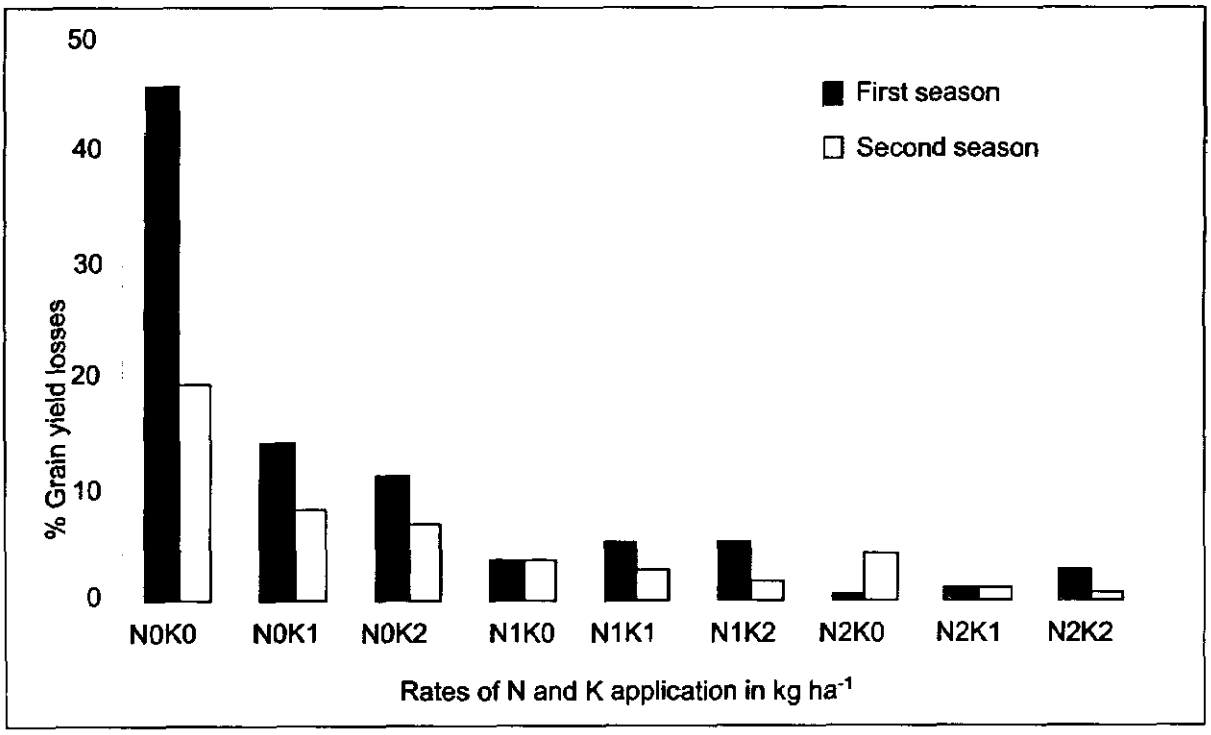

Figure 9. Maize grain yields losses, as affected by different rates of N and K application in the first and second season of 2003. Percent yield loss = 100*(CP-IP)/CP, where CP and IP stand for controlled plot and infested plot, respectively.

2.1.6 *Effects of* Pueraria *and* Mucuna *relay cropping with maize*

by S. Hauser

The effects of relay-cropping maize with leguminous species were investigated on a short-, medium-, and long-term basis.

2.1.6.1 Short-term effects of on-farm on station

A farmer group approached staff at the Mbalmayo Farm on issues of intensive maize production four years ago. The group cleared land and planted several areas to *Pueraria phaseoloides* and left the land under fallow for two years. In 2002, the land was cleared and either burned or mulched and a maize–bean intercrop planted. The beans failed and due to the intercrop intention the maize density was rather low. However, positive effects of the previous *Pueraria* fallows were established. In 2003, the same farmer group decided to use the land for sole maize and planting density was increased to 4 m^{-2} as in other experiments. The natural fallow land between and around the *Pueraria* areas was used as a control measure. In both fallow types, biomass was either burned or retained. Marketable cob density (3.30 versus 1.43; $p < 0.0001$) and grain yield (2.26 t ha^{-1} versus 1.16 Mg ha^{-1}; $p < 0.0001$) were significantly higher after *Pueraria* than after natural fallow.

The positive experience with *Pueraria* encouraged farmers to expand on leguminous relay fallow systems and several areas were planted to *Mucuna pruriens* var. utilis cv. Jaspeada. Maize was planted as in the *Pueraria* experiment after either burning or mulching. *Mucuna* fallow doubled the marketable cob density (3.28 and 1.63; $p < 0.001$) and increased the grain yield (3.16 and 1.91 t ha^{-1}; $p = 0.0007$). Mulching had a positive effect on the marketable cob density, which increased by 23% from 2.2 m^{-2} in natural fallow to 2.7 m^{-2} in *Mucuna* fallow ($P = 0.0033$).

The general trend in the leguminous relay fallow/maize systems had a dominantly positive effect on the legumes in the first years of cropping, with either no or a positive effect of burning. With increasing years of cropping, the effects of the legumes diminished and the effect of burning biomass became negative. The legumes apparently add sufficient N into the soil such that the N in the biomass does not or only marginally contributes to increased yields. However, the N-balance of most leguminous systems was not positive, indicating that the soil N resource was used to produce the higher maize yields. Grain yield levels were (with one exception) maintained at >2.0 t ha-1, which was low, compared to yields attained in the savanna. This should be regarded as reasonably high as it is attained without tillage, fertilizer, or any other purchased inputs.

2.1.6.2 Medium-term effects on farm

In 1998, a two factorial experiment was established in a harvested farmer's field at Ngoungoumou. The first factor was fallow type, at two levels: *Mucuna* planted fallow and natural regrowth fallow, second factor was biomass management at two levels: burned and retained as mulch. The experiment was replicated four times. In 1999, the plots were slashed and either burned or mulched. Maize cv. CMS 8704 (90–100 days to maturity) was planted with two seeds per pocket at 0.5m*0.5m distance on a square configuration. Maize was to be thinned to one plant per pocket. The farmer did weeding. In 2000, 2001, and 2002, maize was planted in the same plots and manner in the first rainy season. The farmer collected *Mucuna* seeds in every dry season and reseeded whenever necessary. *Mucuna* was removed from non-*Mucuna* plots once during each fallow phase.

In the fifth year of maize cropping (2003), the effect of the *Mucuna* fallow was more pronounced than in all previous years. Number of marketable cobs and grain yield were higher in the *Mucuna* fallow than in natural fallow. The biomass management had no effect.

The cumulative grain yield over the five-year period was highest in *Mucuna* when biomass was burned (Table 19). The difference between the fallow systems increased, compared to the previous year, while the effect of the biomass management was insignificant.

Table 19. Cumulative maize grain yield (t ha^{-1}) over five consecutive years (1999–2003) at Ngoungoumou in *Mucuna pruriens* var. utilis cv. Veracruz and natural regrowth fallow.

	Burned	Mulched	Mean	$P_{means\ fallow}$
Natural fallow	7.49	6.04	6.77	0.0122
Mucuna pruriens	9.91	8.34	9.13	
Mean	8.70	7.19		
$P_{means\ biomass\ mgt}$	0.077			

2.1.6.3 Long-term effects

In the seventh year (2003), the experiment was severely damaged by grasscutters at three weeks before harvest. The plant density was unaffected by fallow type and biomass management, yet, grasscutter damage was more severe in burned plots than in mulched plots (1.14 destroyed plants m^{-2} in burned plots versus 0.30 destroyed plants m^{-2} in mulched plots; P = 0.0231). Thus, a higher number of cobs and marketable cobs were harvested in the mulched plots and a higher grain yield was attained (1.76 t/ha^{-1}in burned plots and 2.33 t ha^{-1} in mulched plots; p = 0.0067). The fallow type had an effect on the stover and total biomass yield with the *Pueraria* system outperforming the two other systems. None of the yield parameters had a significant fallow type by biomass management interaction.

The cumulative grain yield during the seven cropping years followed the order natural fallow < *Mucuna* < *Pueraria*. The effect of biomass management was fallow-dependent with burning causing a slight yield advantage in the *Pueraria* and *Mucuna* system, yet a yield loss in the natural fallow (Fig. 10).

2.1.7 Integrated pest and disease management to sustain tree crops production

Compiled by S. Weise (activity carried by S.A. Remi (CRIN) and P. Tondje (IRAD)

Biological control of Phytophthora megakarya *in Nigeria.* To complement the effort in Cameroon, a preliminary set of biocontrol candidates in Nigeria was selected based on laboratory evaluations of their control of *P. megakarya.* Collections were taken in Oyo, Ondo, and Cross River states, to be screened in CRIN using the leaf disc and pod husk pieces methods.

Isolation and screening of antagonistic fungi, bacteria, and yeast from cocoa agroforests for biocontrol potentials against *Phytophthora megakarya*. From the central, southwest, and south cacao-growing zones of Cameroon, biocontrol candidates were isolated, quantified, and stored. The leaf disc biocontrol screening biotest and the cacao pod husk pieces biotest developed by IRAD and USDA ARS are used for screening biocontrol candidates. Four promising isolates of *T. asperellum* have been identified from over 1000 isolates sampled.

Compatibility study of promising biocontrol candidates with commonly used chemical fungicides in Cameroon. This study is establishing the compatibility of promising biocontrol candidates with commonly used fungicides in cacao-farming systems in Cameroon. The objective of this study is to determine threshold use of these chemicals in IPM strategies including biocontrol agents. Laboratory analysis was completed and the write-up is in progress.

Development of appropriate fermentation and formulation methods for mycopesticides. Preliminary experiments in 2002 were pursued and improved using local agricultural waste materials and some promising biocontrol strains are already available.

Field trials of *Trichoderma asperellum* biocontrol agents. The presence of mycoparasites of *P. megakarya* among 735 endophytic fungi isolated from cacao (*Theobroma cacao*) leaves were screened using the precolonized plate method. Three complex-promising biocontrol candidates for *Phytophthora megakarya* (PR10, PR11, PR12) were isolated from a rotten tuber of *Xanthosoma sagittifolium* in a farmer's mixed crop field near Yaoundé.

2.2 Test germplasm to alleviate production constraints and to accommodate consumer preferences

2.2.1 Improved plantain varieties

2.2.1.1 Screening *Musa* hybrids and cultivars for nematode resistance in West Africa

by D. Coyne in collaboration with A. Tenkouano

Nematode inoculum of populations of *Pratylenchus coffeae, Helicotylenchus multicinctus, Meloidogyne* spp., and *Radopholus similis* have successfully been cultured and used in resistance screening on plantain hybrids, using Yangambi Km5 as the resistant check and Valery as the susceptible check.

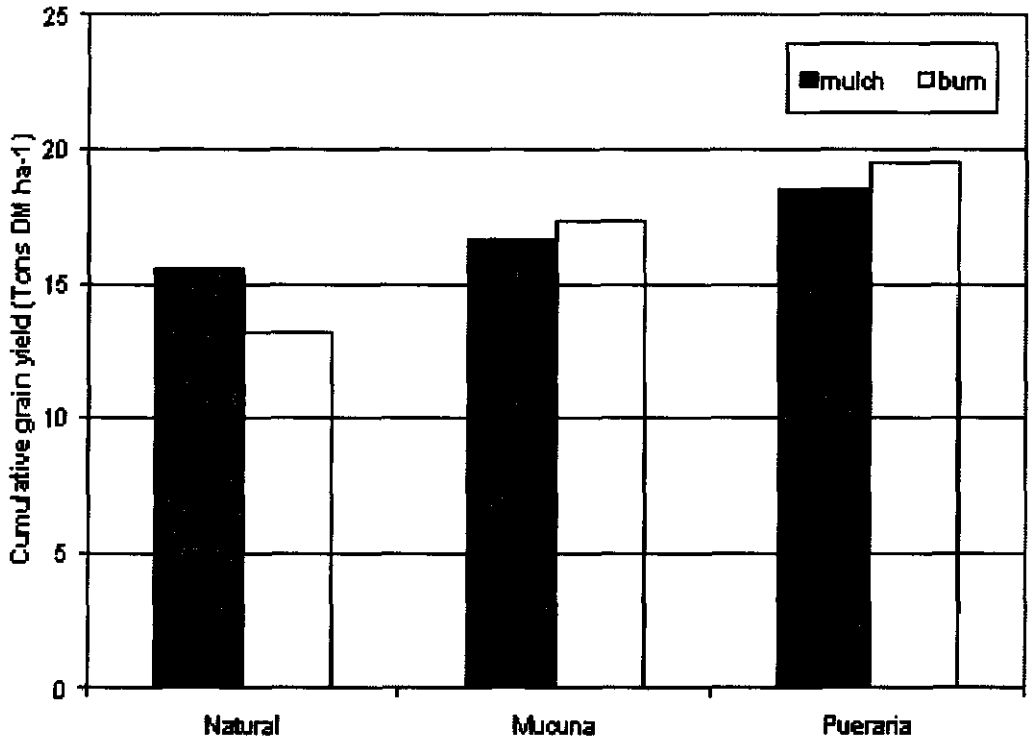

Figure 10. Cumulative maize grain yields over seven consecutive years of cropping (1997–2003) in three fallow types with biomass, either retained or burned annually, Mbalmayo.

Experiments have been established to screen against all nematodes in isolation and in combination in order to assess resistance against the common nematode species.

2.2.1.2 Developing new lines

by A. Tenkouano in collaboration with F. Moonan, D. Coyne, R. Bandhyopadhyay, B. Faturoti, C. Okarter, T. Adeniji, E. Njukwe, D. Amah, and R. Ndango

The emphasis of plantain and banana breeding has been on developing high-yielding varieties with resistance to pests and diseases. Based on feedback from producers and consumers, we have now devoted major efforts to selecting and testing lines that mature earlier, display a shorter stature, and give fruits with no or little propensity to seed production. A conspicuous result in this regard was the selection of the promising dwarf triploid hybrid 33569 (Fig. 11).

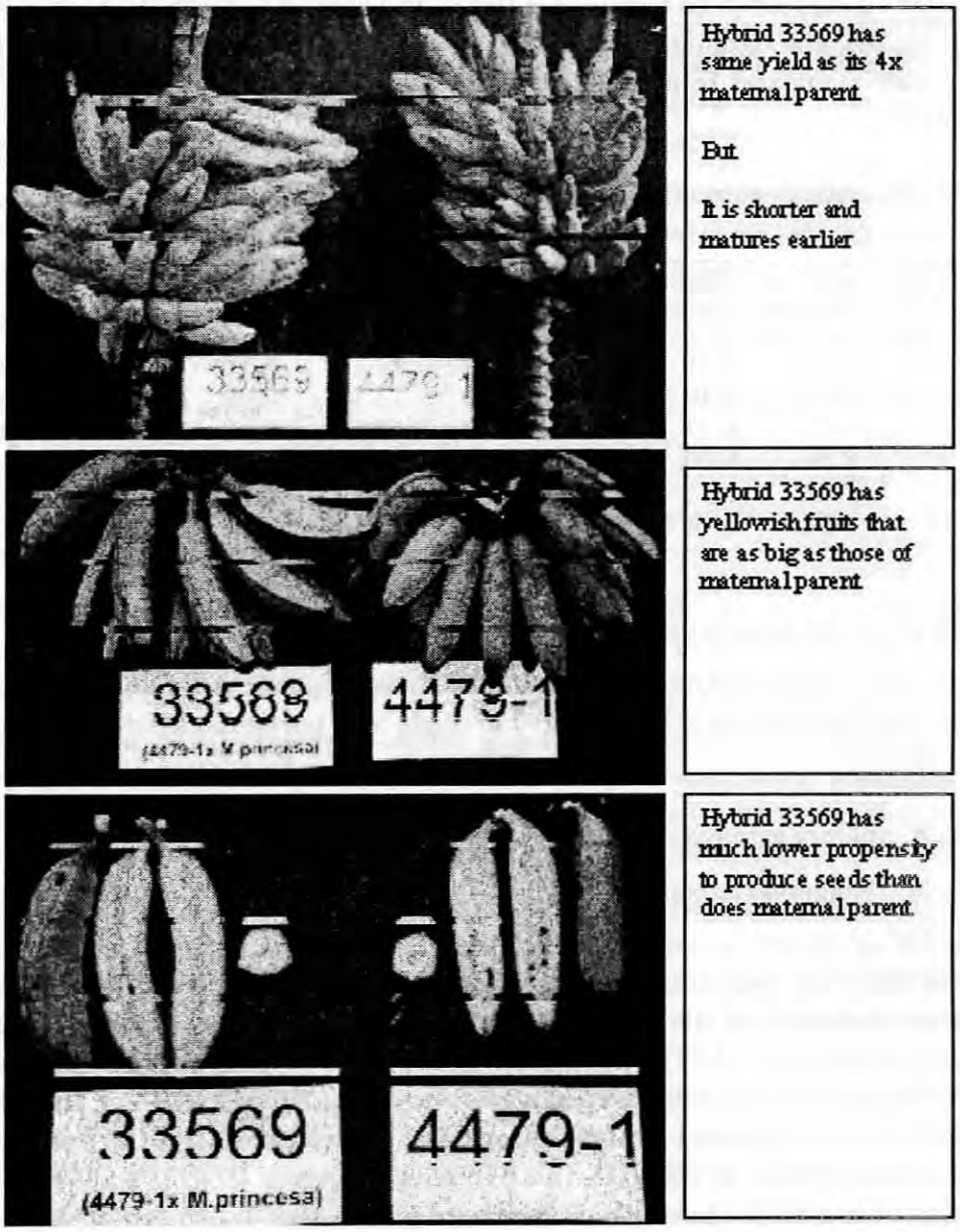

Figure 11. Some characteristics of a promising early-maturing and dwarf secondary triploid plantain-derived hybrid with resistance to black Sigatoka and nematodes.

Hybrid 33569 is an early-maturing secondary triploid with resistance to black Sigatoka derived from a high-yielding tetraploid maternal parent (PITA17 ['Bobby Tannap' x 'Calcutta 4']) and a nematode-resistant diploid paternal parent ('Moron princesa'). Hybrid 33569 had same yield as its tetraploid maternal parent, but it is shorter and matures early; it has yellowish fruits that are as big as those of maternal parent, but displays a much lower propensity to produce seeds than the maternal parent.

Characterization of advanced breeding lines for micronutrient density also continued to provide producers and consumers with varieties that were not only high-yielding but also reduced nutritional deficiencies. Thus, the mineral composition in the flour of some improved banana and plantain that were being distributed to growers in several West African countries (See Project E Annual Report 2002, Pages 14–20) was carried out.

Thus, several hybrids (PITA 14, PITA 21, PITA 23, BITA 3, FHIA 23, and FHIA 25) had relatively high Zn content (> 10 mg/100 g of flour). The same was for Fe content, except in PITA 23 (Table 20). The recommended dietary allowance (RDA) for an average adult male and female was 10 mg and 18 mg Fe/day, respectively, and 15 mg Zn/day for both adult male and female.

Table 20. Micronutrient content of some banana and plantain-derived hybrids (per 100 g flour).

Hybrid	Ca %	Mg %	K %	P %	Zn ppm	Cu ppm	Mn ppm	Fe ppm
BITA 3	0.02	0.10	0.99	0.07	14.14	2.11	6.62	20.31
FHIA 23	0.02	0.12	1.23	0.09	17.34	2.89	13.70	47.34
FHIA 25	0.03	0.11	1.17	0.10	14.95	2.48	11.61	17.39
PITA 14	0.02	0.09	0.91	0.07	15.03	1.79	4.77	27.46
PITA 21	0.03	0.11	1.10	0.07	14.62	2.11	10.32	13.45
PITA 23	0.03	0.11	0.95	0.08	16.14	2.61	13.62	8.19

2.2.2 Improved cassava varieties

Several lines are being developed and evaluated through participatory on-farm demonstrations and multiplications to be delivered to producers, particularly, in Cameroon, DR Congo, and Nigeria.

2.2.2.1 Participatory cassava evaluation in Cameroon

by A. Tenkouano in collaboration with A. Dixon, P. Ilona, E. Njukwe, and NGOs

Several cassava hybrids were introduced to Cameroon in 2001–2003 from Ibadan, Nigeria and evaluated on-station at the Mbalmayo Farm through cassava observation nursery (CON), advanced yield trial (AYT), and uniform yield trial (UYT). Following farmer participatory evaluation of the materials, three improved varieties (92/0326, 96/1414, and 880713) were multiplied and distributed to nongovernmental organizations (NGOs) and farmers' community groups (FCGs) in 2003. Three additional genotypes (88071-3, 880477-2, and 96/0023) selected in 2003 for having high fresh root yields, high starch contents, pest and disease-resistant are currently under multiplication for on-farm evaluation in representative farms across the country in collaboration with NGOs and FCGs.

2.2.2.2 Participatory cassava evaluation in DR Congo

by A. Lema and A. Dixon in collaboration with P. Ilona, N. Mahungu, INERA, SECID, and FAO

Six thousand seedlings were evaluated at Mvuazi (Bas Congo) for major pests and diseases, of which 31 genotypes were selected using their index values for disease resistance and other agronomic traits. In 2003/2004, the selected genotypes were planted in the Bas Congo, Bandundu, and Kinshasa provinces for clonal evaluation.

Meanwhile, clonal evaluation of 112 genotypes selected from seedling nursery in 2002/2003 was carried out in the three provinces and 44 genotypes were retained and advanced to preliminary yield trial (PYT) in 2003/2004. Root yield ranged from 7.0 to 37.0 tonnes/ha (Table 21).

The selected genotypes were resistant to major pests and diseases and produced twice or more the yield of the local variety at each location. Most farmers across the provinces preferred the genotypes 01/1111, 01/1661, 01/1229, 01/1144, 94/0330, and 95/0166. All selected genotypes were advanced to uniform yield trials (UYT) at the same location, but farmers' best choices per location were also planted in on-farm trials.

Also in the 2003/2004 planting seasons, several UYTs were carried out with 18 genotypes in 4 provinces (Bas Congo, Bandundu, Kinshasa, and Kasai Oriental). Fourteen genotypes were common to all provinces where they displayed more resistance to CMD than the local and improved checks. Mean root yield across locations ranged from 5.0 to 20.0 t/ha (Table 22).

The most commonly selected varieties by farmers 95/0211, 95/0528, 96/0160, 99/0395, and 93/0267 were superior in yield to the four locals and two improved checks. Three other selected varieties 92/0067, 93/0053, and 99/038 were specific to Kinshasa, Kasai Orientale, and Bas Congo respectively. The variety 96/1439 appeared to be susceptible to nematodes, resulting in near zero yields at Mvuazi (Bas Congo).

Biplot analysis of stability identified 95/0211 and 93/0267 as the best and most stable genotypes for Kinshasa, Bandundu, and Kasai Oriental. In Bas Congo, the best and most stable varieties were 96/0160 and 95/0528.

On-farm testing of 20 genotypes earlier selected by farmers from trials in Bas Congo, Bandundu, and Kinshasa provinces was carried out, with seven genotypes (93/0267, 95/0211, 95/0528, 95/0925, 96/0160, 96/1087, and TME419) performing well in the sandy soils of the savanna belt and the sandy loam soils of the forest transition belt.

The food quality processing characteristics of these varieties is indicated in Table 23. In conclusion, it was proposed that the following varieties should be multiplied and distributed to farmers in DR Congo—95/0211, 96/0160, 95/0528, 92/0067, 93/0267, and MV99/0395. The first three had broad adaptation while the last 3 were more adapted to the savanna belts.

Table 21. Mean performance of promising cassava lines evaluated in preliminary yield trials in the Bas Congo, Bandundu, and Kinshasa provinces in 2003/2004 seasons.

