Annual Report 2001

Project 5

Improvement of Yam-based Systems

IITA

Research to Nourish Africa

International Institute of Tropical Agriculture | Institut international d'agriculture tropicale

Contents

Preface

IITA's research agenda is subdivided into a portfolio of 14 projects (Annex 1), around which these project annual reports are prepared. These projects address different aspects of attaining sustainable increases in productivity of dominant farming systems and utilization practices in the various agroecologies of sub-Saharan Africa (SSA). Research and training activities carried out in the 14 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, and nutritional status, and reduced drudgery particularly for women. Additionally, IITA serves as the convening center for the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA) and the Systemwide Program on Integrated Pest Management (SP-IPM).

The project logframe is presented in Annex 2.

Highlights from all projects can be found in Annex 3, which thus provides an illustrative overview of IITA's research activities and achievements for the year.

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

Project 5
Improvement of Yam-based Systems

by

K. Amegbeto, R. Asiedu (Project Coordinator), M. Bokanga, K. Cardwell, R.J. Carsky, D. Chikoye, J. d'A. Hughes, V. Manyong, J. Meerman, H. Mignouna, Q. Ng, Y. Ng, S. Nokoe, C. Nolte, H. Shiwachi, G. Tian, P.Vernier, N. Wanyera, S. Soyinka

Project goal

Adoption of improved technologies by farmers, contributing to a sustainable increase in productivity of yam-based systems.

Project purpose

Improved technologies targeted at enhanced productivity of yam-based systems evaluated and disseminated by NARS.

Project rationale

Yams (*Dioscorea* species of family Dioscoreaceae) are diverse in terms of cycles of aerial and underground parts of the plant, geographical distribution, usage, modes of multiplication, and ploidy levels. *Dioscorea rotundata* and *D. cayenensis* account for most of the yam production in Africa where they originated. *D. alata*, of Asian origin, is second in volume of production but has the widest geographic distribution among the food yams.

West and Central Africa account for about 93% of the world's annual yam production of 38 million tonnes. In this subregion the crop contributes more than 200 dietary calories per person each day for millions of people. It is an important source of income for a wide range of smallholders, including women who are especially active in the marketing of yam tubers and products. It also constitutes an integral part of sociocultural life. The dominant yam production zone stretches from Ivory Coast through Ghana, Togo, Benin, Nigeria, Cameroon, Gabon, Central African Republic, and the western part of the Democratic Republic of Congo. Ethiopia and Sudan are the major yam producers in East Africa. Nigeria is by far the leading producer while Ghana is the leading exporter of yams in the world. Yams are also grown in the Caribbean islands and a lot of the yams enter international trade from that region. Brazil leads the production in South America, while Japan accounts for 85% of the production in Asia. Yams are also important in the South Pacific islands, especially in Papua New Guinea. Yams are primarily grown for food and have organoleptic qualities that make them the preferred carbohydrate food wherever they are grown. At harvest, 10 to 30% of the tubers are kept for planting during the next growing season. The remainder is used as food, exported, or lost during storage (5 to 40%).

Increased pressure for land has necessitated an intensification of agriculture. This has resulted in decreasing yields of yams in some areas, due to a lack of essential nutrients or an increase in pest and disease levels in soils under short fallow. Pest and disease pressures, especially from viruses, anthracnose disease, nematodes, and storage pests have been responsible for major losses of food from susceptible varieties in the field and in storage leading to reduced supply to the markets and therefore higher prices. In particular anthracnose disease remains a major threat to the cultivation of *D. alata* in all yam-producing areas.

Nematodes, often interacting with fungal and bacterial pathogens, attack tubers of susceptible varieties in the field and continue their damage during storage leading to loss of food quality and quantity as well as planting materials. The high costs of planting material and of labor also seriously constrain the productivity of yam cultivation.

Technological progress is required to reduce the costs of yam cultivation, expand opportunities for income generation from this heavily traded commodity, enhance sustained high productivity, and exploit more fully the crop's potential to ensure long-term food security in the tropics and subtropics. The development and dissemination of yam varieties with higher and stable yield of tubers with good food and storage qualities will make an important contribution to this. It is also necessary to develop and disseminate strategies for integrated control of pests and diseases in the field and during storage; soil and crop management under intensified cultivation; reduced labor input in yam-based systems; and manipulation of tuber dormancy to increase efficiency in propagation and flexibility in crop cycles, and expanding production in minor producing areas. The yam sector lacks innovative processing technologies that could reduce food losses and create new products with higher added value. Expanded utilization opportunities through processing into various products and improvements in marketing channels would enhance productivity and bring the benefits from the crop to a broader range of consumers.

Development of the capacity of human resources for yam research and development in national programs and the adoption of an end-user approach in the process of technology development would ensure steady progress towards achievement of the project objectives and the sustainability of outcomes. The increasing regionalization of yam research also offers good opportunities for high returns from focused and coordinated research and development efforts.

Outputs

5.1 Farmers' management strategies in yam-based systems and the potential for the acceptance of improved technologies characterized

Background

The indigenous knowledge of yams, a traditional staple, is a valuable asset that needs to be well recorded, analyzed, and utilized for further improvement of the crop. Past studies on yam cultivation and consumption in West and Central Africa (WCA) include those on economics of production and marketing in Cameroon, Côte d'Ivoire, Ghana, and Nigeria. Production practices of yams in the Guinea savanna of Nigeria and Ghana, and many of the principal traditional cultivars of *Dioscorea cayenensis–rotundata* in Benin and Côte d'Ivoire have been described. The postharvest storage of tubers in Côte d'Ivoire and Ghana has also been evaluated. The high costs of planting materials and labor for field operations like land preparation, planting, staking, weeding, and harvesting have been established as dominant production costs. The perception that yams are declining in West Africa where land-use intensity is increasing but expanding where new land is still available or tree cash crops are declining has also been reported. It is important to draw on existing relevant information and establish the current status of the biological and socioeconomic factors that constrain productivity of yam-based production systems, farmers' perceptions

of these constraints, the strategies farmers have adopted for dealing with them over the years, and to identify opportunities for improvement.

Ongoing and future activities

5.1.1 Conduct cost analysis in the domestication of wild yams in West Africa: case studies

by V.M. Manyong, A.V. Houndekon (Universite Nationale du Benin)

Data from two complementary surveys were used to assess the cost of the domestication of wild yams in Benin Republic.

Broad-based survey

The first set of data is from a broad survey in 27 villages of the Nago and Fon ethnic groups of Zou province located in the center of Benin Republic in November 1999. These villages constitute a subset of villages in which farmers still practice the domestication of wild yams, according to a baseline village-level survey by the CIRAD-IITA Yam Research Coordination Unit in that province. A total of 80 domesticators were interviewed. The estimated cost for the domestication of wild yams was based on the activities involved in the domestication process.

The domestication process begins with the identification and collection of wild species that become the seedlings of a first generation. Once identified, the wild yam candidate for the domestication is harvested using such tools like the hand hoe and the machete. Wild tubers are dug up, brought back home, sliced in small pieces, slightly dried off, and wounds are coated with a natural pesticide. Tubers are then stored underground for two to three weeks. The first generation of wild seedlings is ready for planting. These activities occur only once during the process of domestication. The second stage of the domestication process is a classical set of yam production activities, which are seedbed preparation, planting, weed control, and harvesting. Contrary to the first stage, this set of activities is repeated every year until the domestication process is completed. In the farm, wild and cultivated yams are planted in the same field. No special place is reserved for wild yams. However, the area allocated is small and increases over time during the domestication process. The average field size for wild yams of 12 heaps for Year 1 increased by 392% between the first and second years, and 336% between the second and the third years (Figure 1). This change corresponds to an increase from about 0.002 ha to 0.025 ha between Year 1 and Year 3 (on the basis of 6200 heaps per hectare).

In addition to the cost of different activities, the following assumptions were considered: the average duration of three years for the domestication (previous research findings reported a duration of two to six years), harvest from Year 1 is used as seed for Year 2, output from Year 2 becomes seed for Year 3, a life span of three years for the calculation of the depreciation for the equipment, a yearly inflation rate of 3%, and a field size of 6200 heaps/ha. Results are in Table 1. The unit cost of the domestication of wild yam is estimated at Fcfa187 per kg ($0.27 per kg). This amount represents 220% of the market price of the seed yam for cultivated yam varieties in the same area. So it will be economically more profitable to buy planting materials from the existing varieties than from the domestication of wild yams if the cost of production was the only factor involved in that decision.

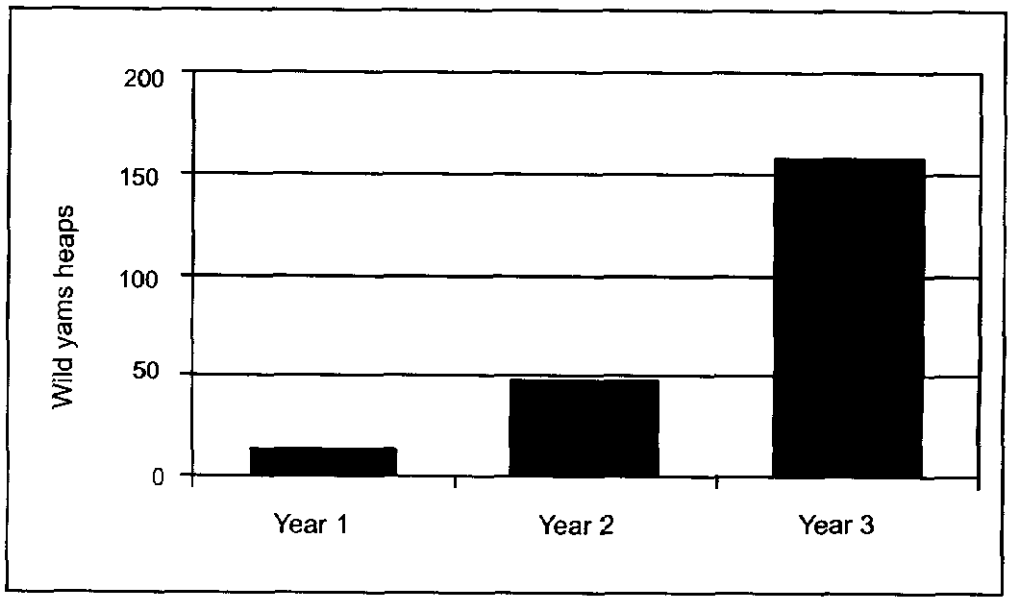

Figure 1. Increases in field size cultivated to wild yams during the domestication process in the Fon and Nago regions of Benin Republic (n = 80).

Intensive survey

A subsample of ten out of the 80 domesticators were selected in the Fon ethnic group (sous-prefecture of Djidja, Zou province) to collect data for a more detailed assessment of the cost of yam domestication. In addition to the usual technique of interviewing farmers, direct observations/measurements were used for data collection. Focus group discussions were conducted on the issues that appear to be common to all the domesticators such as sources of and use of inputs, agricultural calendar for the domestication of yams, the geographic positioning of heaps for wild yams in the field, etc.

The survey questionnaire was developed and pretested and the final version was used for data collection. Data entry has been completed. The analysis is in progress.

Table 1. Cost analysis of yam domestication in the Fon and Nago regions of Benin Republic.