Genotype	Disease resistance score[1]			Yield performance	
	CMD	CBB	CAD	No. of tubers	Fresh weight of tubers (t/ha)
01/1111	1.0	1.2	2.0	63.9	34.6
01/1144	1.0	1.4	2.4	56.7	23.3
01/1229	1.0	1.2	1.8	30.9	21.7
01/1311	1.0	1.0	2.0	29.8	19.5
01/1313	1.2	1.2	2.0	22.9	8.3
01/1316	1.2	1.2	2.0	29.1	10.3
01/1326	1.2	1.2	2.0	40.9	10.3
01/1411	1.2	1.2	2.0	33.7	17.0
01/1526	1.0	1.2	2.0	58.1	21.3
01/1533	1.0	1.4	2.0	47.8	17.5
01/1581	1.3	1.5	1.8	26.9	13.7
01/1661	1.0	1.4	2.0	58.9	37.4
91/02322	1.6	1.4	1.8	44.9	18.5
91/02324	1.0	1.0	2.0	43.3	13.2
91/02327	1.0	1.4	2.0	37.3	9.1
92/0398	1.2	1.4	1.4	25.1	11.3
92B/00068	1.4	1.0	2.0	16.2	9.4
94/0239	1.8	1.4	1.8	21.6	7.3
94/0330	1.0	1.4	2.0	50.3	27.3
95/0166	1.3	1.0	2.0	33.7	24.4
96/0023	1.2	1.4	2.0	22.0	9.1
96/0603	1.2	1.4	2.0	21.1	7.2
96/1089A	1.2	1.2	1.4	37.1	14.2
96/1432	1.2	1.4	2.0	52.4	12.5
96/1529	1.0	1.3	1.5	41.7	14.2
96/1569	1.3	1.3	2.0	42.8	23.5
96/1632	1.2	1.4	2.0	29.8	18.9
96/1708	1.3	1.0	1.8	34.9	11.6
INITA 1	1.3	1.7	1.3	41.8	14.4
INITA 2	1.3	1.3	2.0	13.7	8.9
INITA 3	1.2	1.4	2.4	39.1	27.9
INITA 4	2.5	1.0	1.3	14.6	7.7
INITA 5	1.3	1.3	1.3	38.6	14.3
INITA 6	1.8	1.0	3.0	30.1	13.8
INITA 8	1.6	1.4	2.0	60.8	15.4
LOCALK	4.0	1.0	3.0	19.2	13.4
LOCALM	4.0	1.0	2.0	19.0	12.0
LOCALP	1.0	2.0	1.0	31.1	12.2
MV01/001	1.8	1.5	1.3	53.0	16.6

MV01/002	2.2	1.4	2.0	47.5	21.2
MV01/025	2.0	1.0	2.0	44.5	19.2
MV01/036	2.7	1.0	2.7	45.7	16.4
MV01/038	1.0	1.6	1.8	23.3	9.3
MV01/039	1.7	1.0	2.7	61.1	38.3
MV01/092	1.6	1.2	2.0	54.2	36.7
Prec Ang.	1.2	1.3	1.8	35.1	15.3
Rav	1.4	1.2	2.3	26.2	13.1
Mean	1.5	1.3	1.9	37.3	17.0

[1]Score on a 1 (resistant) to 5 (susceptible) scale; CMD = cassava mosaic disease, CBB = cassava bacterial blight, CAD = cassava anthracnose disease.

Table 22. Mean performance of promising cassava lines evaluated in uniform yield trials in the provinces of Bas Congo, Bandundu, Kinshasa, and Kasai Oriental in 2003/2004 seasons.

Genotype	Disease and pest resistance score[1]						Yield performance[2]		
	CMD	CBB	CAD	CBS	NEM	THP	NPLT	NTUB	FYLD
92/0019	2.1	1.9	1.6	6.0	1.2	1.3	11.6	45.8	7.7
93/0170	1.0	1.4	1.7	25.9	1.4	1.2	12.4	64.1	11.7
93/0267	1.2	1.6	1.7	0.2	1.2	1.4	15.3	96.3	16.1
95/0211	1.1	1.5	2.1	4.0	1.1	1.2	14.6	78.4	20.0
95/0528	1.0	1.5	2.1	0.9	1.1	1.4	13.0	86.6	18.5
95/0925	1.0	1.4	1.7	3.0	1.0	1.2	12.6	60.4	11.4
95/1009	1.0	1.9	1.4	9.0	2.9	1.5	7.4	28.8	5.1
96/0160	1.0	1.5	2.1	4.5	1.2	1.4	15.6	75.0	17.1
96/0249	1.2	2.2	1.2	10.3	1.0	1.0	14.5	56.5	12.6
96/0860	1.3	1.5	2.1	23.2	1.5	1.3	13.7	54.9	10.8
96/1087	1.0	2.0	1.3	0.3	1.0	1.0	13.0	88.0	12.8
96/1439	1.4	1.5	1.8	6.2	5.0	1.3	13.9	25.3	5.1
96/1630	1.2	1.5	1.9	14.9	2.4	1.4	15.0	57.8	13.5
99/395	1.0	2.0	1.0	0.0	1.0	1.0	12.0	51.5	10.1
Tshilobo	2.0	2.2	1.7	1.0	1.0	1.0	10.0	21.0	10.6
Mundjoko	4.0	1.0	2.0	15.0	1.0	1.0	9.0	9.5	6.0
Boma	4.0	1.0	2.0	25.0	1.7	2.7	9.0	28.0	5.8
Ngamanza	4.0	2.0	1.0	0.0	1.0	1.0	11.0	21.0	6.4
Rav	2.6	1.6	1.9	6.9	1.2	1.3	11.3	50.7	12.5
Sadisa	2.8	2.1	1.3	0.2	1.0	1.0	13.8	44.3	13.3
Mean	1.8	1.7	1.7	7.8	1.5	1.3	12.4	52.2	11.3

[1]Score on a 1 (resistant) to 5 (susceptible) scale for CMD = cassava mosaic disease, CBB = cassava bacterial blight, CAD = cassava anthracnose disease, NEM = Nematodes, and THP = thrips. Data on CSB (cassava brown streak disease) represent maximum incidence and not the means across locations. The data on nematode severity are also maximum scores.

[2]Yield traits are the number of plants harvested (NPLT), the number of tubers (NTUB), and the fresh yield (FYLD, t/ha)

Table 23. Biophysical characteristics and farmers' assessment of food quality of cassava genotypes evaluated on farm in four provinces of DR Congo.

Variety	Cortex color	*Fufu*	*Chikwangue*	HCN	Dry matter content (%)
95/0211	White	Very good	Good	Average	46
96/0160	White	Good	Good	Average	39
95/0528	White	Good	Very good	Average	34
92/0067	White	Good	Good	Average	38
93/0267	White	Good	Good	Average	36
MV99/0395	Yellow	Good	Good	Average	36
MV99/038	White	Good	Good	Average	36
Rav	White	Good	*Chikwangue*	Average	36

2.2.2.3 Participatory cassava evaluation in Nigeria

by A. Dixon in collaboration with P. Ilona and NARS

Three sets of UYT with 43 genotypes, comprising of 40 newly selected CMD-resistant genotypes and three other improved checks commonly grown by farmers in Nigeria were planted in 16 locations to identify specific and broadly adapted CMD-resistant genotypes with desired end-users' characteristics (Table 24). The trials covered four states in the south south, five in the southeast, two in the southwest, and five in the middle belt/north central zones. These trials were in fulfilment of the Federal Government's requirement for the release of varieties to farmers in Nigeria. The trials were planted in collaboration with the research institutes, universities, and development agencies.

Two of these trials were planted at two large farm sites, one at Egbema in Imo State and the other at Awka in Anambra State in collaboration with a private sector (Nigerian Starch Mills). The aim was to identify suitable varieties for high starch yield and quality for the company. This starch company with its newly installed capacity to produce native and modified starches should be operational by June 2004. The company would require over 400 tonnes per day of fresh cassava roots through backup production and outgrowers scheme, and would provide a big market for cassava and its products in the country and the subregion.

In addition to identifying the most promising genotypes for farmers in the region, it is expected that these multilocational trials will produce over 700 000 planting-sized cuttings, which will be made available to farmers in 2004.

Some 1210 on-farm trials were also established with 33 CMD-resistant genotypes in 110 communities in 11 states (Abia, Akwa Ibom, Anambra, Cross River, Delta, Ebonyi, Edo, Enugu, Imo, Ondo, and River) to identify CMD-resistant genotypes that are adapted to farmer's agronomic and cultural practices and with high economic returns in terms of root yields and quality characteristics. In each state, 11 farmers in each of 10 communities are evaluating 33 genotypes with each farmer having only three of the improved genotypes. Two checks were included in each of the trials: TMS 30572 is an improved and popularly grown cultivar, common to all the farmers, and the other check is a local cultivar, that is specific to each farmer's locality. Data collection is ongoing.

Demonstration plots of 36 CMD-resistant genotypes including checks were planted in 92 communities across the same states for identification of new varieties and introduction of improved production technologies through farmers' field day activities.

Table 24. Multilocational trials of 40 CMD-resistant genotypes and three checks at 16 locations in Nigeria in the 2003/2004 seasons.

Location	State	Agency	No. of genotypes	Land area (ha)	Min. expected quantity of cuttings for 2004
Umudike	Abia	National Root Crops Research Institute	42	0.7	45 000
Otobi	Benue	National Root Crops Research Institute	40	0.7	43 000
Uyo	Akwa Ibom	University of Uyo	40	0.7	43 000
Awka	Anambra	Nigeria Starch Mill (NSM)	40	0.7	43 000
Warri	Delta	Shell Agricultural Demonstration Farm	40	0.7	43 000
Ishiagu	Ebonyi	National Root Crops Research Institute	40	0.7	43 000
Ubiaja	Edo	IITA	43	0.8	47 500
Nsukka	Enugu	University of Nigeria	40	0.7	43 000
Kubwa	FCT	IITA	43	0.8	47 500
Egbema	Imo	Nigeria Starch Mill (NSM)	40	0.7	43 000
Sabon Gida	Kaduna	Hill View Farms	40	0.7	43 000
Mokwa	Niger	IITA	43	0.8	47 500
Ikenne	Ogun	IITA	40	0.7	43 000
Ibadan	Oyo	IITA	43	0.8	47 500
Obrikom	Rivers	Green River Project (Nigeria Agip Oil Company)	40	0.7	43 000
Onne	Rivers	IITA	43	0.8	47 500
Total				11.7	712 500

Each demonstration plot consisted of 36 genotypes with each planted in 40 m^2 plot at 1 m x 1 m spacing. Eight community-based demonstration plots were planted in all states, except in Akwa-Ibom and Imo where 10 sites were planted. A total of 13.23 ha was planted with an expected 992 250 cuttings. The demonstrations will afford farmers the opportunity to see, evaluate, and select from the complete set of genotypes and improved cultural practices in a single field without going from one on-farm trial to another.

Evaluation and demonstration trials were backed by multiplication of CMD-resistant varieties at primary multiplication centers, in Onne, Ubiaja, Umudike in the humid Forest; Ibadan, Mokwa, and Zaria in the moist savanna; and Kano and Mallam Madori in the Sudan savanna zones. A total of 251 486 plants (46 resistant varieties and three improved cassava varieties popularly grown by farmers) established in 17 ha of land in 2002 provided planting materials for all the trials (multilocational and on-farm trials and demonstrations) and establishment of new multiplication plots in 2003. Thus, about 56 hectares of 41 CMD-resistant genotypes were planted in 2003 in 16 states in collaboration with many stakeholders including extension agencies, research institutes, universities, NGOs, farmers associations, oil companies, and the private sector. It is estimated that a minimum of 5.5 million planting-size cuttings will be produced from this phase of multiplication for the 2004 season. Also, the 17 ha plots of planting materials established in the 2002 season, which provided planting materials for 2003 were ratooned and maintained and will provide a minimum of 2.0 million additional cuttings for the 2004 season.

Finally, to ensure continuous flow of new CMD-resistant genotypes into farmers' fields, a new set of 35 genotypes has been selected and 2.1 ha of multiplication plots have been planted in three states (Oyo, Niger, and River).

2.2.3 Improved yam varieties

2.2.3.1 Breeders' lines

by R. Asiedu

Breeder's lines of *Dioscorea alata* and *D. rotundata* were evaluated in comparison with local check cultivars in preliminary, advanced, and uniform yield trials at Ikenne (forest zone), Atan Ijaye, near Ibadan (forest/savanna transition zone), as well as Ubiaja and Abuja (southern Guinea savanna), Nigeria. Selections were based on tuber yield; reaction to viruses, anthracnose (leaf scorch) disease, leaf spot, leaf blight, nematodes; and tuber quality (dry matter content, culinary attributes).

In UYT of *D. alata* at four sites, the superiority of selections from the 1998 and 1999 series of genotypes were demonstrated at four sites in comparison with cultivars TDa 297, TDa 93-36, TDa 291, and TDa 92-2 (Tables 25 and 26).

The performance of the 2001 series of breeder's lines of the species (*D. alata*) suggested continued progress in generating superior genotypes as in the example in Table 27.

The situation was similar for *D. rotundata* for which promising lines in the 1996 and 1997 series were identified in a trial comparing 37 test genotypes against the TDr 89/02665 (released in Nigeria) and the Nigerian local cultivar TDr 93-31 (Table 28)

Table 25. Performance of *Dioscorea alata* genotypes at four sites (Abuja, Atan, Ikenne, and Ubiaja) in Nigeria.

Genotype	Tuber yield in tonnes/ha				
	Abuja	Atan	Ikenne	Ubiaja	Mean
TDa 99/00240	33.32	33.87	26.62	25.16	29.74
TDa 98/01168	38.86	31.16	18.89	23.40	28.08
TDa 98/01166	29.97	31.53	23.98	24.87	27.59
TDa 98/01176	31.14	34.81	21.42	21.72	27.27
TDa 99/00216	28.36	31.28	16.67	22.10	24.60
TDa 98/01174	26.12	33.44	10.40	21.38	22.84
TDa 99/00344	27.49	21.33	15.54	22.64	21.75
TDa 99/00199	26.29	28.83	9.00	21.98	21.53
TDa 99/00332	27.97	17.74	19.16	19.92	21.20
TDa 98/01183	18.30	32.03	14.95	17.00	20.57
TDa 99/00395	31.80	22.30	9.96	17.86	20.48
TDa 95/00010	22.89	25.78	12.54	17.24	19.61
TDa 92-2	17.75	19.43	8.98	21.61	16.94
TDa 93-36	11.97	17.83	8.55	15.81	13.54
TDa 291	11.89	24.01	4.51	13.15	13.39
TDa 297	13.43	12.60	5.55	12.63	11.05
Means	24.86	26.25	13.91	20.03	

Means of 4 replications. Severity of disease/pest symptoms scored on a scale of 1–5 where 1 = no symptoms and 5 = very severe symptoms). SED: clone = 1.89, site = 1.36, clone x site = 3.85. CV (%) = 24.3

Table 26. Performance of *Dioscorea alata* genotypes at four sites (Abuja, Atan, Ikenne, and Ubiaja) in Nigeria.

Genotype	Leaf spot severity score				Leaf blight severity score			
	Abuja	Atan	Ikenne	Ubiaja	Abuja	Atan	Ikenne	Ubiaja
TDa 99/00240	1.34	2.00	1.00	2.00	1.53	2.00	1.00	2.00
TDa 98/01168	1.03	2.00	1.25	1.75	1.34	2.00	1.75	1.75
TDa 98/01166	1.37	2.00	1.00	1.75	1.34	2.00	1.50	1.25
TDa 98/01176	1.70	2.25	1.25	1.75	2.01	2.25	1.50	1.75
TDa 99/00216	1.03	2.00	1.25	2.00	2.01	2.00	1.00	2.00
TDa 98/01174	1.70	2.00	2.25	2.00	2.01	2.00	2.25	1.75
TDa 99/00344	1.03	2.00	1.25	2.00	1.67	2.25	1.50	1.75
TDa 99/00199	2.03	2.00	1.00	3.00	2.01	2.00	1.50	2.50
TDa 99/00332	1.37	2.00	1.25	2.50	1.34	2.50	1.50	2.25
TDa 98/01183	1.70	2.00	1.25	2.25	2.01	2.25	1.75	2.25
TDa 99/00395	1.03	2.00	1.00	2.00	2.01	2.00	1.50	2.00
TDa 95/00010	2.03	2.25	1.75	2.00	2.01	3.00	2.00	2.00
TDa 92-2	2.03	2.75	2.25	2.00	2.01	2.75	2.50	2.25
TDa 93-36	2.03	2.75	1.75	1.50	2.34	3.25	1.75	1.50
TDa 291	1.70	2.00	1.75	2.25	2.01	2.25	2.00	2.25
TDa 297	1.70	3.00	1.25	2.00	2.01	3.00	1.50	2.00
Means	1.55	2.19	1.41	2.05	1.85	2.34	1.66	1.95
SED Genotype (G)	0.1310	0.1492						
Site (S)	0.0655	0.1472						
G x S	0.2619	0.5889						
CV (%)	20.6	21.6						

Means of 4 replications. Severity of disease/pest symptoms scored on a scale of 1 to 5 where 1 = no symptoms and 5 = very severe symptoms).

2.2.3.2 Collaborative yam trials with NARS partners in West Africa

by R. Asiedu in collaboration with G.C. Orkwor (NRCRI, Nigeria), R. Dossou (INRAB, Bénin), K. Zoupoya and K. N'Kpenu (Togo), and E. Otoo (Ghana)

Populations of *D. rotundata* developed at IITA targeting high yield, pest resistance, and culinary qualities formed the basis for collaborative trials with NARS partners in four major yam-producing countries of West Africa (Bénin, Ghana, Nigeria, and Togo). Selections were made from these trials on the basis of tuber yield; reaction to viruses disease, leaf spot, leaf blight, nematodes; and tuber quality (dry matter content, culinary attributes). The outcome of these trials during the year included the formal release of four IITA-derived clones (TDr 89/01213, TDr 89/02665, TDr 89/01438, and TDr 95/01924) of white yam (*D. rotundata*) by the National Root Crops Research Institute (NRCRI), Nigeria as new varieties. This follows the three the Institute released in 2001.

The Yam Program at the Crops Research Institute, Ghana has nominated three IITA-derived clones (TDr 89/02665, TDr 89/02660, and TDr 98/02977) for inspection by the National Varietal Release Committee of the country. These were among five introduced clones that were identified as promising in farmer-participatory trials covering 44 villages across three agroecozones in the country. They have also performed well in on-station trials.

Table 27. Performance of *Dioscorea alata* genotypes in a UYT at Abuja, Nigeria.

Genotype	Mean leaf disease severity				Tuber yield (t/ha)
	Blight	Spot	Scorch	Virus	
TDa 01/00024	1.67	1.00	2.00	1.00	50.30
TDa 01/00074	1.33	1.00	2.00	1.67	47.09
TDa 98/01166	1.67	1.00	2.00	1.33	33.88
TDa 98/01176	2.00	1.00	2.00	2.00	31.02
TDa 01/00204	1.00	1.00	1.33	1.00	30.09
TDa 01/00012	1.00	1.00	2.00	2.00	28.96
TDa 01/00208	2.00	1.33	2.00	2.00	27.12
TDa 01/00029	1.67	1.00	2.00	1.67	26.72
TDa 01/00081	1.33	1.00	2.00	1.33	26.47
TDa 01/00004	1.33	1.00	1.67	1.67	25.63
TDa 01/00214	1.33	1.00	1.67	1.67	20.38
TDa 92-2	1.00	2.00	2.00	3.00	20.37
TDa 01/00210	1.33	1.00	2.00	2.00	20.24
TDa 01/00046	1.33	1.00	2.00	1.67	15.53
MEAN	1.50	1.10	1.91	1.71	28.84
CV(%)	30.50	14.10	13.90	24.30	19.90
SED	0.37	0.13	0.22	0.34	4.98

Means of 4 replications. Severity of disease/pest symptoms scored on a scale of 1–5 where 1= no symptoms and 5 = very severe symptoms)

Table 28. Performance of selected genotypes of *Dioscorea rotundata* in an advanced yield trial (AYT) at Ibadan (forest/savanna, Nigeria) in 2003*.

Genotype	Mean leaf blight severity	Mean leaf spot severity	Mean leaf virus severity	Nematode infestation	Tuber yield (t/ha)
TDr 97/00632	2.25	2.00	2.50	2.00	26.18
TDr 97/00940	2.00	2.00	2.25	1.75	25.28
TDr 97/00588	3.00	2.00	3.00	1.50	21.31
TDr 97/00893	2.09	2.03	2.58	2.18	20.29
TDr 97/00777	2.25	2.00	2.50	1.75	20.17
TDr 97/00925	2.50	2.25	2.75	2.25	19.28
TDr 97/00903	3.25	2.50	3.00	2.00	18.77
TDr 97/00587	2.50	2.00	2.75	2.00	18.73
TDr 96/02456	2.00	2.00	2.50	1.75	18.69
TDr 96/02581	2.25	2.25	2.50	1.50	18.69
TDr 89/02665	2.75	2.25	2.75	3.50	18.67
TDr 93-31	2.40	2.69	2.39	1.86	8.85
Mean (for 39 clones)	2.45	2.17	2.69	2.14	16.46
CV	0.34	0.27	0.33	0.40	3.77
SED	19.7	17.7	17.3	26.8	31.7

* Means of 4 replications. Severity of disease/pest symptoms was scored on a scale of 1–5 where 1 = no symptoms and 5 = very severe symptoms.

For instance at Bawjiase in the coastal savanna zone clones, the three clones as well as TDr 98/00526 outyielded the three local varieties used as checks by up to three times. These clones were also among the top five yielding trials at Wenchi in the forest/savanna transition zone of the country.

Based on on-station trials over two years at Adeta (south) and Kazaboua (north) in Togo, TDr 89/02665 was among the IITA-derived *D. rotundata* clones selected for further evaluation on farmers' fields in the country. Other IITA-derived clones are TDr 96/00304, TDr 89/02475, and TDr 95/19156. These clones were the most preferred based on field performance (yield and reaction to pests and pathogens) and suitability to preparation of three major yam foods (boiled, fried, and pounded yam) in the country.

The standard set of 12 *D. rotundata* genotypes that were evaluated for a second successive year in 2003 with partners in Bénin, Ghana, Nigeria, and Togo were followed by a set of 20 *D. alata* genotypes (18 breeder's lines from the 1998 and 1999 series and two cultivars) in the same countries. The *D. alata* genotypes were evaluated in comparison with local cultivars of the species for the first time with the partners. This species is cosmopolitan in distribution and dominant in yam cultivation in Côte d'Ivoire but has remained secondary to *D. rotundata* in the rest of West Africa. Results available from Otobi (Nigeria), Save (Bénin), Kazaboua (Togo), and Nyankpala (Ghana), indicated high potential for the selection in each country of new varieties from the set based on plant vigor, tuber yield, and consumer acceptance of basic yam dishes prepared from the tubers.

The best performers across the sites in terms of tuber yield (exceeding 20 t/ha) were TDa 99/00240, TDa 98/01176, TDa 99/00049, and TDa 98/01168. This trial would be repeated in 2004 before conclusions are drawn.

2.2.4 Other crop species

2.2.4.1 Variation within cowpea and soybean genotypes in phosphorus acquisition in low P soils of southern Cameroon

by C. Nolte and R. Abaidoo in collaboration with M. Jemo and Tchienkoua (IRAD)

Maize-grain legume systems in southern Cameroon are gaining importance in peri-urban areas with market access. Farmers are interested in these systems, because they generate in 3–4 months, cash crop and/or, in the case of soybean, they use it to produce home-feedstuff for chicken, thereby lowering the costs of production. One of the major limitations for the growth of legumes is phosphorus deficiency as a result of the low P status of the soils in this region. In addition, N fixation of cowpea and soybean is hampered by low P availability, resulting in low N transfers to a subsequent maize crop. The phosphorus acquisition efficiency (PAES) of a plant indicates its potential to mobilize phosphorus from sparingly soluble sources in the soil. In the humid forest zone of central Africa, soybean cultivars have so far not been selected for their P-acquisition efficiency, nor for their potential to fix N under acid soil conditions. The objective of this work was to identify cowpea and soybean cultivars with high uptake efficiency and high N fixation ability when grown in soils with low P availability in southern Cameroon.