Cost item	Year 1	Year 2	Year 3
1. Labor (Fcfa/ha)			
Seedbed preparation	356 000	366 680	377 680
Weed control	128 000	131 840	128 000
Harvesting	180 000	185 400	185 400
2. Equipment (Fcfa/ha) depreciation	1360	1360	1360
3. Total labor & equipment per ha (Fcfa for 6200 heaps/ha)	665 360	685 321	705 880
4. Number of heaps with wild yams per year per farmer	12	47	158
5.Cost of labor & equipment per heap per year (Fcfa)	107.32	110.54	113.86
6. Cost of wild yam seed per year (Fcfa per farmer)	18 780	20 670	26 641
7. Total cost for wild yam per farmer (Fcfa)	20 067	25 865	44 631
8. Cost per heap of wild yam over 3 years (Fcfa)		282	
9. Cost per ha of wild yam over 3 years (Fcfa/ha)		1 751 343	
10. Production per heap of wild yam over 3 years (kg)		1.5	
11. Yield over 3 years of wild yam (kg/ha)		937	
12. Unit cost of yam domestication over 3 years (Fcfa/kg)		187	

5.1.2 Conduct economic analysis of the yam seed sector

Seed marketing in Nigeria: determinants and constraints

G.N. Asumugha, B.O. Ugwu (National Root Crops Research Institute, Umudike, Nigeria), K.N. Amegbeto, O.C. Aniedu, G.C. Orkwor (National Root Crops Research Institute, Umudike, Nigeria)

Seed yam production and marketing in Nigeria has recently attracted special attention not only in replenishing the stock of planting materials but also as an income generating enterprise for producing households. This study examined the marketing of seed yams by analyzing the determinants of the volume of distribution and identifying major problems encountered by operators. Data were collected from a total of 160 marketing agents randomly selected in both urban and rural markets in Benue, Delta, Enugu, and Nassarawa states. They were analyzed using descriptive statistics and ordinary least square regression techniques.

The period of seed yam trade extends from November to June corresponding respectively to harvest and late planting times. Highest seed prices are observed during the main planting season from March to June, with monthly prices between N10.36 and N25.24 per kilogram. Both males and females are engaged in the seed yam trade. The volume of seed yam traded is determined by literacy level and marketing experience. Limited capital endowment to expand trade, the high cost of transportation, and limited storage facilities constitute major constraints in seed yam marketing in the study area. Provision of low cost and easily accessible sources of credit, and improvements in market access and storage facilities will enhance marketing efficiency and provide incentive to marketing agents.

Seed yam production in Nigeria: factors affecting the adoption of the minisett technique

B.O. Ugwu, G.N. Asumugha (National Root Crops Research Institute, Umudike, Nigeria), K N. Amegbeto, O.C. Aniedu, G.C. Orkwor (National Root Crops Research Institute, Umudike, Nigeria)

Seed yam is a major item in the cost structure of yam production. The minisett technique is seen as a veritable success in yam technology development, which holds good prospects for reducing that cost. This study assessed the techniques used in seed yam production by farmers as well as the determinants of adoption of the minisett technique in Benue and Delta states of Nigeria. A sample of two hundred representative farmers was interviewed using a well-structured questionnaire. Data were analyzed using both descriptive statistics and a probability model of factors affecting farmers' likelihood of adopting the minisett technique in seed yam production.

Farmers in the study area use three types of seed: small whole tubers from "milked" yam, small whole tubers from minisetts, and pieces obtained from sliced ware yam. Relatively few women are engaged in seed yam production. There was no evidence of farmers' specialization in seed production for sale using only the minisett technique. Adopters of the technique aim at satisfying the seed requirement of their own yam production. Availability of external farm labor in addition to family labor, chemical fertilizer, and land to have separate plots for seed and table yam production are positively related to the likelihood of adopting the technique. Its widespread adoption by individual farmers however will depend on the availability and accessibility of inputs, credit facilities, and "superior germplasm" necessary to create substantial demand and develop markets for seed yams. It is expected that the newly released yam varieties will contribute to seed market development in Nigeria.

Economic viability of seed yam multiplication techniques in Togo

M.K. Sedzro, K. Apedoh (Institut Togolais de la Recherche Agronomique, Togo), K.N. Amegbeto

Despite the importance of yams in Togo, relatively few studies have addressed the economics of its production. It is believed that the introduction and commercialization of improved yam varieties to farmers and their commercialization could offset the steady productivity decline observed in recent years. However, the fundamental mechanisms underlying the seed yam subsector and the ensuing economic viability of production techniques are not well understood. The current study aims at conducting a comparative analysis of farm level profitability of seed yam production using traditional or minisett techniques. Preliminary investigations show that no farmer was using the latter technique, therefore, the current analysis is limited to the traditional method. A sample of 60 yam producers were randomly selected and interviewed in three production zones in the Sotouboua district, Central Togo. Seed yam production is achieved mainly through the process of milking, which allows producers to harvest both table yam and seed yam in the approximated proportions of two-thirds and one-third, respectively. Production costs are unevenly distributed among seed (57%) and labor (41%) mainly for mound making and harvesting. The average farm-gate net profit to the producer is estimated at CFA 259,720 francs/ha, corresponding to a CFA 568 francs remuneration per man-day, and a benefit–cost ratio of 1:3. A sensitivity analysis shows that a minimum yield of 10 t/ha is required for the producer to break even.

The fact that users of the minisett technique could not be located despite past dissemination efforts in the country requires further investigations about adoption constraints. Although profitable, labor remuneration with the traditional method is low. Seed yam producers

need to be exposed to other productivity increasing technologies such as chemical fertilizers and pesticides for their adoption in order to increase availability of seeds and reduce the competition between alternative uses of yam tubers.

Characteristics of the seed yam sector in Togo: a study of the Central Region

M.K. Sedzro, K. Apedoh (Institut Togolais de la Recherche Agronomique, Togo), K N. Amegbeto

An organization and performance analysis of seed yam production to commercialization channels is necessary within the context of designing strategies to increase yam production, improve farm income and food security, and alleviate poverty for smallholder farmers. The objective of the current study is to identify the stakeholders involved in the subsector, their roles, and constraints with a view to suggesting measures that would improve their efficiency. Three distinct samples of 50 yam producers, 50 yam traders, and 12 rural and intermediate yam markets were randomly selected in 18 villages in Central Togo, the main yam production area in the country. Preliminary results show that seed production is characterized by a large number of yam varieties (22 identified) grown by farmers, always as the first crop in a rotation but also in association with other crops. Seed yam is jointly produced with table yam and men (98%) dominate production. Production takes place on private and individual farms even though some producers belong to farmers' associations. Farm inputs used are mostly internal, and chemical fertilizers and herbicides are mainly used on grains and legumes such as sorghum, millet, and cowpea. There is a considerable market participation with 32% of farmers interviewed who are specialized in seed production for commercialization, and 41% for both market and own utilization. Seed yam commercialization is conducted by producers and private traders most of whom (98%) are women. According to the practitioners, seed yam trade is informal, but highly profitable. Trade is often limited in space with specialization of traders according to market type because of high costs and other difficulties associated with transportation. The extreme polarization of seed yam production and trade according to gender, which is the same for table yams, requires targeted actions in order to improve incomes and alleviate poverty for the categories of agents involved.