Experiments were designed to identify P-efficient cowpea and soybean cultivars, which yielded well on P-deficient soils and at the same time fixed large amounts of nitrogen.

The experiments were run in 2002 and 2003 at two sites (Minkoameyos and Abang) with contrasting soil types and Al toxicity levels.

For soybean, the field experiment was laid out in a split-block design, in which two factors were used. The first factor comprised 13 cultivars. The second factor had three levels of P application: without P application (0P), 90 kg P ha^{-1} as Togolese rock P (RP), and 30 kg P ha^{-1} as TSP (triple-super phosphate). Four replications were used in the two locations. Soybean cultivars were sown at spacing of 5 cm within and 75 cm between lines. One week after emergence, the plants were thinned to one per hill. At mid-podding (50% flowering) and at maturity, plants were sampled for shoot and root weights. The nodule number and weight were also recorded and 1 g of fresh root was harvested to determine AMF root infection. The P and N content of the shoot was then analyzed and P-utilization efficiency and P-uptake efficiency calculated. The grain yield was recorded at maturity.

Soybean cultivar and P application significantly ($p < 0.0001$) affected grain yield in both locations. The location was significant, but not its interaction with cultivar. The highest values for shoot dry matter at low P supply were obtained from cultivars Tgm1511, Tgm1566, Tgm0944, and Tgm1420 at Abang, whereas at Minkoameyos, cultivars Tgm0944, Tgm1196, Tgm1039, and Tgm1360 had the highest shoot dry matter production (Table 29). With P fertilizer application, cultivars Tgm1511, Tgm1566, and Tgm1419 had the highest shoot dry weight at Abang. At Minkoameyos, cultivars Tgm1360, Tgm1566, Tgm1196, and Tgm1419 responded significantly to P-fertilizer application.

Table 29. Effect of P application on shoot dry matter production (kg ha^{-1}) of soybean cultivars at Abang and Minkoameyos at midpodding (50% flowering).

	Abang				Minkoameyos			
Cultivars	0P	RP	TSP	Means	0P	RP	TSP	Means
Tgm 1420	2.01	2.33	2.41	2.25	1.18	1.18	1.32	1.23
Tgm 1511	2.57	2.28	3.33	2.73	1.19	1.34	1.65	1.40
Tgx 1465-2E	1.64	1.69	2.64	1.99	0.92	1.24	1.26	1.14
Tgm1293	1.57	2.25	2.36	2.06	0.83	1.28	1.27	1.13
Tgm 1360	2.00	2.59	2.73	2.44	1.36	1.65	2.11	1.71
Tgm 1566	2.35	2.69	2.95	2.66	1.18	1.90	2.11	1.73
Tgm 0944	2.02	2.05	2.58	2.22	1.66	1.55	1.65	1.62
Tgm 1540	1.81	2.16	2.71	2.22	1.16	1.33	1.76	1.41
Tgm 1196	1.24	1.50	2.33	1.69	1.42	1.39	1.95	1.59
Tgm 1251	1.56	1.73	2.22	1.84	1.23	1.33	1.56	1.37
Tgm 1419	1.75	2.72	3.19	2.55	1.26	1.43	1.98	1.56
Tgm 1039	1.87	2.15	2.64	2.22	1.41	1.61	1.46	1.49
Tgm 1576	1.47	1.89	2.06	1.81	1.15	1.36	1.53	1.35
Analysis of variance								
Cultivars		***				***		
P-fertilizer		***				***		
Location		***				***		
C x P		ns				ns		
P x L								
C x P x L								

Note: 0P = 0 kgP ha^{-1}; RP (rock phosphate) at 90 kgP ha^{-1}; TSP (triple superphosphate) at 30 kgP ha^{-1}

A significant difference in P accumulation among soybean cultivars was observed at both locations ($P < 0.0001$). Cultivars Tgm1420, Tgm1511, Tgm1566, Tgm0944, and Tgm12039 had the highest P accumulation at Abang, whereas Tgm0944, Tgm1420, Tgm1511, Tgm1360, Tgm1251 and Tgm12039 showed higher P-uptake efficiency.

The proportion of nitrogen derived from N-fixation increased with P addition at both locations, indicating that P was a limiting factor for N fixation. Without P application, high values for N- fixation were obtained from cultivars, Tgm1566, Tgm1566, Tgm11540, Tgm1039, and Tgm0944 at Abang. At Minkoameyos and at the same level of P application, cultivars, Tgm1511, Tgm1360, Tgm1540, and Tgm1039 fixed the highest amounts of N. For cowpea, a fertilizer treatment with triple superphoshate (TSP) and Togolese rock phosphate (TRP) at 0 and 30 and 90 kg of P ha^{-1}, for TSP and TRP, respectively, was applied. Results indicated that, the P-uptake efficiency of cowpea cultivars strongly depended on location, although some cultivars, such as DANILA and IT 82 KD-349, showed efficient P-responders at both locations. Nitrogen fixation of P-efficient and P-inefficient cultivars increased by P-fertilizer application. Based on grain yields, cowpea cultivars were classified into four groups: group 1, efficient responders, i.e., cultivars that produced high grain yield at low P levels in both locations (DANILA, IT82 KD-349); group 2, inefficient non-responders, cultivars with low grain yield at low and high P (IT89KD391); group 3, efficient non-responders, cultivars with high grain yield at high P and low grain yield at low P (IT86D-715); and group 4, inefficient responders, cultivars with low grain yield at high P, but high yield at high P (IT90K59).

2.2.4.2 Physiological mechanisms involved in Phosphorus efficiency of cowpea cultivars

by C. Nolte in collaboration with M. Jemo and W.J. Horst (Univ. of Hannover)

The knowledge about the principle mechanisms involved in efficient P acquisition by plants has evolved in recent years, but their possible contribution to the overall P efficiency of the cropping system is still not well understood. We investigated in this study some physiological mechanisms hypothesized to be responsible for an efficient P-uptake of cowpea cultivars.

A nutrient solution experiment was carried out in a growth chamber at the Institute of Plant Nutrition, University of Hanover, to understand the mechanisms that caused cowpea cultivars to be P efficient. The nutrient solution had the following concentration: 1000 µM $Ca(NO_3)_2$ l^{-1}, 275 µM K_2SO_4 l^{-1}, 325 µM $MgSO_4$ l^{-1}, 8 µM HBO_3 l^{-1}, 0.4 µM $ZnSO_4$ l^{-1}, 0.2 µM $MnSO_4$ l^{-1}, 0.2 µM $CuSO_4$ l^{-1}, 0.1 µM $(NH4)_6Mo_7O_{24}$ l^{-1}, and 40 µM FeEDDHA l^{-1}. Cowpea seeds were germinated in peat for three days and transplanted into the nutrient solution. Seedlings were supplied with 0 or 100 µM P and grew for 14 hours at 28°C and for 10 hours at 20°C. Light intensity during the experiment was 270 µM m^{-2} s^{-1}. When the first symptoms of P deficiency appeared on plants grown without P, root exudates were collected and analyzed for organic acids. The acid phosphatase production at the root surface, dry matter, and P concentration were determined.

Results indicated that P application did not significantly increase the shoot dry matter of P-efficient cultivars IT82D-849, IT86D-715, IT89KD-391, and IT89KD374, whereas the shoot dry matter production of inefficient cultivars DANILA, IT90K-59, and IT89KD-349 increased with P application (Fig. 12). The phosphatase activity at the root surface, measured with fresh roots, was more pronounced in efficient cultivars IT82D-849 and IT89KD-391 when no P was applied (Fig. 13).

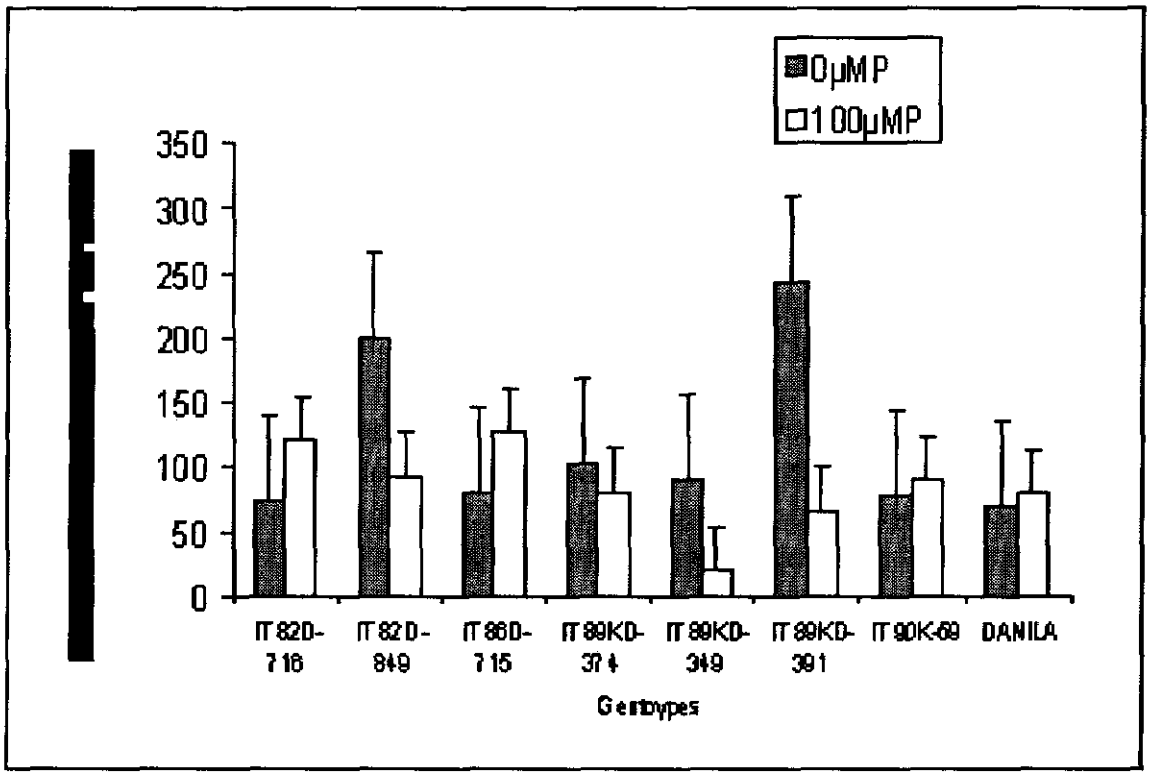

Figure 12. Shoot dry matter production of different cowpea cultivars with and without P addition to the nutrient solution.

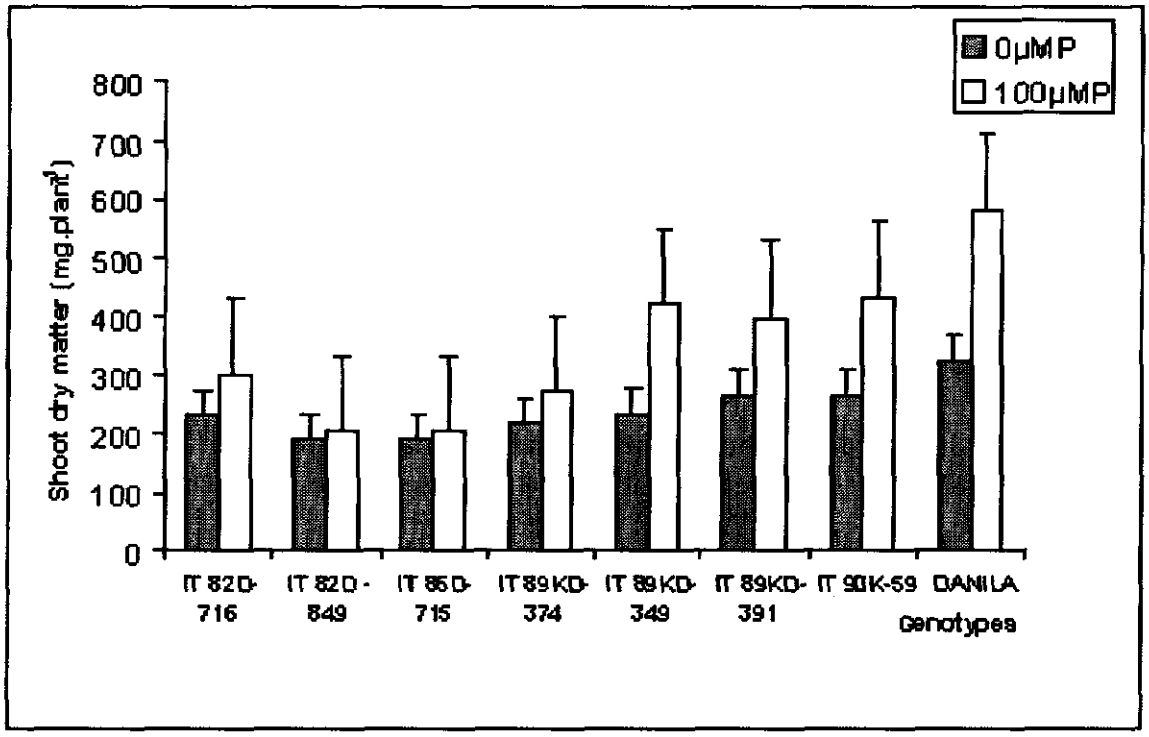

Figure 13. Activity of phosphatase at the root surface of different cowpea cultivars with and without P addition to the nutrient solution.

This could indicate that, under P-deficient conditions, those cultivars were able to solubilize organic P in their rhizosphere, which in turn increased their uptake efficiency. By contrast, inefficient cultivars such as DANILA had no pronounced enzyme activity in general and the phosphatase activity of P-deficient plants was not significantly differed from plants sufficiently supplied with P.

The P-efficient cultivar IT89KD-391 had a two times higher root exudation rate of citric acid in P-deficient solution as compared to P-sufficient solution. As well as citric acid exudation, the rate of exudation of malic acid was high under P deficient plant condition (six time) than P-treated plant probably explaining the ability of the P-efficient cultivars to uptake nutrient from P sparingly available source (Table 30). Cultivar IT82D-849, found to be P-efficient under field conditions, had no high exudation rate of citric acid, but showed a high exudation rate of malic acid. Overall, the total organic acid exudation rate was found to be higher in non P-treated plants than in P-treated ones (Table 30). The exudation rate of citric and malic acid of P-inefficient cultivars was not significantly different between the P treatments.

In conclusion, P-efficient cultivars were found to exude significant amounts of organic acid with respect to malate and citrate acid. In the presence of inorganic P bound to iron and aluminium in soil, chelate iron, and aluminium and P became more available to plant roots. It was also observed that the root surface activity of P-efficient cultivars was higher under P-deficient conditions. This suggests a greater capability of solubilizing organic P in the rhizosphere. Organic P represents usually between 40 and 80% total of P.

Table 30. Effect of P application on the exudation rate of citric and malic acid of different soybean cultivars in a nutrient solution experiment.

	Citric acid		Malic acid		Total	
	0µ molP	100 µmol P	0µ mol P	100 µ mol P	0µ mol P	100 µmol P
Genotypes			P mol h^{-1} cm $root^{-1}$			
IT82D-716	1.05	0.77	12.54	13.18	13.59	13.95
IT82D -849	0.12	1.03	4.99	2.92	5.11	3.95
IT86D-715	0.62	0.54	1.20	1.06	1.82	1.61
IT89KD-374	0.93	0.67	5.38	2.10	6.31	2.76
IT89KD-349	0.22	0.10	1.24	1.03	1.46	1.13
IT89KD-391	0.90	0.33	7.15	1.23	8.05	1.56
IT90K-59	0.36	0.41	7.08	3.56	7.44	3.97
DANILA	0.27	0.24	0.85	1.30	1.12	1.54
Mean	0.56	0.51	5.06	3.30	5.61	3.81
SE	0.36	0.31	4.00	4.10	4.23	4.25

2.2.4.3 The effect of aluminium excess and phosphorus deficiency on P-uptake efficiency of cowpea and soybean cultivars

By C. Nolte in collaboration with M. Jemo and W.J. Horst (Univ. of Hannover)

Acid soils predominate in the humid forest zone of southern Cameroon. In these soils, aluminium toxicity is a ubiquitous constraint to crop production and the Al-uptake by crops always interfered with the uptake of other ions, but in particular with phosphorus. This resulted in a reduction of the P-uptake efficiency of plant species and cultivars. The yield of leguminous crops, such as soybean and cowpea, can be drastically reduced by the effect

of Al. However, cultivars within each species showed variation in their tolerance to excess of Al and phosphorus deficiency. Therefore, a nutrient solution experiment was set up, to screen 12 soybean and eight cowpea cultivars for Al-tolerance and P-deficiency.

First, the growth rates of the main root and the root system of both species were tested under increasing Al concentrations. Based on the main root growth rate, soybean cultivars Tgm1293, Tgx1465-2E, Tgm1196, Tgm1419 Tgm0944, and Tgm1039 were found to be Al-tolerant, whereas cultivars Tgm1566, Tgm1576, Tgm1420, Tgm1251, and Tgm1511 turned out to be Al-sensitive. When the growth rate of the root system was considered, all soybean cultivars were found to be Al sensitive. With respect to cowpea, Al-tolerance was found for cultivars IT 82D-849, IT82D-716, DANILA, IT86D-715, IT90K-59, and IT89KD-374. There was no difference between the growth rate of the main root and the total root system. Cultivars IT89KD-391 and IT82KD-349 were found to be Al-sensitive.

Based on these results two contrasting cultivars of each, soybean and cowpea, were selected and their P-uptake efficiency tested. Excess Al concentration in the solution (30μmol l^{-1}) reduced the P-uptake efficiency of Al-tolerant soybean cultivar Tgm 1039 from 10 to 5 mg P g^{-1} dry root weight, whereas the uptake efficiency of Al-tolerant cowpea cultivar IT89D-374 was reduced from 9 to 2 mg P g^{-1} dry root weight. In general, excess Al reduced the P-uptake efficiency of both, Al-sensitive and Al-tolerant cultivars of soybean and cowpea.

2.3 Develop improved storage and processing methods to promote new marketing options

*2.3.1 The effect of processing on the nutrient content of cassava (*Manihot esculenta *Crantz) leaves*

by B. Maziya-Dixon in collaboration with A.U. Achidi and M. Bokanga

A number of authors have stressed the nutritive value of leafy vegetables in the diet of peoples inhabiting tropical regions and the need to encourage their use. In spite of its promising nutritional content, cassava leaves contain endogenous antinutritional factors, which may limit their nutritive value. The presence of tannins in cassava leaves is a contributing factor to the low net protein utilization. Tannins have the ability to form insoluble complexes with proteins thus interfering with the digestion process by inactivating the enzymes. The consumption of cassava leaves has been associated with some kind of pathological disorders attributed to the cyanogenic glucosides, linamarin, and lotaustralin. In areas where cassava leaves are eaten as a relish, the traditional processing methods in some African countries such as pounding and grinding should reduce cyanide. However, it will be important to investigate the effect of these processing techniques on the composition of minerals, vitamins and other antinutritional factors in cassava leaves. This study therefore considered the effects of two processing techniques (pounding as practised by the Congolese and grinding as practised by Nigerians) commonly used for preparing the cassava leaf dish in Africa.

The leaves of two cassava varieties (*Manihot esculenta* Crantz): TME1 (local) and TMS30572 (improved) were subjected to African household processing: (heat-treated, pounded, cooked, crushed, and ground and cooked) and compared for proximate composition, minerals, vitamins, and antinutritional factors. Laboratory analysis was carried out using standard AOAC methods.

Effect of processing on the proximate composition. The results of effect of processing on the proximate composition of cassava leaves are shown in Figure 14. There were no significant changes observed in ash, lipid, protein, starch, fiber, and carbohydrate contents. However, the free sugar content decreased significantly (P = 0.0002) in the processed leaves (Fig. 15). The reduction in the free sugar content was between 9.93 and 21.73% with a mean of 15.83% for pounded leaves, while the decrease was from 26.30 to 34.83% with a mean of 30.56% for the ground leaves. The average total reduction for both pounded and ground leaves was 23.20%.

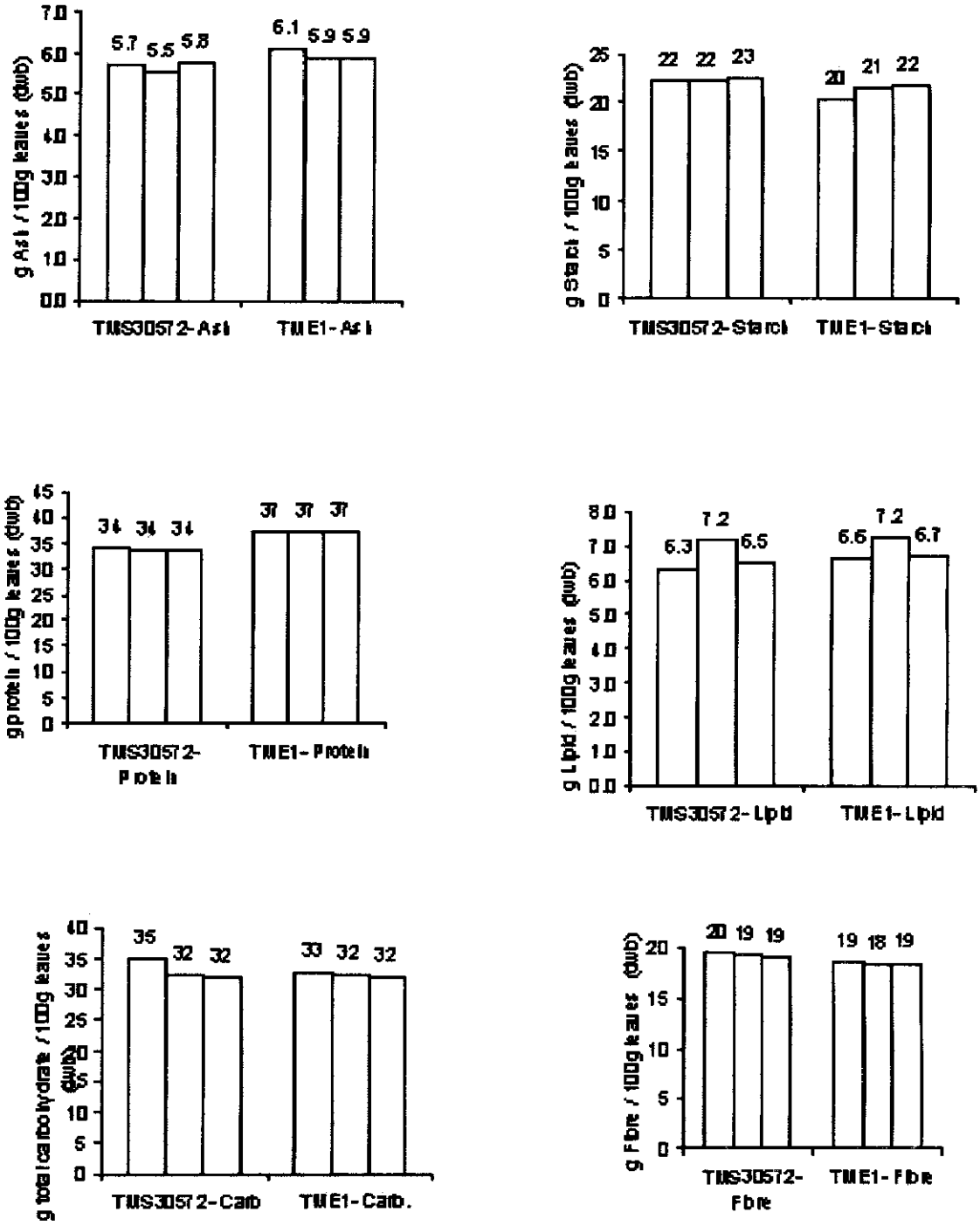

Figure 14. Effect of processing on the ash, lipid, protein, starch, total carbohydrate, and fiber contents of cassava leaves.

Effect of processing on minerals. The magnesium and sodium values for pounded and cooked leaves were higher than the corresponding values for the nonprocessed and the ground and cooked leaves but these differences were not statistically significant. No consistent pattern was observed for the concentration of calcium, potassium, copper, and manganese during processing. There were small reductions in phosphorus and zinc but the reductions were not significant. Iron content increased significantly in the ground and cooked leaves compared to the nonprocessed or pounded and cooked leaves (Fig. 15). The percentage increase in iron for the variety TMS30572 (353.6%) doubled that of TME1 (172.1%) with an overall mean increase of over 262.9%.

Effect of processing on vitamins. Pounding or grinding cassava leaves before cooking brought about a significant reduction (P = 0.0001) in the ascorbic acid and thiamine content of the cooked leaves.

The reduction in the ascorbic acid content was between 75.93 and 77.81% with a mean of 76.87% for pounded and cooked leaves, while the decrease was from 77.60 to 79.62% with a mean of 78.61% for the ground and cooked leaves. The average total reduction for both pounded and ground leaves was 77.74%. The percentage loss for thiamine varied from 33.85 to 36.43% with a mean of 35.14% for pounded and cooked leaves, while the loss was from 37.77 to 40.13% with a mean of 38.95% for the ground and cooked leaves. The average total reduction for both pounded and ground leaves was 37.05%. On the contrary, only slight reductions (4–7%; P = 0.7919) occurred in the carotene content of processed leaves compared to the nonprocessed leaves.

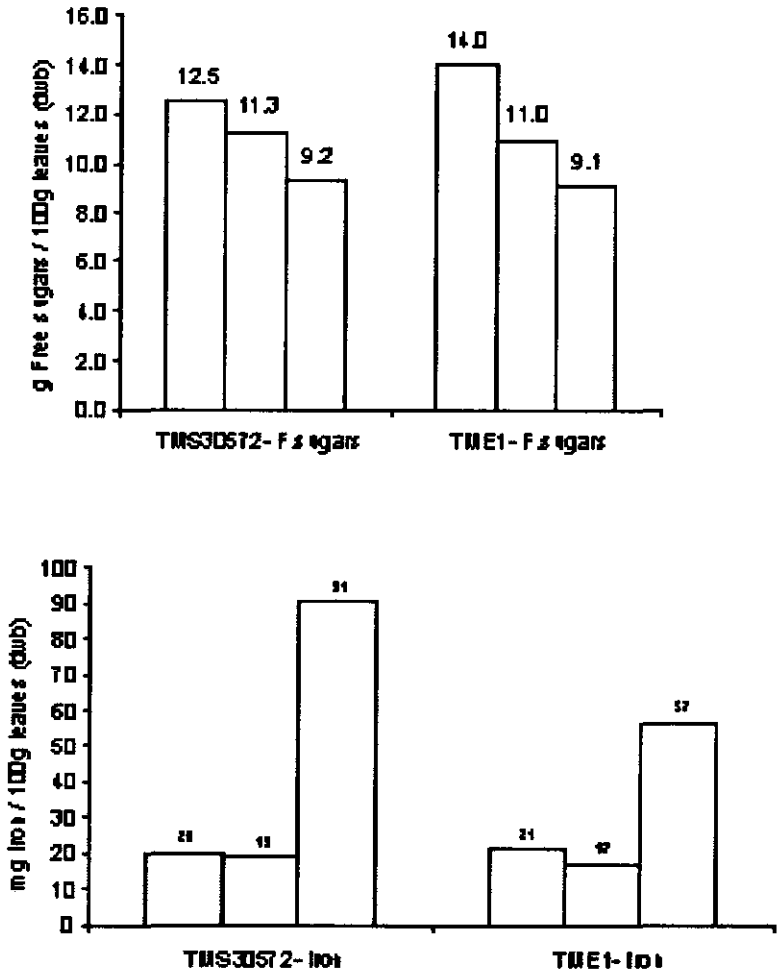

Figure 15. Effects of processing on the free sugar and iron contents of cassava leaves.

The loss ranged from 6.07 to 7.45% with a mean of 6.76% for pounded and cooked leaves, while the loss was from 4.37 to 6.20% with a mean of 5.29% for the ground and cooked leaves. The average total reduction for both pounded and ground leaves was 6.03%. For ascorbic acid and thiamine, the loss in the ground leaves was slightly higher than in the pounded and cooked leaves but the difference was not statistically significant.

Effect of processing on tannins and CNP. Both pounding and grinding were effective in destroying the tannin content of cassava leaves. Percentage tannin reduction ranged from 52.12 to 53.58% with a mean of 52.85% for pounded and cooked leaves, while the mean reduction was from 48.47% for the ground and cooked leaves. Overall total average percent reduction of 55.16% showed that tannin content decreased significantly ($P = 0.0001$) to about half the initial value found in the nonprocessed leaves.

Conclusion. The proximate components, showed no difference between the ash, lipid, protein, starch, and fiber content of nonprocessed, pounded, or ground cassava leaves. However, the free sugars component was reduced by 23%.

Processing had no significant effect on the calcium, magnesium, potassium, and sodium, phosphorus, copper, manganese, and zinc contents of cassava leaves except for iron. Also, pounding did not affect the iron content but grinding resulted in a 4–5 fold increase, attributed to contamination from the metal part of the grinder used.

Both pounding and grinding reduced ascorbic acid and thiamine concentrations to varying levels. Carotene was considerably stable, than ascorbic acid and thiamine with the different processing methods evaluated. On the average, 94% of the original carotene content was recovered after pounding and cooking or grinding and cooking, whereas, about 25% and 60% of ascorbic acid and thiamine content, respectively, was recovered after processing.

The antinutritional factors tannin and cyanogen were greatly reduced with both pounding and grinding. On the whole, tannin was reduced by 50% and cyanogen by over 99%.

Pounding of leaves before cooking was not superior to grinding before cooking with respect to loss of vitamins and minerals but for the increase in iron during the grinding process.

2.4 Design and test sustainable crop combinations and sequences and integrate environmentally sound crop–livestock management options into farming systems

2.4.1 Effects of maize–legume intercropping versus relay cropping on maize yield tested on farm in Cameroon

by C. Nolte in collaboration with K.A.B. Nguimgo (IRAD)

Maize is an important food crop grown for cash in southern Cameroon, especially around big cities. Maize farmers with limited resources hardly apply costly mineral N fertilizers and this in conjunction with suboptimal weed management results in relatively low maize yield. Legumes are known to fix atmospheric N, which could be used with maize in a maize–legumes intercropping or relay cropping systems. If N is in situ produced through biological N fixation in theses cropping systems, a major nutrient limitation to maize yield could be P-deficiency because of limited available P in the forest zone soils.

An experiment was established in four farmers' fields. Each field constituted a replicate, at Nkometou, 40 km west of Yaoundé in March 2002. The following treatments were randomly allocated to each replicate:

- Maize intercropped with *Cajanus*, soybean, cowpea, and *Mucuna* during the first season, followed by sole cropped *Cajanus*, cowpea, soybean, and *Mucuna* during the second season;
- Sole maize during the first season followed by sole soybean, cowpea, *Mucuna*, and natural fallow during the second season.

Each of these treatments was given two levels of P application (0 and 30 kg P ha^{-1}), resulting in 16 treatments. During the first season in 2003, maize planted at 0.75 x 0.50 m with 2 seeds/hill, equalled to 53,333 plants ha^{-1}. *Cajanus*, soybean, cowpea, and *Mucuna* were interseeded between two maize rows. The within-row distance between these legumes, planted at 1 grain per hill, was 0.30, 0.10, 0.20, and 0.40 m, respectively. *Cajanus* and maize were planted simultaneously, while soybean, cowpea, and *Mucuna* were planted 2, 4, and 8 weeks after maize, respectively. In the second season, soybean and cowpea were planted at 0.50 x 0.20 m at a rate of 2 grains per hill for soybean and 1 grain per hill for cowpea. In 2003, each plot received the same treatment as in 2002. Crop varieties used were: CMS8704 (maize), TGX1805-13F (soybean), Asontem (cowpea), and a local perennial *Cajanus* with red kernels originating from the North West province.

During the first season, the applied P did not affect maize or legumes yield. Similarly, maize yield was not affected by intercropped or relay cropped legumes compared to maize following the natural fallow. Maize grain yield ranged from 1483 kg ha^{-1} after sole cowpea to 2280 kg ha^{-1} after sole *Mucuna* (Table 31).

The average maize yield in all treatments was 1874 kg ha^{-1} vs. 2567 kg ha^{-1} in 2002. Average intercropped legume yields were 213 kg ha^{-1} for soybean and cowpea and 1081 kg ha^{-1} for *Cajanus*, irrespective of the P level. In the second season, soybean yielded an average of 513 kg ha^{-1}, which was 20% more than the cowpea yield. Soybean and cowpea yields were 418 kg ha^{-1} and 315 kg ha^{-1}, respectively, in plots with no previous P application. When P was applied at 30 kg P ha^{-1}, 605 kg ha^{-1} of soybean and 526 kg ha^{-1} of cowpea were harvested.

Table 31. Mean yield (kg ha^{-1}) of maize and legumes irrespective of P levels in 2003.

Treatments			First season 2003		Second season 2003
	First season	Second season	Maize yield	Legume yield	Sole legume yield
1	Maize + cowpea	Soybean	1636a	235b	513
2	Maize + soybean	Cowpea	2125a	200b	421
3	Maize + *Cajanus*	*Cajanus*	1935a	1081a*	-
4	Maize + *Mucuna*	*Mucuna*	1574a	-	-
5	Maize	Soybean	1805a	-	-
6	Maize	Cowpea	1483a	-	-
7	Maize	*Mucuna*	2280a	-	-
8	Maize	Naural fallow	2155a	-	-

* Yield of *Cajanus* planted in 2002 and harvested in March 2003.

2.4.2 *Establishment of multistrata cacao agroforests in* Chromolaena odorata *and* Imperata cylindrica *fallow*

by L. Norgrove and S. Hauser

An experiment attempting to rehabilitate land classified as degraded by farmers to a mixed species tree crop system was established in southern Cameroon in 1999. The experiment was designed after a local farmer group approached IITA and requested for assistance in developing such systems on deforested land they classified as unsuitable for food crop production. The tree selection reflected their interests and was a mix of indigenous and exotic species: *Persea americana, Dacryodes edulis, Terminalia ivorensis, Ricinodendron heudelotii,* and *Theobroma cacao.*

We compared the effects of different fertilizer regimes and four temporary shade treatments that had different levels of labor investment, different potential profitabilities and different risks of success: plantain, the farmers choice; cooking banana, far less prone to pests than plantain and higher yielding but not well known; *Inga edulis,* a multipurpose N-fixing tree; and, alleys of the natural regrowth, the "low investment" option.

One year after planting, cooking banana had a leaf area index three times that of plantain and therefore produced more shade. But two years after planting, *Inga edulis* performed better than the other treatments and produced the most shade. The natural regrowth treatment proved to be unsuitable as it was prone to dry season fires.

Timber growth and fruit trees are assessed twice per year. Early growth of all trees was affected by shade treatment but not by fertilizer application. Growth was generally best in the plantain treatments, with the lowest shade. Three years after planting, the trend continued with highest survival and best growth in the low shade plantain treatment. By the start of the dry season (2002–2003), survival of *Terminalia ivorensis* was 71% across treatments and trees averaged 245 cm height. Stem diameter and branching were significantly higher in the plantain treatments and growth was worst in the bush. However, green branch number was highest in the bush treatment, suggesting a developmental delay. *Ricinodendron heudelotii* growth was not affected by shade treatment although stem diameter was higher in plantain plots than in others. *Persea americana* (avocado) did not perform well and therefore not recommended.

By June 2003, survival of safoutiers was significantly lower in the bush treatments than in the other shade treatments with highest survival in the *Inga* (66%) and plantain (54%). Remaining trees were significantly taller (276 cm), with a higher mean diameter (50 mm), higher canopy cover and branching level in the plantain shade treatment than in the other treatments. Also, by June 2003, *Terminalia ivorensis* was affected by treatment with highest survival in the cooking banana (74%), plantain (71%) and *Inga* (69%), all significantly higher than in the bush plots (47%). Remaining trees had a significantly higher diameter (61 mm) in plantain plots than in the other treatments. Fertilizer had an effect on branch formation with greatest formation in the "all fertilizer" and exchangeable cations and P treatments, with least in the unfertilized control. There were few treatment effects on the growth of *Ricinodendron heudelotii* although stem diameter was higher in plantain plots than in others.

The two indigenous fruit trees and *Terminalia ivorensis* were established on short fallow land. Early growth was best in the least shaded plantain treatment. The system might

be adjusted so that the trees were planted concurrently with the temporary shade crop. Fertilizer had few impacts on survival or early growth so was not recommended.

3 Management interventions for sustainable and competitive crop production, postharvest, and peri-urban crop–livestock systems disseminated and promoted

3.1 Mass-propagate and deliver healthy and improved germplasm for participatory evaluation in collaboration with NARS

3.1.1 On-farm introduction of boiling-water treatment in southern Cameroon

by S. Hauser

In May 2003 an on-farm training activity informed farmers about the effects of nematode and weevil infestation of plantain fields and the consequences of planting infested suckers. Fourteen workshops were conducted in 14 villages with a total of 371 (166 men and 205 women) participants representing 48 villages and 62 farmer organizations. In the course of the workshop, farmers were taught how to remove infested material from suckers, identify infested roots, and apply boiling water treatment, as well as the relationship between sucker size and the appropriate time of exposure to boiling water (the larger the sucker, the longer the exposure). At every workshop, at least one set of four demonstration plots was planted to treated (2 plots) and untreated (2 plots) plantain suckers. The number of participants intending to use the technique for future planting was noted (Table 32).

Table 32. Dissemination characteristics for clean planting material in Cameroon.

Area	Number of participants			Number of fields established			
	Men	Women	Intended	03-Jun	03-Sep	Total	% established
Saa	63	34	90	30	12	42	46.7
Ebolowa	12	42	47	10	5	15	31.9
Mbalmayo	17	17	17	4	4	8	47.1
Sangmelina	84	111	120	28	15	43	35.8
Total	176	204	274	72	36	108	39.4

After the workshops, 108 fields were established, representing 39.4% of the intended fields, a reasonably high proportion, considering that those fields were established outside the usual planting season for plantain.

In villages around Saa, north of Yaoundé, farmers using boiling-water, treated and planted up to 500 plantain suckers in individual fields. Plans are currently on to involve larger farmer groups in this activity to train other farmers in disseminating the technique and to follow up on establishment rates, growth, flowering, and yield assessment.

3.1.2 Delivery of yam minitubers to NARS partners

by R. Asiedu

A total of 7502 minitubers from 40 high-yielding and disease-resistant yam genotypes were delivered to the Institute of Agricultural Research, Sierra Leone for multiplication and evaluation. These comprised 577 minitubers from seven *Dioscorea alata* genotypes and 6925 from 33 *D. rotundata* genotypes.

Seed tubers of 20 advanced genotypes of *D. alata* were delivered to NARS partners in Ghana, Togo, Bénin, and Nigeria for the establishment of a multisite yield trial across the subregion. The trials were established at Fumesua and Tamale in Ghana; Kazaboua in Togo; Ina and Save in Bénin; as well as at Ishiagu, Otobi, and Umuahia in Nigeria. Similarly, 23 advanced genotypes of *D. rotundata* were delivered to partners in Bénin and Togo and 21 to those in Ghana for evaluation.

3.1 Introduction of integrated pest management options into crop production systems

3.2.1 Integrated management of diseases and pests of cassava in DR Congo

by A. Lema, R. Hanna, M. Toko, J. Legg, A. Dixon, and N. Mahungu in collaboration with W. Tata-Hangy

Cassava is an important source of calories and vitamins for the majority of DR Congo inhabitants and a source of income for most rural populations. However, several diseases and pests attacking the crop threaten its production. Surveys conducted in 2002 across different agroecological zones in seven provinces of the western, central, and southern part of the country showed that all major diseases including CMD, CBB, and CAD, whose incidence and severity became negligible in the recent past, were resurging. Four major pests were also reported including CGM, CM, African root and tuber scale (ARTS), and several nematode species.

In 1998, IITA in collaboration with INERA initiated a biological control program for cassava green mite. They relied largely on the introduction of the neotropical predatory mite *Typhlodromalus aripo* DeLeon, already introduced into several countries in West and East Africa and where it had substantially suppress CGM infestations. The multiagency and multiinvestor project initiated in 2001 was a major effort to combat the diseases and pests that had devastated cassava production in DR Congo. While the project's emphasis was on combating CMD, it also included the development and implementation of sustainable tactics for all other important diseases and pests of cassava in DR Congo.

In 2002–2003, the plant protection component of the project, cofinanced USAID, DANIDA, and IFAD, focused on the following activities:

1. Evaluation of cassava clones, varieties in different breeding trials to determine their level of resistance against major diseases and pests. This was a collaborative activity with the breeding component of the project.
2. Development of sustainable control tactics for the African root and tuber scale (ARTS).
3. Continuation of the program on the biological control of cassava green mite by its exotic predatory mite, *T. aripo*.

CMD evaluations were based strictly on the presence or absence of symptoms on the plants. Hence, only 4% of clones without CMD symptoms were identified in the nursery. In the clonal, preliminary, uniform, and confirmation yield trials; there were 8, 21, 50, and 70% of clones without CMD symptoms. The low proportion of plants without symptoms in the nursery, clonal, and preliminary trials indicated rigor in the selection process.

Cassava brown streak virus disease (CBSD)-like symptoms were common on cassava

leaves of several clones in the breeding trials at Mvuazi Station. Dry root-rots observed at harvest on infected plants confirmed the presence of CBSD at Mvuazi. Several clones were however symptom-free, suggesting a great variation in disease expression among the screened clones.

Preliminary results on the population dynamics of ARTS in the forest zone in Bas-Fleuve showed higher ARTS population densities on sweet compared to bitter and local varieties. The level of infestation of ARTS was greater in the secondary than in the transition forest. In addition, a yield loss assessment trial with two local varieties showed that protection of the plants from ARTS could substantially increase the number of storage roots and root weight, with one variety responding to a greater extent than the others when protected from scale attacks.

One of the lingering issues with rising ARTS infestations in short fallows was the possible role of declining soil fertility and resultant nutrient stress on the cassava plant, which could in turn exacerbate the existing scale problems. A fertilizer trial conducted in the Bas-Fleuve district resulted in greater scale densities on fertilized compared to unfertilized plants. While this result was unexpected, it highlighted the need for further detailed studies on soil fertility and ARTS infestations.

Releases and follow-up activities of *T. aripo* in DRC continued in 2003, with emphasis on predator redistribution, follow-ups and evaluation of impact in new sites in Kasai Occidental and Kasai Oriental where releases were not yet made. In 2002–2003, *T. aripo* was redistributed in Kebumba near Lubumbashi, Kalukuni, and Luisha on Likasi-Katete road using *T. aripo* infested shoot tips collected from Mvuazi in Bas-Congo. Other redistributions were made in Bena Mbuyi, Bena Kalonji along the Mwene Ditu road using *T. aripo* infested shoot tips collected from Gadanjika. Follow-up surveys conducted in previous *T. aripo* release sites in several provinces confirmed the persistence and impact of the predator on CGM populations. *T. aripo* was redistributed but it failed to establish (Fig. 16). Observations during the survey indicated that *T. aripo* significantly reduced CGM incidence and severity in Bas-Congo and Bandundu provinces. The mean incidence in infested fields at the peak of the dry season was less than 50% in those provinces while *T. aripo* was present in all surveyed fields. Mean density of *T. aripo* in the tips varied between 1.5 and 4.7 per tip. This rather low density per tip was probably the result of low CGM density per leaf, which was low (< 10 CGM/leaf). In Kasai Occidental, *T. aripo* spread over large areas up to Tshimbulu, about 150 Km southwest of Kananga release site, and persisted in all release sites. In Kasai Oriental, the number of fields with *T. aripo* continued to be low. However, the level of damage usually observed during past surveys was reduced in 2002–2003. In Katanga, *T. aripo* was recovered from only one of all the fields surveyed and the incidence of plants with *T. aripo* extremely low (< 10%).

In the framework of the Sustainable Tree Crops Program (SCTP), activities were carried out under this component. The aim was to strengthen farmers' decision-making capacity for sustainable production of tree crops through the implementation of farmer field schools (FFS).

The farmer field school approach is a discovery learning method for addressing complex issues such as disease and insect attacks that are embedded in a complex net of ecological functions. STCP chose this discovery learning method for pilot phase testing targeted for all of the four cocoa producing pilot projects.

3.2.2 Integrated management of diseases and pests of tree crops in West and Central Africa

3.2.2.1 Development of a set of curricula for use in farmer field schools on cocoa in West and Central Africa

by J. Gockowski, S. David, and S. Weise in collaboration with J. Vos (CABI Bio-sciences)

A farmer field school (FFS) "Curriculum development" workshop was held in Cameroon, late March 2003 to address farmers' priority constraints and integrate social messaging on child labor. Master trainers, farmer representatives, and resource persons attended the workshop from all 5 STCP countries, including international resource persons. The workshop focused on integrated pest management strategies in cocoa and associated child labor issues. A first version of the curriculum document was compiled, including instructions for the training of trainers.

3.2.2.2 Running farmer field schools on cocoa in West and Central Africa

by S. David (Principal coordinator), J. Gockowski, and S. Weise

The immediate follow-up was the training of FFS trainers (training of trainers), which was carried out in each of the four cocoa systems-focused pilots between April and June 2003. By the end of the year, about 90 facilitators selected from farmer organizations and 40 from public extension services had been trained in running FFSs and implementing the curriculum. Since June, 161 FFSs have been established through which over 4000 farmers have been trained. The level of enthusiasm has been very high. Follow-up ToTs were initiated in August and September to review experiences and to integrate a curriculum on quality management. Based on observations from monitoring activities in Cameroon, a thre

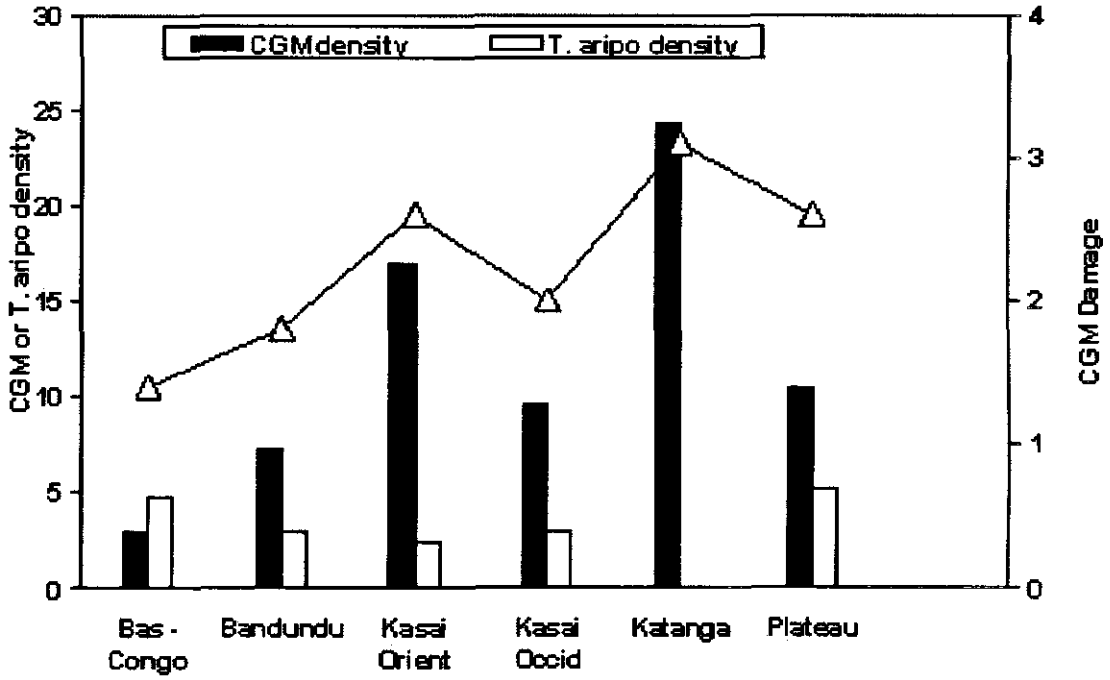

Figure 16. Densities of CGM, *T. aripo*, and CGM damage scores on cassava in six provinces.