5.1.3 Conduct ex-ante adoption studies of improved varieties

Technology adoption within yam-based production systems: prospects for the diffusion of improved yam varieties in Nigeria

K.N. Amegbeto, V. Manyong, R. Asiedu, O. Coulibaly

Yam production in Nigeria has more than tripled over the past forty years from 6.7 million t/yr over 1961–1970. This increase in output is attributable more to a larger area planted than increased productivity. While the area cultivated to yams is still rising, growth rate in production levels declined tremendously from the average of 27.5% between 1986 and 1990 to 3.5% in the 1996–99 period. Decline in the growth rate of yields is more drastic; it dropped from the 14.9% level in the 1986–90 period to –2.5% in the 1996–99 period. The observed productivity decline in Nigeria, as well as in most West African countries, represents a major challenge to increasing yam production and its availability as food in the subregion. Lack of planting material of improved varieties is believed to be a major source of low productivity. One of the major challenges facing research and extension is not only to document farmers' interests but also to devise a way to identify and target farmers that are willing to adopt improved varieties in the diffusion process.

The objective of this study was to document yam growers' attitudes to existing agricultural technologies, and determine the socioeconomic, demographic, and institutional factors explaining their willingness to adopt improved yam varieties. Results from the current analysis will expand knowledge regarding the acceptability of improved yam varieties in East–Central Nigeria. They will also help extension agents and rural development initiatives to target adopters efficiently when disseminating improved yam varieties.

Study area and sampling technique

The area covered comprised Benue, Ebonyi, Enugu, Eastern Kogi, Nassarawa, and southwestern Taraba states as well as the Federal Capital Territory (FCT) located in the moist savanna agroecological zone of the yam-producing belt in Nigeria. The area is characterized by four major cropping systems with yams as predominant crop: (1) the yam–rice–cassava system, (2) the yam–cassava–soybean system, (3) the yam–soybean–rice system, and (4) the yam–rice–sweetpotato system. Another system with maize as a component of five major crops is adjacent to the study area and penetrates the above systems on the northern and southern boundaries. Interviews were conducted from February to May 2001 in collaboration with the National Root Crops Research Institute and the respective state agricultural development programs (ADPs). A stratified random sampling technique was used to select local government areas, villages, and yam producers within the yam-producing zones in each state. A total of 631 farmers representing the sample units were interviewed using a structured questionnaire.

Empirical data analysis

The underlying concept in the empirical analysis is that yam producers face multiple technologies in their production systems. Adoption decisions are selective but simultaneous and interrelated for crops produced on a single farm. Therefore, in modeling adoption, one needs to use consistent and asymptotically efficient models that account for simultaneity. Restricting analysis to a single crop or technology model would not account for such interdependence and will produce biased and inefficient parameter estimates. In the current study, farmers are assumed to maximize utility derived from a portfolio of crops and of technologies adopted. Underlying utilities derived from these decisions are modeled as a multivariate function. The approach systematically considers all major food crops, namely rice, cassava, soybean, and maize grown along with yams in the production systems. Empirical analysis is carried out on LIMDEP 7.0, which provides a specification for multivariate probit models. As an ex-ante adoption study, inference about prospects of adopting improved yam varieties is drawn from farmers' current attitudes towards available agricultural technologies in the form of fertilizers and improved seed for varieties of the major crops in the production systems.

Results, discussion, and recommendations

The description of variables included in the models is summarized in Table 2. Results from a multivariate probit model of chemical fertilizer application to yam (1) or rice (2), and the use of improved soybean varieties (3) are presented in Table 3. The correlation coefficients are positive and significant at the 1% level between fertilizer application on yams and fertilizer application on rice or the use of improved soybean seed. Therefore, there is an efficiency gain in estimated parameters through the joint multivariate model. For the equation on chemical fertilizer application on yams, the coefficients on gender, education level, family labor, farm size, and outgoing visits of the respondent are significant at the

10% level or less. These coefficients therefore suggest that women are less likely to apply chemical fertilizers to yams, and high seed yam prices discourage fertilizer use. On the other hand, formal education, the importance of family labor, farm size, and the farmer's interest in new technologies would increase the likelihood of fertilizer application to yams. Three variables were important in explaining the adoption of fertilizers on rice: education, contact with extension services, and farmers' interest. Agricultural experience, level of education, size of family labor, and contacts with extension positively and significantly increase the likelihood of adopting improved soybean varieties. Women and commercial yam producers are less likely to adopt soybean varieties.

The second multivariate probit model was estimated for use of chemical fertilizer on maize (1), usage of improved rice variety (2), or cassava variety (3). Results are presented in Table 4. The correlation coefficients are positive and significant at the 1% level between (1) and (3), and (2) and (3), thus validating the joint estimation. For the first equation, education level, family labor, commercial farming, accessibility to markets, and farmer's effort to seek information influence the likelihood of adoption. Factors behind the adoption of improved cassava varieties are age and education of the respondent, number of women in the household, commercial farming, and producer's interest. Women producers and family size reduce the chance of variety adoption.

Table 2. Description of the independent variables.

Variables	Description	Mean	Standard	Frequency (%)	Counts
				0	1
AGE	Age of the respondent (years)	49.13	12.41	–	–
GENDER	Gender of the respondent: 0 = female, 1 = male	–	–	14.9	85.1
EDUCAT	Type of education achieved 0 = informal, 1 = formal	–	–	54.5	45.5
AGRICEXP	Experience in agriculture (years)	27.86	12.24	–	–
YAMEXP	Experience in producing yams (years)	24.37	11.67	–	–
NUMBER OF WOMEN	Number of women in the household	1.52	1.36	–	–
FAMILY LABOR	Number of grown family members who work full time on farms	5.90	4.94	–	–
FAMILY SIZE	Number of persons in the household	11.58	7.74	–	–
FARMTYPE	Market orientation in yam production: 0 = subsistence, 1 = market oriented	–	–	22.5	77.5
FARMSIZE	*Total number of yam mounds planted*	7088	6716	–	–
SEED PRICE	Unit seed yam price in Naira	20.62	11.77	–	–
SEEDSIZE	Size of seed yam used in planting (in grams)	555.25	250.26	–	–
ROADS	Road conditions in the area as assessed by respondent: 0 = bad, 1 = good	–	–	26.7	73.3
IN-VISITS	Number of extension visits received by respondent during the past 2 years	7.74	12.33	–	–
OUT-VISITS	Number of personal visits made by respondent to extension and other institutions during the past 2 years	2.03	3.197	–	–

Globally, estimates from these models show that, among farmers who are interested and willing to adopt improved yam varieties, women have been less likely adopters of previous agricultural technologies as a whole. In areas where the price of seed yam is high, the likelihood of applying chemical fertilizers on yams is limited. Based on competition among crops in the production systems studied, producers with large yam farms have not been much of fertilizer users on maize. Similarly, market-oriented yam producers were less inclined to adopt improved soybean varieties, whereas the opposite attitude is observed towards chemical fertilizer application on maize or adoption of improved cassava varieties.

Table 3. Multivariate Probit estimates of chemical fertilizer application on yams and rice, and the use of improved soybean varieties in East Central Nigeria.

	Dependent variables					
Independent	Chemical fertilizer application on yams		Chemical fertilizer application on rice		Usage of improved soybean variety	
Variables[+]	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	–0.140	0.740	–1.14***	–2.908	–1.088***	–2.749
Age	–0.0011	–0.213	0.0029	0.554	–	–
Agricexp	–	–	–	–	0.013*	1.753
Gender	–0.495**	–2.470	0.0855	0.465	–0.549**	–2.276
Education	0.550***	4.057	0.345***	2.749	0.627***	3.281
Number of women	0.110	0.127	0.0094	0.176	0.110	1.542
Family labor	0.052***	3.254	0.0013	0.122	0.0528***	2.704
Farm size	0.0002*	1.723	–0.000001	–0.063	–0.000005	–0.374
Seed size	–0.0001	–0.489	–	–	–	–
Seed price	–0.0114**	–2.195	–	–	–	–
Farm type	0.079	0.498	0.145	0.958	-0.633***	–3.794
Roads	0.212	1.518	–0.0685	–0.511	0.142	0.774
In-visits	–0.0006	–0.121	0.0145***	2.833	0.0153**	2.309
Out-visits	0.082***	3.574	0.0705***	3.820	0.079	3.496

Notes: Correlation coefficients (t-values); Rho (1,2) = 0.488*** (7.267); Rho (1,3) = 0.310*** (2.799); Rho (2,3) = –0.052 (–.535); Log likelihood function = –850.921; Sample size = 563

Significance level: *** (1%), ** (5%), and * (10%)

[+]See Table 2 for description

This study has identified a set of factors explaining the adoption of agricultural technologies in yam-based production systems by farmers. Based on the results, successful diffusion of newly released yam varieties should be designed carefully in order to reach women producers of yams who have been less likely to adopt existing technologies. Beyond targeting educated and labor endowed farmers, areas with a relatively good road network and reliable extension services, the trials of successful cassava variety dissemination or maize fertilizer diffusion could be followed in introducing improved yam varieties to market-oriented producers. There seems to be high competition between seed yam and fertilizer for working capital. The introduction of improved yam varieties in areas that experience declining soil fertility should be coupled with rapid and cheaper seed yam multiplication techniques or a credit scheme that would allow farmers to afford the use chemical fertilizers for their application on yams.

Table 4. Multivariate Probit estimates of chemical fertilizer application on maize, and improved varieties of rice and cassava in East Central Nigeria.

	Dependent variables					
Independent	Chemical fertilizer application on maize		Usage of improved rice varieties		Usage of improved cassava varieties	
Variables +	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	–1.00 ***	–2.87	–1.26***	–3.02	–3.83***	–7.83
Age	–	–	0.0165**	2.15	0.056***	6.24
Agricexp	–0.0046	–0.882	–	–	–0.025***	–2.831
Gender	–0.256	–1.32	–0.053	–0.27	–0.871***	–3.98
Education	0.411 ***	3.206	0.116	0.875	0.526***	3.279
Number of women	0.090	1.520	0.0427	0.684	0.106*	1.62
Family labor	0.022*	1.625	–	–	–	–
Family size	–	–	–	–	–0.027***	–2.639
Farm size	–0.00002*	–1.77	–	–	–0.0001	–1.018
Farm type	0.446***	2.913	0.064	0.406	0.746***	3.634
Roads	0.269***	2.02	–0.0859	–0.642	0.23	1.45
In-visits	–0.0005	–0.099	0.0099**	1.962	0.0079	1.41
Out-visits	0.0568***	2.802	0.0748***	3.906	0.0556***	2.58

Notes: Correlation coefficients (t-values); Rho (1,2) = 0.0978 (1.289); Rho (1,3) = .271*** (3.169) Rho (2,3) .3375*** (3.977); Log likelihood function = –932.64; Sample size = 565

Significance level: *** (1%), ** (5%), and * (10%).