3.1 Integrate appropriate soil, weed and crop management options, including varietal associations and mixtures

3.3.1 Reaction of plantain genotypes to black Sigatoka and effectiveness of varietal mixtures in reducing disease severity across the Nigerian plantain belt

by A. Tenkouano and J. Lemchi in collaboration with B. Faturoti and NARS

Resource-poor farmers in many regions of the world have adopted coping strategies based on intraspecific (cultivar mixtures) and interspecific (various forms of intercropping) to maximize land and labor use efficiency, and minimize risks of crop failure. Thus, it was suggested that (i) new hybrids be adopted only to the extent that traditional cropping and consumption practices were not drastically disrupted and (ii) resistant hybrids be introduced into the farmers' cropping system through association with their own landraces and other crops.

Therefore, we established varietal mixture trials (VMT) at > 60 sites in collaboration with farmers and extension agencies across the Nigerian plantain belt. Three tetraploid hybrids (PITA14 [TMPx 7152-2], PITA17 [TMPx 4479-1], and BITA3 [TMBx 5295-1]) were planted in alternation with the popular landrace Agbagba, following a checkerboard layout.

The postulate was that resistant hybrids reduced inoculum spread to plants of the susceptible plantain landraces, increased landrace yields (preferred for their culinary and rheological properties), and preserved genetic diversity while exposing farmers to new, high-yielding hybrids, for which novel processing options had been developed by IITA.

Preliminary data analysis indicated that the landrace produced higher yield (7–8 kg per plant) associated with less disease (INSL > 50%) under mixture with the hybrids than when grown sole (bunch weight < 5kg, INSL < 45%). This performance remained considerably less than that of the hybrids (Fig. 17).

Increase in the yield of the landrace would meet the people's preferred plantain food source as well as allow surpluses from the hybrids to be used for alternative processing options that could expand shelf life and diversify income opportunities.

Results from a baseline survey indicated that farmers cultivated more than one plantain/banana variety. Thus, there are excellent prospects for adoption of the hybrid-landrace varietal mixture approach to boost plantain production.

3.1 Demonstrate and promote value-adding postharvest technology options

3.4.1 Promoting postharvest cassava processing technologies for dietary diversity and income generation in Nigeria

by B. Maziya-Dixon assisted by A. Okoruwa

A total of 500 women and processors from different parts of Nigeria were trained in the production of high quality cassava flour, starch, *tapioca*, *abacha*, cookies, cake, cassava bread, composite bread, salad cream, *gari*, *fufu*, croquettes, strips, chinchin, and titbits. In addition, 300 cassava recipe books were distributed.

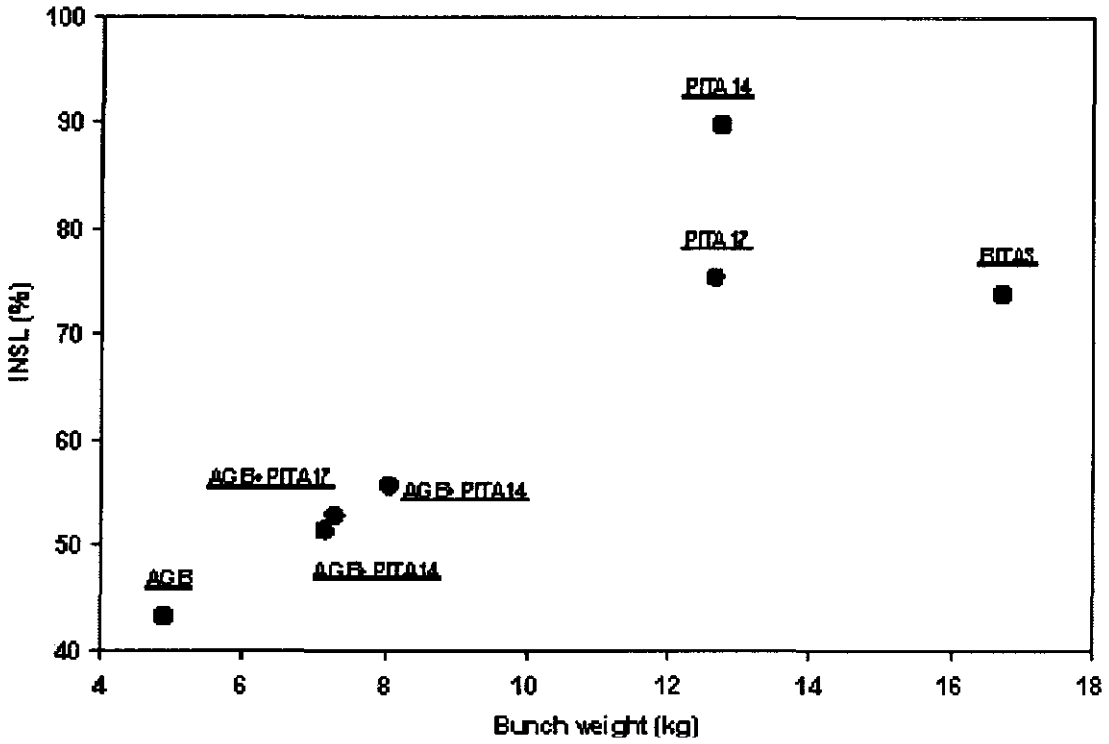

Figure 17. Biplot of bunch weight and index of non-spotted leaves (indicator of level of resistance to black Sigatoka) showing the advantage of growing the susceptible landrace "Agbagba" (AGB) in mixture with resistant hybrids "PITA14", "PITA17", and "BITA3".

3.4.2 Promoting postharvest cassava processing technologies for dietary diversity and income generation in DR Congo

by A. Lema and A. Dixon in collaboration with P. Ilona, N. Mahungu, INERA, SECID, and FAO

In 2003, product and market development activities were intensified as an integral component of the Multidonor-Cassava Development Project that began in 2002, when a food technologist joined the Project Team in DR Congo. Hence, a number of improved technologies (Table 33) for the production of high quality flour, *fufu*, starch and their allied products were introduced, demonstrated, and packaged into microenterprise options for rural and urban investors.

Table 33. Cassava processing options being promoted in DR Congo.

Province	Technology	Location	Beneficiaries	Target products
Bas Congo	Quality flour (unfermented)	Mvuazi and Kolo	Women associations and over 400 bakers	Bread and confectioneries
	Quality flour (rapid fermention)	Mvuazi and Kolo	Women associations	Quality *fufu* for urban markets
	Protein enriched *chikwangue*	Mvuazi, Kisantu, Mbaza Ngungu	Women associations	Quality food especially for children
	Improved drying of products	Mvuazi	Women associations	Flour, *fufu*
	Cassava/wheat flour composite	Mvuazi, Kisantu, Mbaza Ngungu	Women associations and bakers	Bread and confectioneries
Bandundu	Quality flour (unfermented)	Luwala, Ngashi/ Kiyaka	Women associations	Bread and confectioneries

To this effect, postharvest training was carried out for 40 associations in Bandundu, Bas Congo, Kasai Oriental, and Kinshasa provinces (809 women and 211 men).

4 Promoting agroenterprise development and market linkages

4.1 Develop and strengthen regional market and information systems

4.1.1 A method for the quantification and spatialization of urban supply flows: the case of fresh cassava roots in Yaoundé

by S. Dury and V. Robiglio in collaboration with D.F. Tita, L. Temple (CIRAD), and F. Isseri (INC)

The continuous increase in urban populations necessitated the supply system of foodstuffs to towns. These systems had to be maintained to improve the food. Increased production from rural areas through research ameliorates food security. However, agronomic researchers faced the problem of identifying priority intervention zones since they lacked data on important production and supply areas. This study aimed at devising a method for the identification, quantification, and spatialization of urban flows from a specific market study.

Three different sources of data were collected from cassava producers, transporters, and retailers involved in bringing fresh cassava roots to Yaoundé markets. Estimations, based on ECAM 96 (DSCN et al. 2000), showed that about 50 000 cubic metric tonnes of fresh cassava roots were consumed in Yaoundé in 2002. This represented a final value of 2.5 billions FCFA and about 30% of the household expenditure for root and tubers.

Survey results showed that there are no specialized wholesale markets for fresh cassava roots in Yaoundé. Eight markets performed several activities: wholesaling (in the sense of unloading products coming from rural areas); semi-wholesaling (selling to retailers from other markets); and retailing (selling in small quantities to final consumers). Seven other markets are purely for retailing. Retailers' transactions in the eight markets with multiple functions constitute about 80% of all retail sales in Yaoundé. These markets were identified to be those from which information on important supply areas could be gathered from producers as they arrived from the numerous supply villages.

It was also found that there are no specialized wholesalers involved in the marketing of fresh cassava roots, as is the case with some other food items such as plantains and cocoyams. The supply of the product is guaranteed by about 30 000 producers who commercialize in little quantities in three different types of bags (30, 75, or 100 kg). Average individual quantities handled per trip ranged from 250 kg to about 500 kg depending on the market. Small-sized vehicles (bush taxis) carried the bulk of transportation between production areas and the city. They are not specialized but carry people and other kinds of products (fresh cassava roots, cassava leaves, leafy vegetables, plantains, etc.).

Some 130 cassava sellers and 55 drivers were interviewed in July 2002 at Mvog-Mbi, Ekounou, Essos, and Mokolo markets, the four main of the eight multiple functioning markets. 94% of all the farmers interviewed were women and they came from 61 different villages. Matomb was the most important (modal value of 15/130) of the villages cited, Okola ranked second (modal value of 14/130), followed by Elat (6/130). Considering the quantities supplied, Matomb ranked first with 13% of the total, while Memia was second with 6%, and Olenguina ranked third with 5%. Drivers mentioned another 49 villages

(with no quantities) as important suppliers. All the villages are located within a radius of 1–4 hours drive to Yaoundé.

When grouping the identified villages into subdivisions (*arrondissement*), we found that Mfou and Awae were the most important with 18 and 10 villages respectively. They supplied 18% and 19% of the total quantity, respectively. Four other subdivisions Matomb, Mbalmayo, Ngog-Mapoubi, and Okola had four supply villages each. Their quantities in volume represented 17%, 12%, 7%, and 5% of the total, respectively.

This study gave a first insight into the main production zones of fresh cassava supplying the main markets in Yaoundé. Unfortunately, the study took more time than expected due to the absence of wholesalers, and the multiplicity of sellers. To complete the study, surveys should be conducted in the other four markets, and also in villages, supplying all the eight markets. This will allow double-checking of the information gathered in the urban market, and understand why certain villages are more specialized in selling cassava than others.

4.1 Develop and empower farmer associations, rural entrepreneurs and farmer-owned support services (biopesticides, seed market, pilot-processing plants etc.)

4.2.1 Empowering tree-crop farmers at pilot sites in WCA under the sustainable tree crops program (STCP)

4.2.1.1 The STCP Pilot Project in Cameroon

Compiled by J. Mva Mva

The setting up of the pilot project in Cameroon witnessed several phases from the year 2000. In support of these endogenous initiatives and considering the results obtained in the preliminary phase, the main preoccupations of the pilot project in Cameroon will revolve following:

- Improve the revenue of small-scale farmers of perennial crops.
- Protect biodiversity.
- Protect the universal rights of children.
- Collaborate between the government and the industry.
- Master information on the origin of products sold in the world market.

The Cameroon pilot project effectively began its activities in October 2002 with member organizations of the STCP National Network as its main partners. The pilot project intends to strengthen the capacities of cocoa producer organizations through the implementation of a series of activities to carry out an inventory, test, compare, evaluate, and validate the various approaches and types of intervention in view of developing sustainable and integrated cocoa production systems so as to improve profitability of cocoa yields and consequently ensure an increase in farmers' revenue.

Strengthening farmer organizations

This entails helping farmers' organizations in setting up professional and reliable agricultural enterprises that will respect the ecological environment and defend the rights and interests of their members while ensuring a systematic control of child labor in cocoa plantations. In this area, two main activities were successfully carried out:

Factual balance sheet

SOCODEVI in partnership with ODECO (a local NGO) completed the phase of diagnosis of member organizations of the STCP National Network through a factual balance sheet. Results of this stage indicated that member organizations of the Network had trained human resources to effectively carry out social activities that lacked the required qualified personnel in the management of business enterprises. Furthermore, they lacked the necessary financial and productive base for the transformation of their organizations into agricultural enterprises. Moreover, the lack of a common vision on their evolution towards setting up of agricultural enterprises within the eight organizations constituted one of the main weaknesses of member organizations of the Network. All of these problems are obstacles to the growth of member organizations of the Network. It is therefore necessary to carry out brainstorming within the Network so as to come up with a common vision on the type of agricultural enterprise needed, and help each member in its progress towards the success of the common vision, putting in place agricultural enterprises.

Training in accounting management and group animation

Member organizations of the Network, with technical assistance from ODECO, worked towards improving their internal functioning/management in terms of transparency, trustworthiness, and credibility of their respective organizations through the implementation of mechanisms for the mass mobilization of members on the basis of simplified accounting systems. The two workshops organized by ODECO on animation/internal dynamics and simplified accounting enabled the training of 38 rural animators and 35 local accounting officers. Accounting documents such as the cash logbook, members' register, and cash deposit order were established. Follow-up on the field revealed some shortcomings in the practical use of the knowledge acquired.

Market information systems

Four main activities were carried out in this area.

Training of marketing agents of the organizations. Two workshops organized by CAPCAO and SALSTRA enabled the training of about 50 marketing agents within the organizations. These workshops enabled the development of tools for the collection of statistical data on marketing such as the marketing journal. However, follow-up on the field proved that less than a third of the 22 organizations present during the training effectively used the tools developed, thereby rendering difficult the task of elaborating campaign balance sheets at the level of organizations and by extension at the level of the whole Network.

Reflection on the use of GPS/GIS production databases. Reflection is currently going on to determine how the databases could be better exploited so as to render them more useful to farmers. The database contains georeferenced data on cocoa farms of members of associated farmer organizations, which includes size, tree composition, production, and management aspects.

Setting up of an information management center. The setting up of an information system on market prices constituted another phase of the partnership between the STCP pilot project and the PA3C project (ICCO project). PA3C, with the assistance of the NCCB, has already set up an information system for producers on prices in the various local markets, CIF and FOB prices by SMS (mobile telephone), fax or internet. During the

setting up of the database on cocoa plantations of members of the Network, two members of the Network were trained on information management. In the same connection, the acquisition of computers enabled the setting up of an information management center whose main objective at the moment is the distribution of a monthly information bulletin, "The Network Newsletter".

Collective sales. Collective sales have become the main medium of marketing for member organizations of the Network. During the 2002–2003 campaign, producers noticed a marked increase in prices on the basis of the quantity available and the bulking of the produce to areas of easy access for buyers. This method was thus adopted within the Network but the lack of effective data collection tools was an impediment to the success of the various activities carried out.

Technology/knowledge dissemination

In this domain, emphasis was laid on putting in place farmers' field schools (FFS) within organizations of the network. Two workshops on the training of farmers' intermediaries were organized on integrated pest management and the production of quality cocoa. About 30 facilitators were trained to run the 25 FFS opened among member organizations of the national network. Activities within the schools have begun and comprised of about 650 farmers. This activity was carried out in collaboration with personnel of the Ministry of Agriculture who equally took part in the two training seminars. However, the FFS still needs some modifications/recycling with the facilitators and clarifications to the Organizations so that they can run farmers' field schools and make them a useful tool for the transfer of production techniques.

Social issues

Activities in this area are jointly carried out under the control of the ILO, which has developed two projects to "Fight against child trafficking with the aim of labor exploitation" (LUTRENA project) and to "Fight against child labor in cocoa plantations in West and Central Africa" (WACAP project). The greater part of the work entailed supporting the two project coordinators to define the different aspects of their actions and finalizing their respective plans of action. The STCP pilot project thus gave its support in the official launching of the two projects and in the organization of the different commemorative days in honor of childrens' rights.

Coordination activities

During the year, the activities of the national network focused mainly on: farmers' days, animation of the national network, national coordination and representation of network.

Together with National Network members, the Pilot Project made contacts with many potential collaborators and supporters of STCP activities.

4.2.1.2 The STCP pilot project in Côte d'Ivoire

Compiled by R.Y. Assamoi

The Côte d'Ivoire STCP 3-year program focused on cocoa as tree crop during its first phase, and has as main beneficiaries, 17 cooperatives with more than 20 000 cocoa producers. But due to the sociopolitical crisis in Côte d'Ivoire, only eight cooperatives were trained instead of 17 cooperatives initially planned.

Strengthening farmer organizations

- SOCODEVI carried out a needs assessment study of the eight cooperatives to identify current strengths and weaknesses in the areas of internal democratic governance, financial management, cooperative organization and management, internal management and marketing.
- The eight cooperatives (mainly the board members and the delegates of the sections) were trained by SOCODEVI on cooperative principles, organization, and strategic planning etc. Seven out of the eight cooperatives are performing well.
- Cocoa sale through the coops increased revenue between 2 and 10% depending on sales strategy (i.e., timing of sale, volume of sale, and the shortening of the supply chain).•

Market information systems

The main activities planned aimed at setting up a database and information system so that each coop can have access to information on the international market (prices), the objective being the improvement of the producers' price. This component was not implemented by SOCODEVI as planned, because of the crisis and will followed up on in the subsequent year.

Technology/knowledge dissemination

- Master trainer identified and trained for farmer field school implementation. Thirty-eight farmer field school (FFS) facilitators have been identified and trained during two Training of Trainer sessions;
- Sixty-four FFSs were launched, and about 1600 farmers are being trained on: agroecosystem analysis, weeding and pruning old trees, and integrated pest management.

Social issues

The eight cooperatives and their communities were informed on the child labor issues with the technical assistance of WACAP/ILO and Winrock International. Producers will be trained on hazardous work on cocoa farms while FFS will be initiated in the next session.

Coordination activities

- New institutions have been identified and are members of the STCP National Network and a new national network coordinator has been elected.
- A full time pilot project manager is in place alongside one farmer field school master trainer.
- The Head of State and the Government were briefed on the STCP Pilot Project objectives and activities on several occasions (STCP launching workshop and other meetings).
- Negotiations were held with key partners and with STCP pilot project implementers (ANADER, CNRA, SOCODEVI), and awards signed.
- The Pilot Project is linked up with CIRAD/CNRA to cooperate on activities related to the regeneration of cocoa plantations using the participatory technology development approach (PTDA).
- Pilot Project Manager is linked up with Winrock International on child labor activities related to education and with WACAP/ILO on integration of activities through the eight cooperatives.

- Contact has been made with potential institutional partners, e.g., ADM, Exporters Association, potential local funding institutions, and concrete opportunities of collaboration identified.

4.2.1.3 The STCP pilot project in Ghana

Compiled by I. Gyamfi

The actual implementation of project components focused more on technology dissemination and project coordination and management. The advancement made in technology dissemination stemmed from the presence of both staff and the necessary systems and structures for running farmer field schools (FFS) at the pilot project level, namely; tested curriculum, trained facilitators, and willingness of communities to participate and the appropriateness of the training methodology. Much emphasis was placed on establishing similar structures and systems for an accelerated implementation of the other program components in the second year.

Strengthening farmer organizations

SOCODEVI has been implementing a needs assessment study related to Kuapa Kokoo Union (KKU), an STCP partner. The outcomes as well as recommendations of specific capacity building efforts will be the basis for STCP activities in the subsequent year.

Market information systems

A sensitization workshop on spatial data collection and the use of geographic information system (GIS) was held in Accra on 22 October 2003. USGS facilitated the workshop. The objective was to help the beneficiary producer organization, Cocobod and CRIG to appreciate the GIS tool and how it could be used to assist in managing decision-making and monitoring the environment. KKU has expressed its willingness to cover the cost of data collection in the GIS exercise.

Kuapa Kokoo management and staff of its Research and Development Unit identified additional activities that KKU would like STCP to address to improve upon the internal market information coordination. The team identified the need to link up marketing collection areas with a radio communication and create a central database at the KKU head office to coordinate this marketing information.

Technology/knowledge dissemination

Master trainers to the project visited several target area to support and assist the FFS facilitators to effectively conduct FFS training in cocoa integrated pest management (IPM). Farmer participation in terms of attendance at the FFS was 100%. FFS are progressing as planned and farmers as well as some non-participants are implementing the new IPM methodologies on their farms.

To register new farmers for FFS 2, the master trainers are doing a reconnaissance in the target area to ascertain the presence and number of farmers in the target area who belong to other producer organization other than Kuapa Kokoo Union (KKU). A follow-up would be made to the management of the producer organization's offices in Kumasi to introduce the STCP and the roles and responsibilities of any FO willing to participate in the STCP

as a beneficiary. Selection of actual participants in FFS 2 will then be done jointly with the selected FO.

FFS training in nursery development and management started in November. The STCP coordination office facilitated the purchase and distribution of hybrid cocoa planting materials from the Cocoa Research Institute, Ghana (CRIG). A total of 11 000 cocoa pods were distributed to approximately 600 farmers who were participants and non-participants in the STCP farmer field schools in the target area. The planning material distributed was estimated to plant 916 acres (366 hectares) of land if properly managed.

The STCP coordination office prefinanced 26 bicycles to resolve the transportation problems encountered by FFS facilitators in their communities and farmer field school locations. The facilitators are to repay for the bicycles with deductions from their monthly allowance. The *Daily Graphic* newspaper of Thursday 13 October 2003 reported the presentation.

Social issues

The STCP designed modules and protocols to inform farmers and communities about the program have been delivered to all FFS participants throughout the 30 farmer field schools. All 780 farmers in the FFS are now conversant with child labor issues and its implications for cocoa marketing in the global market. These farmers have become informal advocates on child labor issues in their respective communities. Community members are usually curious to learn from farmer participants in the FFS what they had been taught.

Two meetings were held with the Youth Education and Skills (YES) program staff of CARE in Takoradi (1–17 October 2003), to review STCP progress in radio participation under the YES program.

The PPM participated in a "Consultative meeting on child labor monitoring" in Accra, Ghana. The ILO/IPEC/WACAP coordination office in Ghana organized the meeting, with participation by ICA and WCF. The meeting sought to gather stakeholders' views on the type of systems and structures to be put in place to assist in monitoring and reporting the country's address on child labor issues in agriculture, including cocoa.

Coordination activities

- The national network coordinator kept a close touch with the project management office to track programmatic activities.
- The Pilot Project Manager participated in relevant meetings at the national level to increase collaboration and support for STCP (USAID Ghana, USAID GDA, Abt Associates, AMAJARO Ghana Ltd [private license buying company], Cocobod of Ghana).