+See Table 2 for descriptions

Varietal characteristics of yams preferred by farmers in Ghana

K. Marfo (Crop Research Institute, Kumasi, Ghana), K.N. Amegbeto

This study was aimed at identifying the varietal characteristics preferred by farmers, and to determine the relationship between farmer circumstances and varietal choice. A formal survey using a questionnaire designed by IITA with minor revisions to suit local situations was carried out in four districts—Awutu-Efutu-Senya (Central Region) in the coastal savanna–forest transition; as well as Ejura (Ashanti Region), Techiman (Brong Ahafo Region), and Wenchi (Brong Ahafo Region) located in the forest–Guinea savanna transition in Ghana. A total of 125 farmers were interviewed and results provide evidence that most farmers preferred new varieties with the following attributes: white flesh color, early maturing, good marketability, big size and high yielding, cylindrical tuber shape, smooth skin texture, easy to harvest, and not shrinking in storage. One characteristic for which a significant proportion indicated a preference, contrary to what the majority wanted in a new variety, was the number of tubers per mound. As indicated by the scores, growth cycle, marketability, yield, and storability are the most important factors for both *D. alata* and *D. rotundata*. There may be a need to target the small but significant proportion of farmers whose preferences fall outside the most preferred characteristics. Alternatively, research could concentrate on the major preferred characteristics and leave the other varieties to spread through participatory varietal selection and informal seed transfer.

The analysis on the willingness to pay for new varieties provides results on relationships, some of which are unexpected. However, it was observed that visits to extension, where

farmers themselves call on extension staff and show openness to new ideas, is an important characteristic. The more experienced farmers did not express willingness to adopt new varieties. The use of new varieties of other crops does not show a willingness to pay for new yam varieties.

There is a need for further examination of responses on characteristics of farmers' varieties, since different names may refer to the same variety. It would be interesting to determine the extent to which desired characteristics are present in existing varieties and establish real gaps. Where there are varied attribute preferences for a particular characteristic, further analysis is required to find out whether it relates to specific household or farmers' personal characteristics.

Determinants of farmers' willingness to pay for improved seed yam varieties in Benin

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Yams *(Dioscorea* spp.*)* represent a major category of food crop in Benin where *D. rotundata* is the most utilized. Current low yields observed at farm level are partly due to deterioration in varietal performance and proliferation of pests and diseases. There is a real need to introduce improved varieties that are more productive and adapted to the ecologies and socioeconomic environment in major production and consumption centers. The current study aims at identifying factors explaining farmers' willingness to pay for improved *D. rotundata* seeds. Results show that producers are willing to pay as much as 5 to 50% more for seeds of improved varieties compared to local ones. There is stratification among producers with respect to the acceptable price difference between seeds of local and improved varieties of *D. rotundata*. Results from a multinomial logit model show that age, gender, formal education, farm size, distance to wholesale market, and chemical fertilizer application on maize are factors explaining willingness to pay. The implications are that extension could target men and young producers for the diffusion of improved varieties. The level of education could be an additional criterion in areas where cotton is not perceived as the only cash crop. Even though women are not directly involved in yam production, they could benefit from the purchase and adoption of improved varieties by men through increased food availability and tradable surpluses. Being the principal agents in yam trade, women could also increase their revenues that would contribute to poverty reduction.

5.1.4 Assess economic advantages of hot-water therapy for disinfecting seed yams against nematodes in Nigeria

K.N. Amegbeto, V.M. Manyong, O. Coulibaly, R. Asiedu

Nigeria remains by far the world's largest yam producer, accounting for 68.4% of total production (37.82 million tonnes) and 69% of total area cultivated (3.94 million hectares) in 2000. The prevalence of numerous pests and diseases of the crop undermines farm productivity and threatens the availability of such a huge production for food and as a source of income. The pests, especially nematodes, often interact with fungal and bacterial pathogens, under favorable environmental conditions such as temperature and humidity, and are responsible for a lot of damage to yam tubers at the farm level.

Hot-water therapeutic treatment of seed yam before planting has been developed as a means to reduce nematode damage to seed yams. The technology has been introduced to farmers in selected areas in Nigeria since 1997 for testing and validation. However, the manner in which it affects profitability of yam production and storage is not well known.

Neither is documentation available on its soundness for recommendation and wide promotion in nematode infested areas. Furthermore, there is a need to investigate the feasibility of alternative sources of energy for heating since the current practice, based exclusively on firewood may not be sustainable in the long run. The objective of this study was to assess the profitability of the technique, and determine whether it could be recommended for popularization in nematode infested areas. Policy measures that would provide incentive to farmers in considering petroleum gas as an alternative source of energy during treatment are simulated.

Interviews were carried out in January and February 2001 in 13 villages in Oyo North and southern Kwara State where farmer managed trials of the hot-water treatment have been conducted with the support of IITA scientists since 1997. The study area is located in the moist savanna agroecological zone, which is part of the major yam production zone in Nigeria. Data were collected on the input requirements for hot-water treatment using a sample of 19 trial participants. Additional crop budget data were obtained from an earlier IITA study (by V.M. Manyong and others) in which the scientists surveyed 600 yam growers in the northeastern zone adjacent to Oyo North and southern Kwara. Hot-water treatment is currently carried out at farmer level with cooking pots, kitchen appliances, and firewood as source of energy. The profitability of the technique is compared to that of yam production without treatment. Because no farmer was able to acquire and use the improved equipment made of a metallic tank, a burner, and petroleum gas, we do not attempt to evaluate the profitability of that setup. Two scenarios are considered with respect to the level of nematode infestation: (1) a low level of infestation corresponds to 10% preharvest loss as opposed to (2) a high level which corresponds to 40% losses. In addition, selling yams at harvest or storing them for sale later when market prices are relatively high are evaluated to determine the advantages derived from each strategy. A simulation is performed to find policy measures that would achieve break-even net profit levels of treatments using liquefied petroleum gas as an alternative source of energy.

Profitability of hot-water treatment

Economic analysis of the production systems shows that variable costs represent approximately 99% of total cost, making current capital investment in yam production negligible. This may change, however, when the improved equipment for hot-water treatment is adopted. Labor retains the largest share (64 to 66%) while material input costs represent 15 to 17%. Miscellaneous charges that include the opportunity cost of working capital account for 16% (Table 5). Differences in the shares emanate from the fact that less labor is needed to harvest, transport, and store yams when nematode infestation and preharvest losses are high. Yet, extra labor is required for the above operations as well as conducting the hot-water treatment. Material input costs also are increased by the use of firewood during the treatment. Globally, yam production in the study zone is profitable with a benefit–cost ratio between 1.55 and 2.18 depending on the level of nematode infestation, and whether seed yams are treated.

Under a low infestation scenario, the net profit equals N146 087 per hectare when production is valued at harvest. This profit is 1% below the level obtained with hot-water treatment. The benefits generated through seed yam treatment are almost totally absorbed by the costs incurred using extra labor and firewood. In terms of returns to labor, there is no significant difference between treatment and no treatment, the average being N629 and N630 per man-day, respectively. Therefore, where nematode infestation is low and yams

are not stored after harvest, the economic advantages do not provide sufficient incentives for farmers to engage in hot-water treatment. However, hot-water treatment makes a big difference when yam storage is practiced; it generates a N119 353 profit, which is more than twice the profit level of N45 576 achieved without treatment. Similarly, returns to labor more than doubles that of no treatment. Consequently, farmers who store yams for some time before selling should seriously consider the hot-water treatment even if nematode infestation is low.

Under high nematode infestation, treating seed yams before planting is more profitable and generates a net profit of N147 776 per hectare, which is 2.32 times the profit obtained without any treatment against nematodes. Similarly, labor remuneration with treatment is almost twice the level of N346 per man-day achieved without treatment. On the other hand, yam storage is subject to a loss of N65 484 per hectare without treatment. Hot-water treatment makes a difference though by generating a positive return after storage. In many

Table 5. Economic advantages of hot-water treatment of seed in yam production (based on a hectare.

Budget item	No treatment under: High infestation	Low infestation	Hot-water treatment using firewood
Production (kg[a] Storage[b]	**7200**	**10 800**	**12 000**
Losses in storage (kg)	4896	4860	3600
First quality yams (kg)	72	1836	4800
Second quality yams (kg)	2232	4104	3600
Gross income (N): without storage	180 000	270 000	300 000
Gross income (N): with storage	62 400	182 880	288 000
Variable costs (N)	114 802	122 332	150 543
Labor (%)	64.88	63.60	66.53
Material inputs (%)	16.38	17.46	15.31
Transportation (%)	3.06	3.26	2.49
Miscellaneous (%)	15.67	15.67	15.67
Storage related expenses (N)[c]	11 500	13 391	16 423
Fixed costs (N)	1581	1581	1681
Total costs (N): without storage	116 383	123 913	152 224
Total costs (N): with storage	127 884	137 304	168 647
Net profits (N) : without storage	63 617	146 087	147 776
Net profits (N) : with storage	(65 484)	45 576	119 353
Returns to labor (N/man-day)			
No storage	346	730	629
With storage	(339)	213	476
Benefit/cost ratio			
No storage	1.55	2.18	1.97
With storage	0.49	1.33	1.71

[a]Preharvest losses from low germination and death of young plants due to yam nematodes are as high as 40%, according to earlier IITA studies.

[b]Based on weight losses and change in the end use of tubers after two months of storage, as estimated in earlier IITA studies.

[c]Include labor for transportation and barn work, opportunity cost of tying down capital for 2 months, and other related expenses.

cases as shown in the current study, profitability of yam production, as measured by the returns per hectare and per man-day, is higher than otherwise when farmers engage in both production and storage. Reducing losses in storage below the current level of 30%, which are due to factors other than nematodes, would make yam business even more profitable to farmers.

Policy simulations

Firewood and liquefied petroleum gas are substitute inputs for the hot-water treatment of seed yams in agriculture. An increase in labor and/or firewood scarcity will systematically increase the cost of firewood use and naturally encourage a shift toward other sources of energy, namely petroleum gas. Also, relying on firewood alone will not lead to environmental sustainability in the medium-to-long run. As agricultural wages and firewood prices are not policy instruments that could be easily manipulated, it is necessary to determine the required minimum rebate on gas prices that would achieve break-even profits between the two substitute inputs.

Different levels of firewood prices are simulated jointly with hypothetical percentage rebates on petroleum gas price to achieve break-even profits. In the simulations, firewood price is increased by 5 basis points and the corresponding gas price rebate is searched for numerically until break-even profit is obtained. At a given firewood price level, any rebate on petroleum gas price that is higher than the break even level (shown in Table 6) will systematically make substitution economically feasible. Results show that given the current price for firewood, a 51% rebate on gas price would make farmers indifferent regarding the use of either input, other things being equal. On the other hand, firewood prices would have to increase by 45% if rebate on gas price is not a feasible option to achieve the same indifference level. Many combinations of firewood price increase (0 to 45%) and gas price rebates (0 to 51%) achieve economic break-even profits providing enough room for the appropriate policy intervention.

Table 6. Break-even policy options between firewood and liquefied petroleum gas.

Increase in the price of firewood (%)	Break-even net profits (Naira/ha)	Rebate on gas price (%)
0		51
5		45.5
10		34
15		39.5
20	147 776	29.5
25		22.5
30		17
35		12
40		5.5
45		0

Conclusions and recommendations

The preceding analysis shows that firewood treatment of seed yams using kitchen appliances generate higher benefits compared to what is obtained without treatment when nematode infestation is high. Therefore, the technique could be recommended to farmers in such areas. Hot-water treatment reduces losses in storage but could not prevent other sources of loss. Although there are no significant differences in profit levels when yams are sold at harvest with low nematode infestation, farmers who must store yams for some time before selling should seriously consider the hot-water treatment. Otherwise, given the current level of quantity and quality deterioration in storage, the strategy is not advisable to producers in the study zone. This is contrary to the general opinion that farmers will be better off by storing farm products and marketing them when prices are high. The current finding identifies a challenge for further research on yams.

Simulations suggest a wide range of policy options, from 0 to 51% rebate on gas price at various firewood price levels, to achieve break-even profits of inputs. Efforts to promote the technique should seriously consider financial aspects since switching from no treatment to hot-water therapy and specifically, from firewood to liquefied petroleum gas, would incur additional cost. The optimal level of gas price rebate beyond the break-even point that would systematically trigger a voluntary substitution of firewood is an area for further research.