4.2.1.3 The STCP pilot project in Nigeria

Compiled by C. Okafor

The Nigeria Network of the STCP established a community-based pilot project focused on cocoa, in line with the STCP goal of improving the economic and social well-being of smallholders through sustainable tree crops systems. To achieve this, four key integrated mechanisms were applied:

- Strengthen community-based organizations
- Develop trade and information systems
- Implement technical packages to raise productivity and product quality
- Establish and implement child labor programs

The Nigerian pilot activities commenced operations in November 2002. The first year's activities focused on the four components of the pilot project.

Strengthening farmer organizations

Farmers' associations such as cooperatives are a vital means of providing support to and mobilizing the resource-poor for sustainable development. With this in mind, the Tonikoko Farmers Union (TFU) was given the necessary technical, material, and financial support to evolve as an umbrella organization for 26 societies (membership of about 1100 farmers) so as to dialog with government agencies and carry out commercial transactions with the banks, input suppliers, produce buyers, and exporters. Sustained organizational capacity building activities concentrated on the leadership of the TFU and its nodal societies (Tonikoko Farmers Societies), emphasizing on cooperative management skills, conflict resolution and management, group formation, and negotiation skills. In the second year, the registration process for TFU as an umbrella cooperative union will be completed, while attention will be concentrated on implementing TFU's organizational development (OD) plan prepared by SOCODEVI.

Market information systems

Critical initial steps have been taken to establish basic support systems to improve cocoa quality, farmers' access to markets and credits. Deeper insights into the prevailing cocoa trade structures have been gained. A commercial house that has warehouse facilities, offices, and training and information facilities has been acquired and renovated. The pilot project has facilitated linkages between TFU and some cocoa buyers/exporters. This resulted in some trade transactions involving about 66 metric tonnes of cocoa during the last trading campaign. A study and consultations on tree crop financing facility have been completed. Arrangements have been concluded with the United States Geological Survey (USGS) to organize a training workshop on GPS/GIS.

Technology/knowledge dissemination

The pilot project also seeks to develop and/or disseminate productivity-enhancing technologies with low negative environmental impact through farmer field school (FFS) approach. The FFS program kicked off in Nigeria in April 2003, with the training of 42 extension workers and farmers to serve as facilitators of the FFS. Farmers received the farmer field schools well and have a total initial enrolment of 1300 farmers from 42 communities. About 7000 seedlings have been distributed to the farmers through community-based nurseries. The first batch of FFS participants will pass out early in the second year while a new batch will commence training thereafter and run for a full cropping season.

Social issues

In collaboration with ILO/IPEC/WACAP, the project's initiated efforts aimed at sanitizing farmers against all forms of child labor, through the FFS, thus laying the foundation to fully implement WACAP programs in the pilot project area.

Coordination activities

The National Network did not only provide support to the pilot project but also assisted in linking STCP activities with existing national and regional efforts in the tree crops sector. The Network was reconstituted in August 2003 to make it more active and visible than it had been so far.

The pilot project coordination office facilitated shared vision of the project by implementing partners as well ensuring smooth implementation of the project activities. The project management has also facilitated several review meetings—established fruitful contacts with development investors and government agencies; maintained good working relationships with collaborators such as WACAP, SOCODEVI, and USGS; elaborated and submitted periodic reports; and established a project office in Akure. Despite the teething problems usually associated with a participatory development project, the pilot project has recorded significant accomplishments and generated useful insights in many areas.

4.1 Promoting linkage of small and medium-scale enterprises (SME) to input and output markets (re: RUSEP)

by P. Kormawa

Access to markets is a problem for poor farmers who do not have the means of transporting their commodities to the market, especially those living in villages with poor feeder roads. Farmers usually transport their commodities to the market on their heads, on bicycles, or in lorries. Also, the nature of production (small farm sizes) increases collection costs of commodity, thus serving as disincentive for traders dealing with small-scale farmers. The poor access to markets has significant implications for marketing and cost of commodities

Also, the agricultural input delivery system is still inefficient with the public sector playing the dominant role. This has inhibited private sector-led agriinput development. Although farmers are aware of the need for and usefulness of agrochemicals (fertilizers, fungicides, herbicides, and insecticides) and biocontrol agents, these are hardly freely available in the country.

A major area that has been neglected or given low priority is the development of an active market development information system. Since stakeholders in the agricultural marketing chain need information about local, regional and global prices, stocks, and availability of inputs and outputs in various markets, a market information system (MIS) is crucial for the market to function. Although commodity markets are liberalized in Nigeria, the atomized and un-integrated production and marketing system causes a major bottleneck for small-scale farmers. Major market constraints include poor pricing and marketing arrangements, and lack of well-coordinated marketing networks of producer organizations. An effective MIS will capture information on product standardization (chips, flour, starch, etc.); price and pricing, inventory levels, product range, utilization possibilities, alternative markets price profiles, etc. The existence of strong marketing structures is also imperative for farmers to maintain sustainable crop production and soil management strategies.

Under the Rural Sector Enhancement Project (RUSEP) funded by USAID, several interventions were carried out in Nigeria to (i) improve farmers' access to inputs and markets, (ii) link farmers to processors and suppliers, (iii) facilitate access to credit along the commodity chain continuum.

4.3.1 Leveraging private sector credit for small farmer commercialization

Access to formal credit by small-scale farmers is one of the major problems constraining small farmer commercialization in Nigeria. In most cases, the farmers do not qualify for loans offered by the credit institutions, due to lack of appropriate collateral. In addressing this constraint RUSEP developed an effective partnership with a leading private Bank

(Union Bank Plc) in Nigeria. The bank provided loans to groups of farmers (10–15 farmers per group). RUSEP had worked with the bank and the farmers to develop a new set of financing arrangements before granting the loan. Farmers were trained on how to manage groups, as well as crop enterprises, bookkeeping, and credit use. Farmers were also linked to input dealers to ensure that they purchased quality inputs in time and quantity required for the production of crops demanded by identified markets or brokers.

In collaboration with the Union Bank Plc, RUSEP facilitated N3.2 million to farmer groups in Katsina State in 2002 without collateral. At the end of the farming season, 98% of the farmers repaid the loan. Following this success, in 2003, the Bank provided about N10 million (US$80 000) to 712 beneficiaries in three states. Of the total credit, about 13% was available to women farmers. In doing this, RUSEP opened the doors of banks to a new set of partners whose needs though small made a difference to improve farm productivity and incomes.

4.3.2 Facilitating formation of processors' association

In Abia State, 45 small- and medium-scale processors were trained in product development to diversify cassava for industrial uses and to build processing clusters. The processors were also trained on the production, packaging, waste management, and quality assurance methods for high quality cassava flour, ethanol, starch, and chips. After the training, 25 came together to register the Cassava Processors' Association of Nigeria (CAPAN), and acquired a site in Aba to set up a cassava-processing venture. The United Nations Industrial Development Organization (UNIDO) offered to assist with the provision of equipment for the plant. Following the same approach, RUSEP assisted with the formation and registration of the Oil Seeds Processors Association of Nigeria (OSPAN). The objective is to build up these associations into limited liability companies.

4.3.3 Providing support to enhance private sector investment

RUSEP conducted a detailed study on sourcing high quality cassava chips for alcohol distillery. The objective was to provide support for private sector investment in the agricultural sector in Nigeria. Using results from the study, RUSEP provided technical advice to one investor leading to the acquisition of US$15 million alcohol distillery plant that will use cassava as raw material. RUSEP also developed a blue print for the supply chain development and management. When this plant starts operations during the first quarter of 2005, it would provide assured market for about 6000 cassava farmers. This is just an example of how RUSEP provides and links farmers to markets.

4.3.4 Market information promotes profits for farmers and traders

Lack of transparency in the rural marketplace, haggling, and bargaining for price discovery are major constraints to trade in Nigeria. RUSEP therefore established an active market information service in Nigeria. Market data on 21 commodities were collected from 16 markets nationwide, processed, and transmitted via radio broadcasts in local languages, website (www.rusep.org), newspapers, and email (rusep@cgiar.org) to various market participants. Through this service, RUSEP empowered farmers and commodity brokers with the knowledge required for enhanced market participation and negotiation. A commodity broker who regularly used the RUSEP price information wrote "RUSEP price survey (especially for maize) for week 31 was correct, current, and useful. It may interest you to

note that maize is being delivered to Nigeria Eagle Flour Mills, Ibadan at N20 000/tonne = N20/kg just as your survey showed for Ibadan. Keep it up!"

RUSEP also helped to organize listeners groups as well as traders groups. The groups were trained on how to use market information for decision-making. The radio listeners groups in Katsina and Adamawa states reported that the information helped them to sell maize last season for 5–10% higher than they normally did without the price information.

4.3.5 Developing reliable input supply systems to enhance commercialization

Many small farmers in RUSEP zones had bumper harvests from growing higher-yielding crops and increased their incomes from selling farm products. This was achieved through RUSEP intervention in technology transfer and commercialization program. The introduction of improved seeds by the project was done alongside functional training for preseason, inseason, and postseason operations. Farmers were grouped by commodity and provided with improved seeds of maize, rice, sorghum, groundnut, cassava, and yam.

In 2002, 5820 farmers and an additional 2750 in 2003 were given improved planting materials and trained on improved agronomic practices. These farmers were able to raise yields by 30–60% over the previous harvests. Capacity building activities in postharvest processing and storage helped farmers to reduce postharvest losses, which further consolidated these gains. Tables 34 and 35 present a summary of improved inputs transferred to farmer groups in 2002 and 2003.

Table 34. Summary of transfer of improved inputs to farmers groups by RUSEP in 2002 and 2003.

Year	2002	2003
Number of RUSEP farmers to date	5820	8570
No of RUSEP farmer groups	242	534
Credit (₦)	3 200 000	9 598 000
Improved seeds		
Cassava (bundles)	530	46 640
Grains (tonnes) *	6.92	189.29
Yam (setts)	1000	150 000

*Grains include maize, sorghum, groundnut, and rice, yam setts include minisett and ware yam

Table 35. RUSEP Planting material linkage 2003.

Location (hub)	No. of farmers	Maize (kg)	Rice (kg)	Sorghum (kg)	Ground-nut (kg)	Ware yam (pcs)	Yam minisett (pcs)	Cassava stems (bundles)
Southwest Oyo	1756	8632 (545)*	Nil	Nil	Nil	Nil	Nil	38 940 (389)
Southeast Abia	2010	Nil	2550 (45)	Nil	Nil	70 000 (7)	80 000 (2)	7700 (154)
Northwest Katsina	3292	41, 632 (2775)	Nil	39 025 (2269)	Nil	Nil	Nil	Nil
Northeast Adamawa	1512	5900 (590)	28 880 (720)	Nil	18 200 (455)	Nil	Nil	Nil
Total	8570	56 164 (3910)	31 430 (765)	39 025 (2269)	18 200 (455)	70 000 (7)	80 000 (2)	46 640 (543)

Total number of ha cultivated for each commodity. Note that Katsina and Adamawa states do not fall within Project E domain.

4.3.6 Capacity building for enhanced commercialization

Building capacity of farmers, processors, and dealers through functional training was a major activity in the project. RUSEP provided specialized training using experts from credible private, public, and NGO institutions (Table 36). The following training were provided: seed and cassava planting material enterprise development, group management, savings, credit use and management, and value adding cassava products development.

Table 36. RUSEP training beneficiaries by State and gender.

State	Beneficiaries	Type of training						
		Group management[E]	Improved agronomic practices & technology	Storage & use of fertilizer agrochemicals[I]	Credit management and use[F]	Postharvest handling & storage[E]	Produce marketing[E]	Product processing
Abia	Male	180	998	30	180			
	Female	206	302	0	206			35
	Total	326	1300	30	326	370	70	35
Adamawa	Male	117	1080	1080	117			
	Female	27	0	0	27			
	Total	144	1080	1080	144	1200	1123	
Katsina	Male	159	1626	1226	159			
	Female	2	0	0	2			
	Total	162	1626	1226	162	1397	1397	0
Oyo	Male	94	560	5				
	Female	18	70	70				69
	Total	112	630	630	112	630	630	69
Grand total		744	4636	2966	744	3030	3220	104

E = enterprise training, F = financial training; I = input management training; and P = training on improved processing technique

4.3.7 Database of agricultural institutions

RUSEP produced an electronic database of information on over 1800 organizations and institutions dealing with agricultural technologies in the RUSEP states. The database is an information tool for those concerned with the development, dissemination, and use of agricultural technologies in the pilot states and other parts of Nigeria, including private sector agribusinesses, institutions involved in technology generation and dissemination, formal and informal rural financial institutions, farmer groups, and NGOs. The database covered different sectors of particular interests to the economy and population of the rural sector in RUSEP states. The organization provided detailed information on the basic information, general characteristics, major activities, programs, collaboration, and means of information dissemination. Both web-based and CD versions of the database are available.

4.3.8 Developing community-based seed entrepreneurs

Availability of high quality seeds and planting materials to farmers was a major constraint to small-scale farmers in Nigeria. Recycling of seeds from previous harvests, led to low farm yields. To assure continuity, RUSEP in collaboration with the National Seeds Service developed community-based seed supply systems and trained farmers to become community seed entrepreneurs. RUSEP has trained 27 seed entrepreneurs in three communities in three states who were now producing seeds to farmers within their communities. We estimated that these would provide seeds for sale to 3000 farmers in 2003/2004 farming season. The entrepreneurs were linked to agrochemical dealers and credit to support their business. This is one effort of RUSEP at developing sustainable transfer of improved technologies through local entrepreneurship.

5 Dissemination and adaptation of improved management interventions monitored and evaluation of their impact on farmers' livelihoods and institutional capacity

5.1 Establish the impacts of improved germplasm, soil, weed, disease, and pest management systems

by J. Lemchi and A. Tenkouano

A deliberate effort to deliver improved plantain hybrids to farmers in Nigeria was undertaken in September 2000, beginning with a workshop of stakeholders to delineate the modus operandi and the intervention scale. Subsequently, mass-propagation of improved plantain hybrids was carried out to establish approximately 110 on-farm demonstration trials in 11 states in partnership with the public extension agencies ADPs, Ministries of Agriculture [MoA]), oil companies (Shell Nigeria, Nigeria Agip Oil Company-Green River Project), churches, other community-based organizations, and contact-farmers (CPs).

Within two and a half years of the project's farm level commencement, some visible and significant results were recorded. Two sets of detailed data on project performance were collected at two periods, (March–May 2003 and September 2003), covering 73% of CPs in all 11 states and 16% of CPs in 7 states. The results are highlighted below.

5.1.1 Crop yields

Majority of farmers could not maintain sufficient records of their activities. However, the available data indicated that farmers harvested hybrids earlier and more frequently than the locals (Table 37). The average bunch size was higher for the hybrid varieties than for the landrace (Table 38). Bunch weight reflected market value because bigger bunches attracted higher prices than smaller bunches.

5.1.2 Cash earnings and household food supply

Participation in the project has made significant positive impact in the income and food economy of the farmers. The farmers have earned reasonable cash income from sales of fruits, suckers and processed plantain/banana products. About 71% of the farmers surveyed in May 2003 made cash earnings from sale of fruits and suckers. On the whole, average proportion of fruits sold ranged from 4.4 to 92.1% with a mean of 55.5% from the May 2003 data, while from the September 2003 data, proportion of harvested fruits marketed ranged from 31.4 to 89.5% with a mean of 65.6% (Table 37). For the hybrid fruits, market share of total harvests ranged from 4.4% to 100% with a mean of 54% while the market share of the locals ranged from 12.5 to 100% with a mean of 67% (Table 37) from the May data. From the September data, average market share of total harvests was 58.6% for the hybrids and 75.3% for the local variety (Table 37). Initially, the demand for the hybrid fruits was slightly low, a phenomenon usually associated with new technologies. The farmers played active part in creating awareness on the hybrid fruits in various ways.

For instance, majority of the farmers gave out the initial harvests from the hybrids to other people in their communities (to create awareness), while some gave to churches as a sign of reverence and appreciation to God for the hybrid.

From the May data, Mr Adjarho a farmer from Ughelli in Delta state remarked that he gave all the hybrid harvests to others (apart from the ones consumed by the family) to create

awareness and inform his people on the hybrid varieties while Mr Ekikosa, a farmer from Iworo (Ijebe-Ode) in Ogun State, noted that more than 50% of harvests from the hybrid varieties were processed into flour for family consumption. However, results from the September data showed that market share of the hybrid fruits improved (Table 37). Majority of farmers remarked that the demand increased and traders paid for the fruits in advance before full maturity and harvest.

Higher average bunch prices were recorded for the hybrid bunches relative to the local variety, reflecting the relatively bigger bunch yields of the hybrids relative to the locals. From the May data, average bunch prices ranged from N90.00 to N863 with a mean of N251.20 for the hybrids, while that of the local ranged from N100 to N450 with a mean of N238.52 (Table 37). The price trend was maintained, and in fact widened (in favor of the hybrid fruits) from the September results (Table 37). This constituted a major shift from the initial situation whereby bunch prices were higher for the locals than the hybrids, mainly because traders were not familiar with the hybrids nor were they aware of novel processing options for such new materials.

Table 37. Summary of harvests and sales from contact farmers.

Variety	No of bunches harvested			Proportion sold (%)			Average bunch price (₦)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
May 2003 survey (11 states, 45 [73%] contact farmers)									
Hybrids	1	140	46.0	4.4	100	54.0	90.00	863.00	251.20
Local	2	100	32.0	12.5	100	67.0	100.00	450.00	235.52
Both	1	240	75.6	4.4	92.1	55.4	90.00	863.00	244.96
September survey (7 states, 10 [16%] contact farmers)									
Hybrids	50	200	118.3	29.3	82.3	58.6	200.00	500.00	365.44
Local	20	135	86.0	37.5	100	75.3	80.00	500.00	297.50
Both	70	335	204.3	31.4	89.5	65.6	80.00	500.00	332.94

Table 38. Bunch weight of hybrid and local plantain and banana from farmers' plots (May 2003).

Variety	Bunch weight (Kg)		
	Minimum	Maximum	Mean
PITA14	7.0	17.6	13.6
PITA17	7.0	21.6	14.1
PITA26	5.0	15.8	8.7
BITA3	11.0	28.0	18.0
FHIA17	18.0	37.0	25.5
FHIA18	-	-	-
FHIA20	15.0	15.0	15.0
FHIA23	16.0	28.0	22.7
FHIA21	-	-	-
FHIA25	19.0	46.5	32.7
CRBP39	11.0	12.0	11.5
Agbagba	4.6	12.2	7.4

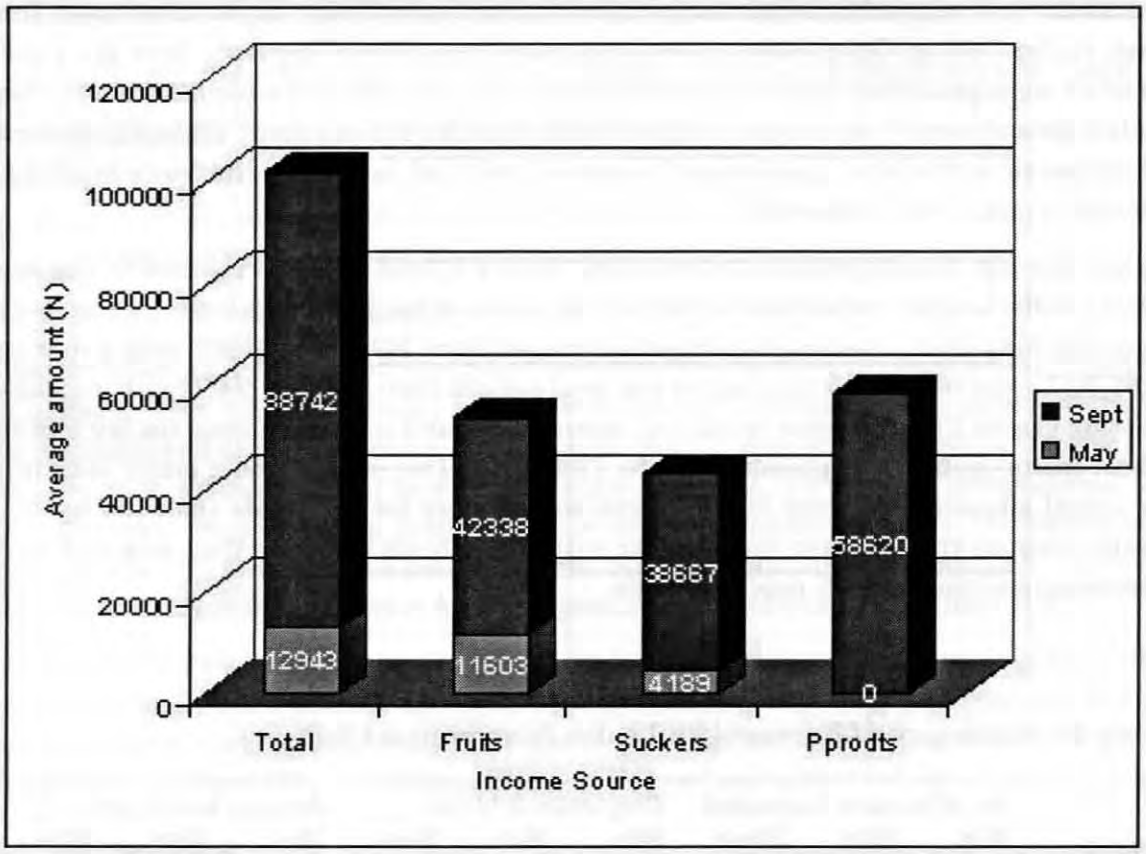

Figure 18. Summary of average income earning by farmers as at May and September 2003 (Pprodts = processed products).

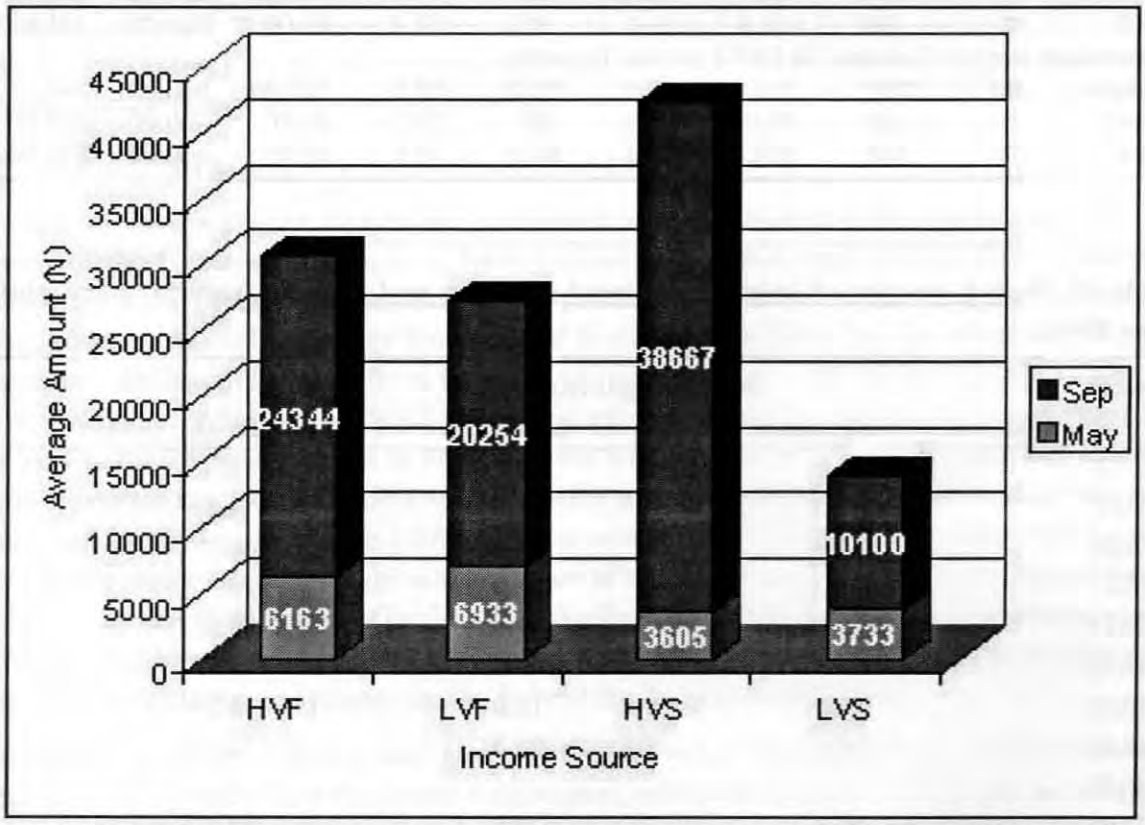

Figure 19. Relative contribution of hybrids and landraces to income-earning by farmers as at May and September 2003. (HVF = Hybrid variety fruits, LVF = local variety fruits, HVS = hybrid variety suckers, LVS = local variety suckers).

Training was necessary because the project was concerned with promoting novel postharvest processing in addition to increasing yield output, which afforded contact farmers additional income opportunities. Similarly, demand for planting materials stimulated sucker sales, providing a third source of income from plantain plots. The relative magnitude of the three sources (fruits, processed products, and suckers) is depicted in Figure 18.

It is noteworthy that sales of hybrid fruits, suckers, and processed products contributed more to the income inflow than the locals (Fig. 19).

The increased contribution to earnings by the hybrid variety plants were as a result of fast plant cycling, increased sucker production and sales, as well as processing. Though the farmers that sold processed products processed both hybrids and locals, they noted that more fruits were obtained from the hybrid varieties than from the local for processing. The farmers in particular remarked that there has been intense pressure for the hybrid suckers by other farmers in their localities.

Apart from cash income, the hybrids are made significant contribution to household food supply. Hence, farmers consumed significant proportion of the harvests in their homes, ranging from 10 to 100% with an average of 45% in the various methods they consume their local plantains and bananas. Thus, the introduction of the hybrid varieties is made significant economic impact in the household food security and income of the participating farmers.

5.1.3 Technology adoption and spread

Adoption and diffusion were key indicators of technology suitability and acceptance by the target beneficiaries. The definition of technology adoption varied depending on the situation and the nature of package being assessed. In this study, adoption was assessed in terms of expansion in hybrid cultivation intensively or extensively and extent of application of techniques taught.

It may be too early to evaluate adoption of the technologies being disseminated, especially for such perennials as plantain and banana, but preliminary data could help to understand trends. For example, the March–May 2003 survey indicated that 45% of the farmers had expanded the hybrids into new fields (Fig. 20).

Indications that this proportion would grow with the stabilization of rains, was corroborated with the September 2003 survey showing that 80% of the farmers had established new fields with the improved hybrids. This showed a high adoption level, noting that it was less than two and a half years since the hybrids had been introduced to the farmers.

The average size of the new plots ranged from 0.14 to 0.45 ha. Interestingly, expansion was also done with the landraces, which were interplanted with the hybrids, the farmers having realized that they would get improved yields of the landraces when planted with the hybrids. Thus, while the hybrids made fast inroads into the farming system, cultivation of the locals was preserved and expanded.

Farmer-led technology diffusion of the project triggered off through the dissemination of the hybrid planting materials, harvested fruits, as well the acquired skills. Sucker spread was through sales and free gift to other farmers. Most contact farmers provided an average of 15–20 sucker hybrids to other farmers. As demand for suckers increased, free gifts subsided in favor of sales.

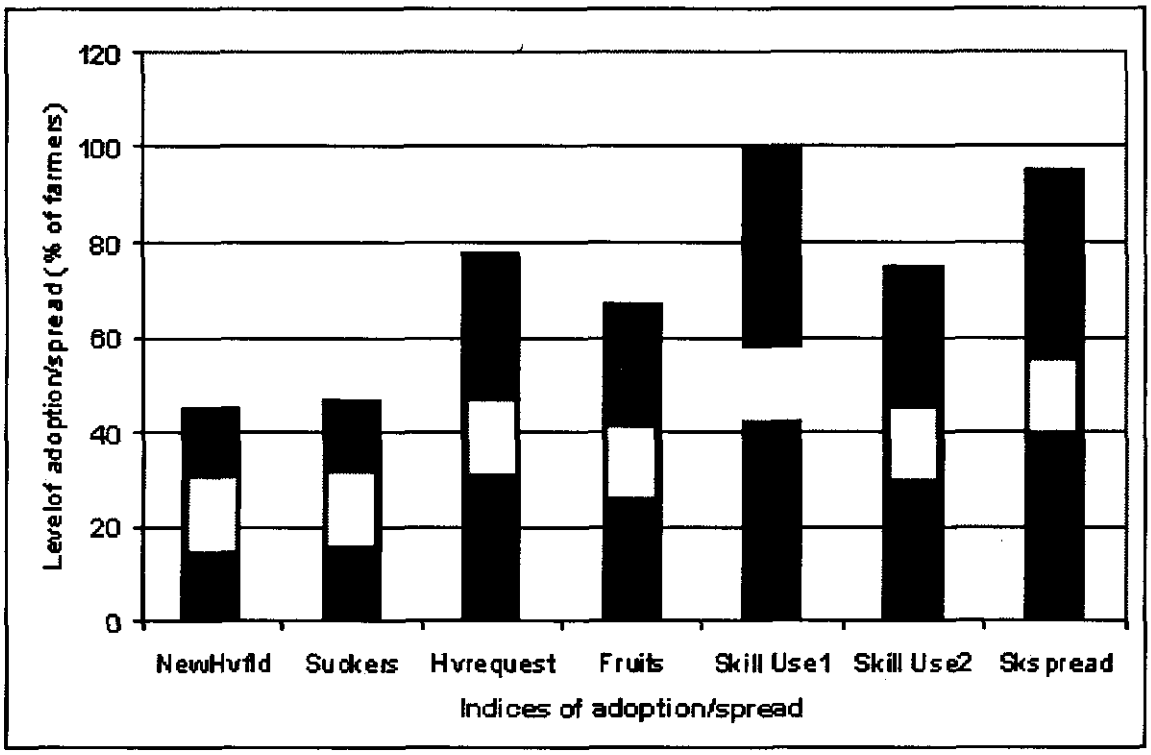

Figure 20. Extent of plantain and banana technology adoption and spread in Nigeria (NewHvfld = new hybrid variety fields, Suckers = suckers sold/given out, Hvreqest = outstanding request for hybrid suckers, Fruits = fruits given out, Skill Use1 = farmers practicing skills acquired, Skill Use2 = proportion of acquired skill being practiced, Skspread = farmers teaching skills acquired to other people).

5.1.4 Capacity building

The project adopted an integrated approach whereby hybrids were introduced along with desired agronomic/management practices, sucker production and management, and postharvest/processing options. Farmers were taught the management and agronomic practices of weeding, mulching, fertilizing, propping, manuring, desuckering, harvesting, fire prevention, plant spacing, pruning, pest/disease identification and management, site selection, planting, debudding, inter-cropping, etc. Training on sucker production and management techniques centred on rapid low-cost sucker production methods, and sucker handling and management.

Training on postharvest and processing options focused on fruit handling, methods of production of array of processed products from plantain and banana and traditional and enhanced packaging and preservation. All the farmers had put some of the training into practice, an indication of good adoption prospects. The farmers were particularly zealous on training such as sucker, wine, malt, and flour production (and associated products), chips, etc., from the plantains and banana hybrids, and some of them made significant income from the production and sale of suckers, and processed products, in addition to fruit sales.

In addition to sucker spread and fruits sales and/or gifts, farmers have also taught others what they had learned (relations and friends). Thus, contact farmers taught at least 10 other people, which was an encouraging diffusion rate.

5.1 Establishing the socioeconomic impacts of improved storage, processing methods, and expanding market opportunities

5.2.1 Socioeconomic benefits of the plantain and banana hybrid delivery project in Nigeria

by J. Lemchi and A. Tenkouano

Currently, plantain and banana cultivation is grown within homesteads by majority of farmers, which does not allow for increased production to respond to increasing market demand. The homestead system (where few mats/stands were mixed with other crops) was the traditional pattern of plantain and banana production especially in the southeastern region (resulting from scarcity of land and production habit) that discouraged expansion and commercial production.

Through this project, farmers became aware that plantain/banana can be cultivated as plantation crops outside the homestead and gave it adequate attention. The scale of production changed among the farmers. Traditionally, production was small-scale, where few stands were grown around homestead together with other crops (vegetables, staple crops, palms, fruits, other agroforestry trees and shrubs, etc.). There is now a clear trend for commercial production, not only for fruits, but also for suckers, the lack of which has been a major constraint to expansion of plantain cultivation.

Another aspect of production orientation that is fact changing, resulting from the project is plantain and banana processing and utilization methods. Some of the farmers now produce various processed products both for market and home consumption beyond the traditional methods of boiling, roasting, and frying (dodo). Through processing, the shelf life is extended, and the products made easy to transport and to the market, thereby reducing the problems associated with perishability, transportation, and marketing.

5.1 Establishing the economic and environmental impacts of sustainable crop combinations and sequences and sound crop–livestock management options among farmers

See section 3.3 on varietal mixtures and section 5.1 on farmers' perception of their benefits for plantain and banana. Preservation and expansion of cultivation of the landraces along with the hybrids maintained genetic diversity whereas the use of hybrids as "biopesticides" reduced the need for environmentally hazardous chemical pesticides, which farmers could not afford.

5.1 Establishing the economic and welfare effects of strengthened domestic and regional markets and information systems for the upstream and downstream sectors

5.4.1 Economic impact of RUSEP

by P. Kormawa

A major thrust of RUSEP was to facilitate links among farmers with commodity brokers, and input markets (see Section 4.3.). An estimated total benefit of N304 million (ca US$2.4 million) ensuing from the project interventions is illustrated in Table 39.

The value of inputs facilitated by RUSEP to farmers is presented in Table 40. The value of improved seeds facilitated by RUSEP was US$18 8881 in 2003. Equivalent to US$18 8881.3 at N130 to US$1. Inputs were valued at the purchase price at the beginning of the

year as follows: maize N80/kg, rice N100/kg, groundnut N70/kg, sorghum N50/kg, cassava N150/bundle, and yam N300/piece.

Table 39. Value of RUSEP's contribution to the agricultural sector in Nigeria.

	Industrial demand (t)	Supply from others (t)	Required by industry (t)	Quantity produced through RUSEP linkage (t)	% of requirement by industry	Value (million Naira)
Cassava	500	0	500	1400	280	112.0
Maize	33200	29302	3898	3199.2	82	67.18
Rice	4800	3600	1200	479	40	47.9
Sorghum	45750	41175	4575	1527.2	33	41.6
Soybean	1500	1200	300	1131.3	377	34.93
Total						303.61

Table 40. Value (Naira) of improved inputs to farmers (groups) in 2003 in the RUSEP project.

Improved Seeds	Quantity	Value (Naira)
Cassava (bundles)	46 640	6 996 000
Grains (tonnes)	189.29	15 308 570
Yam (setts)	150 000	2 250 000
Total		24 554 570

5.1 Establish the impacts of effective farmer associations and rural agroentrepreneurs, linkages of SME to input and output markets, and policy options and strategies that increased efficiency and sustainability

This was an ongoing activity that coincides with IITA's shift to a R4D mode of operation along a research-thru-development continuum. Hence, several megaprojects following a commodity-chain approach were launched, but were too young for evaluation of the impacts of farmer organizations and agroentrepreneurs. The following summarizes actions pertaining to the tree crops (cocoa) sector under STCP.

5.5.1 Monitoring, evaluation, and impact assessment framework development for project interventions

by J. Gockowski (Principal Coordinator)

The initial phase of STCP was to test new innovations and approaches for trading systems, information and knowledge dissemination, and capacity development of farmer organizations. It was also important that the program monitored and evaluated interventions with great attention. As the first step in this process, a workshop was held in Ibadan (Nigeria) to explore monitoring, evaluation, and impact (ME&I) and to discuss the processes for accomplishing the impact objective. A consensus set of indicators was developed by different outputs for inclusion into the monitoring and evaluation frameworks of activity workplans.

To assist in monitoring and evaluation of interventions in the tree crop sector in West Africa, development agents require an assessment framework illustrated with practical examples of the peculiarities of the West African tree crop sector. Using input from the above activity, different approaches to categories of problems were illustrated.

5.5.2 Evaluation of pilot project impacts on cocoa marketing and trade

by S. Weise in collaboration with P. Abbott (Principal Investigator, Purdue University)

Purdue University created an impact assessment framework for STCP pilot projects as part of this activity. Implementation of this evaluation tool is one component of the design of the Trade and Information Systems Program (TISP) regional project, and components of this framework have been used by researchers on this project as well as at IITA in support work for TISP and in research activities. In that new conceptual framework, the focus was on the four market failures which STCP pilot projects should address in their activities relating to marketing and information systems, namely: economies of scale in assembly, distribution and transportation, spatial oligopsony, and information and credit.

5.5.3 Economic and environmental comparative assessment of the impacts of smallholder tree crop systems and slash-and-burn annual cropping systems in Brazil, Cameroon and Indonesia

by J. Gockowski (Principal Coordinator)

A comparative assessment of tree-based cropping systems and annual cropping systems in terms of sustainable production and ecosystem integrity in the humid tropics was the object of this study. Included in this effort were an examination of social policy and political mechanisms for increasing the spatial extent of cocoa agroforests in Cameroon.

Completed studies

Buri, M.M., R.N. Issaka, and R.J. Carsky. Developing fertilizer recommendations for white yam (Dioscorea rotundata***) in central Ghana.*** Yam is a high potential crop in the savanna zone and exported nutrients must be replaced. To help guide sustainable production, mineral fertilizer trials were conducted across the central yam-growing belt of Ghana to identify the most limiting nutrient elements and establish economically justified fertilizer recommendation levels. Fresh tuber yields significantly responded to mineral fertilizer in all nine combinations of years and sites. In 2000, the mean fresh tuber yield increase over the control (15.5 t/ha at three sites without fertilizer applied) was 27% with 15-15-20 kg/ha N, P_2O_5, K_2O and 45% with 30-30-40 kg/ha N, P_2O_5, K_2O. A partial budget analysis showed that both 15-15-20 and 30-30-40 kg/ha N, P_2O_5, K_2O were economically justified by a marginal rate of return greater than 2. Soil analysis revealed that K was adequate at all sites. N was low at all sites except one, and P was adequate at all but one site. In 2001, compared with complete (N-P-K) fertilization, plots without N, P_2O_5 and/or K_2O applied had significant yield reductions of 7.4, 6.2, and 4.2 t/ha, respectively, at two sites combined. In 2002, yield losses due to withholding individual nutrients were not significant while the addition of 45-45-60 kg/ha N, P_2O_5, K_2O resulted in mean increase in tuber yield of 129% at four sites. Based on these results, 15-15-20 or 30-30-40 kg/ha N, P_2O_5, K_2O was recommended in all of the agroecological zones of central Ghana.

Chabi-Olaye, A., C. Nolte, F. Schulthess, and C. Borgemeister. Effects of cover crops on maize yield and plant damage by* Busseola fusca *in southern Cameroon. Cover crops have been previously tested for their effect on maize grain yield and soil fertility properties. However, interactions with lepidopteran stem borers, the most important maize pest in southern Cameroon, and populations of their natural enemies have been neglected. Various authors showed that individual nutrients such as N, K, and Si affected growth, survival and fecundity of stem borers. Thus, a field trial was designed to investigate the effect of several leguminous cover crops on maize yield and stem borer attacks with particular reference to *Busseola fusca* (Fuller) (Lep.: Noctuidae). A continuous maize production system was compared with rotation systems in which maize followed a *Mucuna, Cajanus,* or a bush fallow. Destructive and non-destructive sampling methods were used to quantify the impact of changed soil nutrient status on borer infestations and activity of associated natural enemies, and finally on plant growth and yield. Depending on the cover crop species in the rotation, and compared to a continuous maize production system, maize in the rotation systems had 1.3–1.9 more borers per plant. By contrast, grain yield loss due to borers in the continuous cropping system was significantly higher, suggesting that increased nutritional status of the plant enhanced both borer fitness and plant vigor but with a net-benefit for the plant.

Coyne, D.L., K.L. Sahrawat, and R.A. Plowright. 2003. The influence of mineral fertilizer application and plant nutrition on plant-parasitic nematodes in upland and lowland rice in Côte d'Ivoire and its implications in long-term experiments. *Experimental Agriculture* ***20: in press.*** Mineral fertilizer application and consequent plant nutrition has for a long time influenced associated plant-parasitic nematode population densities, offering the potential as a nematode management option. Observations were made on the influence of mineral fertilizer application on nematode populations on three separate long-term rice experiments, (differential mineral application on upland and on lowland rice and P application on upland rice) were carried out between 1994 and 1997 in Côte d'Ivoire. On upland rice, treatments with K or N withheld from the comprehensive mineral application treatment (range of elements including N, P, K, Ca, Mg, and Zn) led to lower densities ($P \leq 0.05$) of *Pratylenchus zeae* at harvest than the comprehensive mineral application, in 1995. By withholding K or Mg, *Helicotylenchus psuedorobustus* densities were greater than with either the control (no mineral application) or comprehensive mineral application in the same year. No differences were observed between treatments in 1994, or between treatments for densities of other nematode species present (*Meloidogyne incognita, Criconemella tescorum*) or for total nematode density. In the lowland rice trial, no treatment effects on nematode species (*Hirschmanniella oryzae* and *Uliginotylenchus palustris*) were observed. In the P application trial on a P-deficient Ultisol, *Heterodera sacchari* densities were lower ($P \leq 0.05$) in treatments receiving 180 kg/ha P, than untreated in 1995. In 1996, no differences were observed between untreated and 135 kg/ha P, while in 1997, higher densities of *H. sacchari* were present in 135 kg/ha P than untreated. Regression analysis of nematode densities against mineral straw content in the P application trial revealed a negative correlation between *M. incognita* and Mn ($P \leq 0.001$) and Ca ($P \leq 0.05$), and between *P. zeae* and Zn or Fe ($P \leq 0.05$). A positive correlation was observed between *Helicotylenchus* spp. and Mg ($P \leq 0.05$). This study provides strong arguments for the assessment of nematode constraints in long-term research trials, the omission of which may severely limit the validity of the primary experimental objectives.

Coyne, D.L., H.A.L. Talwana, and N.R. Maslen. 2003. Plant-parasitic nematodes associated with root and tuber crops in Uganda.* African Crop Protection *9: in press. In a nematode survey of eight commonly grown root and tuber crops (cassava, sweetpotato, potato, yam, tannia, taro, carrot, and turmeric) from a total of 4303 fields in Uganda, 68 species of plant-parasitic nematodes from 28 genera were extracted from soil and roots. About twice as many nematode species were recovered from soil (64) as from roots (36), while 32 species were found only in soil and four species only in roots, usually in mixed populations. *Meloidogyne* spp. (root-knot nematodes) were the most frequently recovered nematodes across crops, with the major species (*M. arenaria, M. hapla, M. incognita,* and *M. javanica*) observed on cassava. Some nematodes were recovered only from specific crops. Sweetpotato was associated with the greatest diversity of species (55 species in 25 genera), followed by cassava (40 species in 19 genera), and yam, which was sampled principally in the northern and eastern regions of Uganda (39 species in 14 genera). The study examined the distribution of the plant-parasitic nematodes, which provides information for more detailed local population studies and nematode pathogenicity evaluation on important root and tuber crops.

Dury, S., J.-C. Medou, D.F. Tita, and C. Nolte. Limites du système local d'approvisionnement alimentaire urbain en Afrique subsaharienne : le cas des féculents au sud Cameroun. La croissance démographique urbaine des trente dernières années s'est accompagnée d'une augmentation des quantités de produits commercialisés afin d'assurer la sécurité alimentaire des urbains. Au Cameroun, l'ajustement s'est réalisé en incluant un nombre croissant de productrices au marché, sans changements majeurs des systèmes de production ni tension excessive sur les prix entre 1983 et 1996. Cet équilibre dynamique semble actuellement remis en cause puisque, entre 1996 et 2002, les prix réels des principaux féculents (plantain, manioc, macabo) ont presque doublé. L'analyse de la demande (alimentaire, industrielle), de l'offre urbaine (production, mise sur le marché, exportations) et des institutions du marché (information, marges et organisation du système de distribution), semble indiquer que l'actuelle flambée des prix est essentiellement liée à l'augmentation des coûts de transport (due au non entretien des routes et à l'augmentation des prix des carburants) et à la reprise des cours du cacao, dans un contexte structurel où le système atteint ses limites (faible rémunération des producteurs et des commerçants). Les prix aux producteurs ne semblent pas suffisamment incitatifs pour entraîner actuellement une spécialisation/intensification. On montre par ailleurs que les changements de systèmes de production (intensification) se sont opérés dans les filières à forte valeur ajoutée (igname et pomme de terre) et dans celles où des variétés améliorées ont été diffusées (manioc amer et maïs).

Hauser, S., C. Nolte, and R.J. Carsky. What role for planted fallows in the humid zone of West and Central Africa? Crop management without fertilizer input, commonly practiced by most farmers in the humid zone, requires soil fertility to replenish it during fallow period. Hypothetical relationships between fallow length and crop yields assume, that the replenishment after the cropping phase starts on high annual increments, leading to early recovery of most soil fertility while slowly approaching a maximum level. The few available empirical data, however, indicate that this assumption was wrong. Within the first eight years of fallow, biomass and nutrient accumulation was either progressive (low initial increments) or linear. Planted fallows were supposed to replenish soil fertility faster or to higher levels than natural regrowth and should thus lead to higher crop yields. Two major types of planted fallows are tree-based and herbaceous fallows. Data from West and

Central Africa did not confirm that tree-based fallows were capable of attaining higher crop yields than natural regrowth or other planted fallows. The majority (53.4%) of experiments with tree-based fallows showed no differences to the control. Crop yield declines were found in 25.7% of cases and only 20.9% resulted in significant yield increases. Improvements of soil properties were more frequently positive (34.3%) than negative (9.8%), yet, most often (55.9%), there was no effect. Short-term slash-and-burn rotations, one-year cropping with 1–4 years fallow, tree-based fallows were not suited to transfer their advantage in biomass and nutrient accumulation into higher crop yields. There were indications that a tree-based fallow may require relatively fertile soils to outperform the natural fallow. In Cameroon, a 3–4-year old natural fallows showed an advantage on poor soils over tree-based fallows with *Calliandra*. Data on herbaceous, planted fallows were scarce, yet indicated, that a higher success rate in terms of significant positive effects on crop yield could be attained. Positive features of some herbaceous fallows, such as easy establishment, rapid weed suppression, and labor efficient slash-and-burn crop establishment made the technology more accepted and adopted by farmers. Furthermore, fallows had to be specifically designed for responsive crops, such as maize. However, one type of fallow could not serve the multitude of crops and intercrops grown in the region. Depending on the major constraints to crop production or income generation, planted fallows were designed to address the constraints. This focused on marketable fallow by-products, potentials for weed and pest reduction, or reduced labor requirements rather than effects on soil fertility. Thus, future impact through research on planted fallows will depend on exact targeting of specific fallow types and species to the most responsive crops and to explicit farmer circumstances.

Jemo, M., C. Nolte, and D. Nwaga. Response of* Mucuna utilis *(var. Veracruz) to* rhizobial *and* Arbuscular mycorrhizal *fungus (AMF) inoculation in an acid soil of southern Cameroon. Herbaceous legumes, such as *Mucuna*, provide large amounts of nitrogen to a subsequent cereal crop for high grain yield. However, not all *Mucuna* actually fixes sufficient N as found in farmers' fields in Bénin Republic. This could be due to lack of appropriate rhizobia strains nodulating with *Mucuna* or to low nutrient availability, particularly phosphorus. *Mucuna utilis (var. Veracruz)* was cropped for two years in acid and P-deficient soil in the humid forest zone of Cameroon, to study its response to rhizobial and mycorrhizal inoculation. A factorial experiment with three factors was carried out in RCB design. Each factor had two levels: rhizobia inoculation (R0/R1), mycorrhizal inoculation (M0/M1), and P- fertilizer application (P0/P1). *Mucuna* was inoculated with *Glomus deserticola* and *Gigaspora* spp. and/or a mixture of rhizobia strains VU1D1, VUXY1, VSXY1, isolated from cowpea and soybean nodules and their rhizosphere soil. P was applied as single super phosphate at a rate of 30 kg P ha^{-1}. Shoot and root growth, N accumulation in the plant, nodulation, and mycorrhizal root infection were observed. Results indicated that the effect of rhizobia inoculation on nodule dry weight largely depended on mycorrhizal inoculation or P application. Rhizobial inoculation increased significantly ($P < 0.05$) the dry weight of nodules when combined with either AMF inoculation or P application. Application of P independently increased the nodule dry weight of *M. veracruz* in both trial years. The total amount of N accumulated in vines, leaves, and at 14 weeks after planting was 272 kg N ha^{-1} after inoculation with AMF and rhizobia, and 234 kg N ha^{-1} in uninoculated plants. The percentage of AMF root infection across treatments ranged from 0 to 29% and significantly increased by either AMF inoculation alone or AMF and rhizobia inoculation. The total dry *Mucuna* biomass ranged across treatments from 7.0 to 13.7 Mg ha^{-1} and increased with rhizobia or AMF inoculation on average by 78% and 24%, respectively. Significant relationships between biomass, nodulation, and N and P uptake were observed.

This suggests that *M. veracruz* can establish and fix N effectively in this acid soil of the humid forest zone, provided sufficient rhizobial or AMF inocula were present in the soil or were added through management techniques. Further studies aimed at determining the status of both inocula in soils of the humid forest zone were required.

Nguimgo, K.A.B. and C. Nolte. On-farm test of soybean varieties and farmers' perception of soybean for improving soil fertility in southern Cameroon. Groundnut is the traditional grain legume grown for household consumption in the humid forest zone of Cameroon. Recently, farmers showed increasing interest in cultivating soybean, a relatively new crop in the forest zone in Cameroon. In 2002, an experiment was carried on farm using soybean varieties with promising performances in previous on-station and on-farm trials. Three soybean varieties (TGX1879-7F, TGX1838-5E, and TGX1805-13F) were distributed to extension agents to be planted in farmers' fields in a RCB design with a local variety as a check. A total of eight extension agents, covering eight extension zones, were involved with 80 and 60 participating farmers, respectively, during the first and second cropping season. Data were collected from 67 fields during the first season and 58 fields during the second season. Planting densities were 200 000 plants ha^{-1}. Soil properties at the test sites were: pH (H_2O) 4.3–5.9, C/N ratio 10.3–12.1, Bray1-P 2.59–9.26 mg P kg^{-1}, and exchangeable bases 2.01–11.0 cmol (+) kg^{-1}. During the first season, mean grain yields of TGX1838-5E, TGX1805-13F, and the local variety did not differ significantly and were 1.41, 1.62, and 1.51 Mg ha^{-1}. The mean grain yield of TGX1879-7F was with 0.91 Mg ha^{-1} significantly lower due to poor seed germination. There was a significant G x E interaction, thus no variety yielded consistently better across the sites and seasons. Similar results were found in the 2nd season albeit with lower overall grain yields: 1.13, 1.18, 1.21, and 1.16 Mg ha^{-1} of grain for TGX1838-5E, TGX1805-13F, TGX1879-7F, and the local, respectively. On a subset of 30 fields in the first season, it was found that TGX1838-5E gave with 3.22 Mg ha^{-1} significantly more haulm yield than TGX1805-13F, TGX1879-7F, and the local with 2.40, 2.36, and 2.50 Mg ha^{-1}, respectively. The mean harvest indices were 0.44, 0.38, 0.69, and 0.60. It was found that 111 farmers, in the six villages where the experiment was successfully conducted in 2002, produced an estimated 6820 kg of soybean in 2003. Most of these farmers used the improved varieties TGX1838-5E and TGX1805-13F. Farmers reported the presence of nodules on the roots of soybean at harvest and were aware of their potential to improve soil fertility. The main constraints to farmers were commercialization, threshing at harvest, and weeding, notably when farm sizes became larger.

Nolte, C., B.O. Zo'o, and J.P. Dondjang. Farmer's perception of planted* Calliandra *tree fallows for shortening fallow cycles in southern Cameroon.

Fallowing land after one cropping period of 18 months is the traditional method of restoring soil fertility and breaking weed cycles in subsistence fields of southern Cameroon. Traditionally, land remained in fallow for 10 years or longer. This system still operates in remote areas with very low population density. In areas with higher population density, however, i.e., close to major urban centers, such as Yaoundé, fallow cycles have been shortened on average for 3–5 years. Farmers often reported increased soil fertility and weed problems in rapid appraisals. Planted *Calliandra* tree-fallows have been recommended after 10 years of research in southern Cameroon to combat declining soil fertility and increased weed pressure in shortened-fallow-crop cycles. We tested variants of this technology with farmers in six representative villages of a forest margin benchmark area. Thirty *Calliandra* fallows, planted with different spatial tree patterns (equidistant, alley, cluster, and border plant-

ing), were established in farmer-managed fields in 1996. After a two-year fallow period, farmers in the six villages were asked to appreciate the fallows. A total of 60 farmers were interviewed, 26 of them participated in the trial and owned *Calliandra* fallows fields while 24 did not participate. Interviews were conducted within a group during field visits and individually at farmers' homestead. Open-ended questions were asked about knowledge of the trial objectives, farmers' attitude and perception of fallow techniques in general, and multiple-choice questions in semi-structured interviews about the trial run. Farmers were also asked to rank answers to questions pertaining to required labor for managing the fallows, growth of *Calliandra* as compared to the natural vegetation, anticipated regrowth potential of *Calliandra* after burning, and likely competition to crops. Data were analyzed according to the frequency of answers and the unidimensional scaling method of Likert et al. (1993). Majority of farmers (81.6%) knew that dominance of a specific fallow vegetation enhanced soil fertility. Farmers listed 16 species of the natural vegetation they linked with "sufficient" soil fertility restoration of a fallow. *Chromolaena odorata* topped the list with 16.7%. Eighty percent of farmers had seen *Calliandra* for the first time, whereas 20% had come across the tree in former ICRAF-led projects. They saw equidistant tree planting as the most efficient for weed suppression and soil fertility restoration, followed by alley, and cluster planting. However, farmers thought that equidistant tree planting had higher management requirements than planting trees around the field borders, in clusters, and in alleys. Farmers noted that crop distance to trees determined tree-crop competition and thus favored border and cluster planting over alley and equidistant planting patterns. Tree-regrowth potential after burn and equidistantly planted had serious problems vis-à-vis alley-, cluster-, and border-planted trees. In general, 45% of farmers were satisfied with the research interventions conducted in their village, whereas 43.3% felt their major problems had not been addressed nor their interests met.

Nolte, C., T. Tiki-Manga, and S. Badjel-Badjel. Biomass production and nutrient accumulation in tree, shrub, and herbaceous legume fallows of southern Cameroon. In southern Cameroon, short fallows are increasingly used for crop production. Crops are grown without the use of mineral fertilizer and farmers rely on fallows to restore soil fertility. Two-year old fallows planted with *Calliandra* trees, *Flemingia* and *Cajanus* shrubs, and a herbaceous legume (*Pueraria*) were evaluated on 15 farmer fields in three villages for biomass production and nutrient accumulation and compared with a natural fallow, dominated by *Chromolaena*. With the exception of *Flemingia*, fallow species could be easily established under a cassava crop in farmers' fields. *Calliandra* tree-fallows produced 28.0 Mg ha-1 of dry mass, significantly more than *Flemingia/Cajanus* shrub fallows (17.3 Mg ha-1), *Pueraria* fallows (10.8 Mg ha-1) and natural fallows (10.1 Mg ha-1). The tree fallows accumulated in their aboveground biomass 262 kg N ha-1, significantly more than 152, 148, and 99 kg N ha-1 in shrub, *Pueraria* and natural fallows. Accumulation of P and K in the tree and shrub fallows was superior to the other fallow types, but no difference in Ca and Mg accumulation was found. *Calliandra* tree fallows have thus a higher potential to retain crucial nutrients during the fallow phase in the plant-soil system than other fallow types. However, most (72%) of the dry mass and about half of all the nutrients were found in stem wood (> 2.5 cm) and 20–30% in branch wood. A similar result was found in the shrub fallows. These fallow types contained most of their nutrient mass in woody components, which are unavailable to subsequent crops if not burned.

Nolte, C., T. Tiki-Manga, and S. Badjel-Badjel. Establishment and early growth of Calliandra trees on farms in southern Cameroon. *Calliandra calothyrsus* trees have been extensively tested as species for planted fallows on acid soils in the humid tropics. A suitable tree specie should be fast-growing and persistent if it is to be recommended to farmers for use. Tree fallows were established from 2 to 3 months old potted seedlings on farmers' fields in villages of southern Cameroon, varying in soil properties. On average, 20% of the trees had to be replanted after one dry season or 4–6 months after planting. After 12–14 months, trees had reached average heights of 3 m, had a stem diameter of about 2 cm, and had two branches. The tree planting pattern affected stem diameter significantly, but neither height nor branching. Diameter and height were highly significantly related (r2 = 0.89). Stem diameter at 12–14 months was also highly significantly related (r2 = 0.53) to biomass production after 30 months of growth. Tree diameter at 12–14 months negatively correlated to soil organic carbon in 10–20 cm, and positively correlated to C/N ratio and exchangeable Ca in 0–10 cm.

Nolte, C., T. Tiki-Manga, S. Badjel-Badjel, J. Gockowski, and S. Hauser. The effect of* Calliandra *tree fallows on groundnut, maize, and cassava yields in mixed-food crop fields of southern Cameroon. Shortened fallow periods led to a decline in crop yield in the traditional mixed-food crop fields in southern Cameroon. Farmers did not use fertilizers for crop production in these field types. Planted fallows with adapted tree species could sustain or increase crop production under those conditions as found in other parts of Africa. Two-year old *Calliandra* tree-fallows, planted in alleys, clusters, equidistantly, or around plot borders, were compared with two- and 4–5-year old natural fallows in their effect on groundnut, maize, and cassava yields on 18 farmer fields in southern Cameroon. Trial fields covered a wide range of soil and environmental conditions. The tree fallows had no significant effect on maize and cassava yields with the exception of border planting, in which trees were not rigorously pruned prior to cropping. Here, cassava root yields were significantly reduced. Cassava root yields declined with decreasing planting distance to trees. Groundnut yield, the most important crop in this field, was adversely affected. However, maize grain yields related positively to biomass produced by *Calliandra* trees, notably on soils with pH over 5.3. The data showed that all crop yields could increase with higher plant densities, irrespective of fallow type. Tree-fallows, with the exception of border-planting, showed less adaptability than 4–5-year old natural fallows to sites with low crop yields, whereas no difference in two-year old natural fallows.

Sodjadan, P.K., A.M. Toukourou, R.J. Carsky, et P. Vernier. Effets des précédents plantes de couverture sur la production de l'igname en zone de savane au Bénin et au Togo. L'igname (*Dioscorea* spp.) est généralement cultivée sur défriche de jachère longue pour bénéficier du niveau élevé de fertilité de sol mais l'augmentation de la pression démographique entraîne une réduction générale de la durée des jachères. Dans le but de mettre au point des systèmes de production durables à base d'igname, des essais ont été menés respectivement à Gobé au centre du Bénin et à Laouno et Tchébébé au centre du Togo en vue d'évaluer l'effet des jachères des légumineuses Aeschynomene histrix, *Mucuna pruriens*, et *Pueraria phaseoloides* sur l'amélioration du rendement de l'igname. La quantité de biomasse aérienne sèche la plus élevée a été produite généralement par le *Mucuna* qui a réalisé l'accumulation biologique d'azote la plus élevée de l'ordre de 91 à 120 kg/ha. Sur tout les essais, le précédent jachère de *Mucuna* a augmenté de 3,2 t/ha (50%) en moyenne le rendement de tubercules frais d'igname. Des accroissements hautement significatifs ont été enregistrés à Laouno en 2002 sur des parcelles de deux ans de jachère (2,7 t/ha) et à

Tchébébé après un an de jachère (4,0 t/ha). Dans ces cas, le précédent jachère de *Mucuna*a été économiquement rentable avec des taux marginaux de rentabilité supérieur à 100%. La pratique de la jachère plantée de *Mucuna* pourrait se substituer à la pratique de la jachère de longue durée en vue d'intensifier l'exploitation des terres pour la production de l'igname.

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Scientists				
Agronomist/Breeder	Akoroda, M.*	Nigeria	Onne	100
Yam Breeder	Asiedu, R.	Ghana	Ibadan	40
TARGET *Musa* Coordinator West Africa (Joint w/IPGRI)	Attey, A.N.	Cameroon	Njombe	100
Plant Pathologist	Bandyopadhyay, R.	India	Ibadan	25
Agronomist	Carsky, R.**	USA	Cotonou	80
Entomopathologist	Cherry, A.**	UK	Cotonou	20
Nematologist	Coyne, D.	UK	Ibadan	20
STCP Technology Transfer Specialist	David, S.*	Liberia	Yaoundé	80
Cassava Breeder	Dixon, A.G.O.	Sierra Leone	Ibadan	40
Agroeconomist (Joint withCIRAD)	Dury, S.**	France	Yaoundé	40
Agricultural Economist	Gockowski, J.	USA	Yaoundé	40
Food and Agricultural Engineer	Halos-Kim, L.	Philippines	Ibadan	20
Acarologist	Hanna, R.	USA	Cotonou	20
Soil Physicist	Hauser, S.	Germany	Yaoundé	80
Virologist/Germplasm Health Unit Head	Hughes, J.	UK	Ibadan	20
Cocoa Geneticist	Kolesnikova-Allen, M.	Russia	Ibadan	20
Agricultural Economist	Kormawa, P.+	Sierra Leone	Ibadan	C
Geospatial Laboratory Manager	Legg, C.	UK	Ibadan	30
Virologist (joint appointment with NRI)	Legg, J.	UK	Kampala	20
Coordinator, DR Congo Cassava Project	Lema, K.*	DR Congo	Kinshasa	40
WASNET Coordinator	Maroya, N.	Bénin	Accra	20
Musa Geneticist	Moonan, F.	USA	Ibadan	20
Principal Scientist	Neuenschwander, P.**	Switzerland	Cotonou	20
Soil Fertility Specialist	Nolte, C.	Germany	Yaoundé	80
Project Manager Cassava in Niger Delta	Okoro, E. *	Nigeria	Onne	100
Participatory Technology Transfer Specialist	Schrotz, G.*, **	Germany	Yaoundé	n/a
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Plantain/Cassava Breeder	Tenkouano, A.	Burkina Faso	Yaoundé	60
STCP Manager	Weise, S.	Canada	Yaoundé	80
Soil Chemist	Wendt, J.+	USA	Kampala	C
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* joined during the year, ** departed during the year, + complimentary

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Postdoctoral Fellows				
Plant Pathologist	Mwangi, F.M.*	Kenya	Ibadan	40
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Weed Scientist	Nielsen, O.K.	Denmark	Ibadan	55
GIS Specialist	Robiglio, V.	Italy	Yaoundé	65
Entomologist/Ecologist	Wijnans, L.*	Netherlands	Yaoundé	40
Visiting Scientists				
Virologist	Offei, S.	Ghana	Ibadan	20
Virologist	Ogbe, F.	Nigeria	Ibadan	20
Acarologist	Toko, M.	DR Congo	Cotonou	20
STCP/SOCODEVI Farmer Organization Specialist	Boivin, M.*	Canada	Yaoundé	80
Yam Agronomist (CIRAD)	Cornet, D.	Belgium	Cotonou	80
Legume Agronomist (IRAD)	Nguimgo, B.*	Cameroon	Yaoundé	80
Consultants				
Economist	Amegbeto, K.N.	Togo	Ibadan	30
Economist/Musa Technology Exchange	Lemchi, J.	Nigeria	Onne	80
Economist	Nkamleu, G.B.	Cameroon	Yaoundé	55
Agroecologist	Norgrove, L.**	UK	Yaoundé	80
Modeler	Tchiakam, B.	Cameroon	Yaoundé	80
Entomologist/Biodiversity Specialist	Tindo, M.	Cameroon	Yaoundé	40
STCP Pilot Sites				
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Nigerian NPP Manager	Okafor, C.*	Nigeria	Akure	80
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Graduate training

Name	Degree	Country	Thesis title	Sponsor	Supervisor
Achidi, A.	PhD	Nigeria		Self/IITA	Maziya-Dixon
Aigbe, S.O.	PhD	Nigeria	Host-pathogen relationships in the development of root and tuberous root-rot in cassava	Self/IITA	Bandhyopadyay
Aina, O.O.	PhD	Nigeria	Variability in shoot and root characteristics of cassava genotypes as it influences yield in Nigeria	Self/IITA	Dixon
Akinwale, A.	PhD	Nigeria		Self/IITA	Maziya-Dixon
Akou, J.E.	Ing. Agro.	Cameroon	Use of leguminous plants against ARTS	IITA	Wijnans
Alabi, F.	PhD	Nigeria	Characterization of resistance in cassava to cassava mosaic begomoviruses	Self/IITA	Dixon
Amougou, D.	MSc	Cameroon	Economic evaluation of the impact of improved varieties, plant health measures and fertilizer use in plantain production systems of southern Cameroon.	Self	Hauser
Ariyo, O.	PhD	Nigeria	Marker-based evaluation for virus resistance and reactions of new cassava elite clones to cassava mosaic disease in different agroecological zones	IITA	Dixon
Atangana, T.	Tech Sup	Cameroon			Hauser
Bah, S.	PhD	Guinea-Conakry	Genetic relationships and investigation of G x E interaction of cassava germplasm in Guinea Conakry	DAAD Germany	Dixon
Bidzanga	PhD	Cameroon	Farmers ecological knowledge and management of cocoa multistrata systems in Cameroon	STCP	Nolte
Birang, A.M.	PhD	Cameroon	Soil macrofauna diversity, density, and function along a land-use intensification gradient in the humid forest zone of southern Cameroon	Wageningen University	Hauser
Chabi-Olaye, A.	PhD	Bénin	Effect of maize cropping patterns and management on population dynamics of maize stemborers and their natural enemies in Cameroon	German Science Council (DFG)	Nolte
Doumtsop, F.A.	Ing. Agr.	Cameroon	Morphology and rearing of *S. vayssierei*	IITA	Wijnans

Graduate training (cont'd)

Name	Degree	Country	Thesis title	Sponsor	Supervisor
Egwu, N.J.	MSc	Nigeria	Adoption prospects of IITA hybrid plantain in southeastern Nigeria (completed)	Private/ visiting collaborator)	Lemchi
Fotso, K.A.	DUA-Ir	Cameroon	Cast structure, nest and colony size, diet breadth, and habitat requirements for *A. tenella*	IITA	Wijnans
Jemo, M.	PhD	Cameroon	Mycorrhization, efficiency in P uptake, nodulation and N-fixation of cowpea and soybean varieties for integration into intensive maize–legume systems	IITA grant part DAAD grant	Nolte
Kanmegne, J.	PhD	Cameroon	Quantification of nutrient fluxes and ecosystem functions in different land-use systems of the Campoman forest reserve	Dutch Campo Man project Kribi	Nolte
Kekenou, S.	PhD	Cameroon	Effect of fallow vegetation type on *Zonocerus variegatus* populations	Self	Weise
Kolade, G.	MPhil	Nigeria	Induction of ploidy in improved genotypes and landraces of cassava	Self/IITA	Dixon
Mateck, E.	BSc	Cameroon	Environmental effects of copper fungicides	Self	Norgrove
Mekoa, C.	DEA	Cameroon	Effect of fallow age, planting material, sucker cleaning and fertilizer application on the yield of two varieties of plantain (*Musa* spp. AAB, subgroups French and False Horn)	ASB	Hauser
Messiga, A.	MSc	Cameroon	Root-rot and nematode infestation of cassava in the Puma area of Cameroon (cosupervision with Drs Coyne and Bandyopadhyay)	Core, Project E competitive fund	Nolte
Morufat, O.B.	PhD	Nigeria	Studies on in vitro tuberization and microtuber dormancy in selected species of *Dioscorea*	Self	Shiwachi
Motue, G.	Tech Sup	Cameroon			Hauser
Moyib, O.K.	MPhil	Nigeria	Molecular characterization of improved cultivars and popularly grown Nigerian landraces using SSR markers	Self/IITA	Dixon
Muamba, K.	BSc	DR Congo		Self	Shiwachi
Nanga, J.L.	Ing. Agro.	Cameroon	Effect of hormone dose and substrate composition on ex-vitro mass-propagation and seedling establishment of plantain varieties	IITA/SMIP/ Self	Tenkouano
Ndzany, T.	BSc	Cameroon	Effects of soil water content, shade, and soil type on cocoa	Self	Norgrove
Ngo Kanga, F.	Ing. Agr.	Cameroon	Plant parasitic nematode composition and density under different fallow types and effects of leguminous cover crops	IITA	Hauser
Ngobo, M.	PhD	Cameroon	Plant community composition, characteristics, and productivity of shortening fallows in southern Cameroon	Completed	Weise
Nguenkam, A.	DESS	Cameroon	Effect of timing of field preparation and planting on weed emergence	Self	Weise
Ojunjobi, A.A.	PhD	Nigeria	Characterization and genetic analysis for resistance to cassava bacterial blight in improved and local germplasm of cassava	Self/IITA	Dixon
Oselebe, H.	PhD	Nigeria	Ploidy and genome effect on combining ability and heterosis in *Musa* populations	IITA/USAID/ Self	Tenkouano
Oyederu, O.	MSc	Nigeria	Adoption of chemical control measures against *Imperata cylindrica* (Speargrass) in Ogoja and Emere, Nigeria	DFID Weed	Nielsen

Graduate Training (Cont'd)

Name	Degree	Country	Thesis title	Sponsor	Supervisor
Raji, A.	PhD	Nigeria	Assessment of genetic diversity and heterotic patterns in African improved and local cultivars of cassava	Self/IITA	Dixon
Selatsa, A.A.	Ing. Agr.	Cameroon	Phenetic redundancy and diversity among popular plantain accessions based on morphological markers and farmers' perception	IITA/SMIP/Self	Tenkouano
Sonwa, D.	PhD	Cameroon	Ecology and diversity of cocoa multistrata systems in southern Cameroon.	IITA fellow	Weise
Tchienkoua, M.	PhD	Cameroon	Improving P-availability in intensive maize cropping systems in the FMB through integration of P-efficient grain legumes	IITA grant	Nolte
Tieche, B.	MSc	Cameroon	An allometric equation to estimate the aboveground biomass of *Inga edulis* from simple, non-destructive measurements	Univ Ghent	Hauser
Tietche, B.	MSc	Cameroon	Allometrics of *Inga edulis*	Self	Norgrove
Tueche, B.	DSEE	Cameroon	Contribution a l'etude des proprietes, des mechanismes de transfert et d'alimentation hydriques des aquifers de la couverture ferrallitique de Mbalngong au sud-ouest de la ville de Yaoundé	DGIC	Hauser
Twizeyimana, M.	MSc	Nigeria	Screening plantain and banana cultivars for resistance to black sigatoka disease caused by *Mycosphaerella fijiensis*	Self/IITA	Bandhyopadyay

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Publications 2003

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