5.1.5 Conduct ex-ante adoption studies on hot-water therapy for disinfesting yam seed tubers

Farmers' perceptions and factors associated with willingness to adopt hot-water therapy for disinfecting seed yams

N.K. Amegbeto, V.M. Manyong, O. Coulibaly, R. Asiedu

Yam plays an important role in providing food and income and is of considerable socio-cultural value to many people in West Africa. Yam is susceptible to pests, diseases, and especially nematodes causing yield loss, rots, and tuber quality reduction in the field and in storage. Infestation of yams by nematodes, especially *Scutellonema bradys* and *Meloidogyne* spp., could suppress sprouting and reduce yields by 40%, or market value by 52%. The damage could also be loss of the edible portion of the tuber by 25% to 100%. Yet damage by nematodes seems widespread given their distribution in Nigeria and jeopardizes farm households' productivity, income, and food availability in many communities.

Among the methods available for reducing nematode infestation, hot-water treatment of seeds before planting has proven to be very effective on-station. The technique is a step towards sustainable yam production as it has the advantage of not leaving residues in the soil or in the tuber, which could be a health risk to consumers and of environmental concern. It was developed and has been tested since 1997 on farmers' fields in selected states in Nigeria for technical validation within existing farming systems. Although farmers have been impressed and shown interest in the treatment, there has not been a comprehensive evaluation of their perception of the technique. The objective of this study was to evaluate farmer participatory trials using the hot-water therapy for disinfesting seed yams, analyze farmers' perceptions, and identify factors explaining their willingness to adopt the technique. The results of this study will help researchers design appropriate, effective, and acceptable technologies to reduce nematode damage in yam production and conservation. They will also help national and nongovernmental extension services to provide appropriate assistance

to farmers towards increasing availability of quality seed and ware yam, higher income, and poverty alleviation in rural areas.

The study covered Oyo North and southern Kwara State located in the moist savanna agro-ecological zone, which is part of the yam belt in Nigeria. Interviews were carried out in 13 villages where farmer-managed trials of the hot-water treatment have been conducted with support from IITA scientists since 1997. Three categories of farmers were targeted during the interviews: (1) farmers actually involved in the hot-water treatment trials, (2) those who have been exposed to group demonstrations of the technology but have not applied it on their fields, and (3) those who have never heard about it. Since the technology is at the stage of on-farm trials without popularization, the current investigation is an ex-ante adoption study in order to document perceptions and its acceptability. Hence all categories of farmers need to be interviewed. In line with recent approaches in agricultural technology adoption studies, socioeconomic, demographic, technical, and perception variables are tested against farmers' expressed willingness to adopt the technique. Given the limited number of trial participants and the sample size, Fischer's Exact Test is used to check for the degree of association between variables.

Adoption of recommended practices

Contrary to improved equipment made of a metallic tank, petroleum gas, and a burner used during village demonstrations, farmers in the study area have found their own adaptation for the technique. None of the participants contacted has been able to duplicate exactly the improved equipment. Farmers' experimentation with the technique is based on firewood and cooking pots. The capacity or size of these pots is rather limited. On average 30 seeds are treated per round whereas the metallic tank used for demonstrations can handle 100 to 150 seeds depending on seed size. While a metallic net was part of the improved equipment, there was no appropriate kitchen tool available to farmers for handling preheated seeds. Also, 43.75% of trial participants treated seed yams for 15 minutes or less, which is below the recommended time of 20 to 25 minutes while 25% treated the seeds longer than the recommended duration. These findings call for emphasis on training farmers and for designing appropriate equipment for handling preheated seed yams. Further investigations are needed to find local materials, such as oil drums or other substitutes, for cooking pots, energy-saving stoves, and seed handling tools.

Farmers' appreciation of treatment effectiveness

Results from the survey show a high level of satisfaction among farmers. Typical nematode symptoms on yam tubers such as cracks, "crazy" roots, galls, necrotic spots, and rots are reduced after treatment as reported by 83 to 94 % of trial participants. A small number of respondents reported better foliage or early cure of cuts on yam tubers as a result of the treatment whereas no one indicated a case of worsening symptoms. The majority of farmers (68% to 83%) also confirmed higher seed germination rates, better plant vigor and quality of yam tubers, and higher market value obtained from planting treated seeds. When nematode infestation is high, it could lead to low germination and even death of young plants, which contributes to lower yields. About 56% of trial participants obtained higher yields following treatments. With respect to the number of ware yams, there is an even split between farmers who observed an improvement (39%) and those who did not observe any difference (44%). Although the positive perceptions are overwhelming, there has not been systematic appropriation of the technique; trial participants have not yet incorporated it

into their farming system. The intensity of use as measured by the percentage of heaps planted with treated seeds is less than 1% on average.

Constraints identified by farmers

Although the method is appreciated by trial participants, factors specific to the technology and socioeconomic environment of farmers constrain its use. An estimated 75% of farmers found the technique not appropriate for their scale of yam production whereas 50% were not satisfied with the bulkiness of the equipment; 44% indicated fear of losing seed yams through heat damage. Similarly, 41% mentioned the cost of acquiring the equipment or insufficient family labor, while 19% lacked income to acquire it. The higher capacity of the metallic tanks would reduce labor requirements by 43%. More training and demonstration of the technique could remove some of the fears while research should seek improvement on the size and bulkiness of the heating tank.

Willingness to adopt hot-water therapy

Test statistics show no significant differences among the three categories of farmers interviewed with respect to their willingness to adopt the technique. Experience in growing yams and number of women in a household are closely associated with willingness to adopt the technology at the 5% and 10% significance levels, respectively (Table 7). This could be explained with the division of labor within households in the study area. Cooking and processing of agricultural produce are carried out mainly by women in Oyo North and Kwara State. Since hot-water treatment is similar to parboiling used in processing yam tubers into chips, a task carried out by women, it is likely that a higher number of women in the household could be an impetus to adopting the technique.

Table 7. Results of Fischer's Exact Test.

Variable	No. of respondents	Class	Significance (*P*-value)
Age	58	4	0.479
Number of women	55	5	0.018
Gender of respondent	58	2	1.000
Family labor	58	3	0.664
Yam growing experience	58	5	0.079
External exposure	58	5	0.146
Education level	58	3	0.376
Category of farmer[a]	58	3	0.126
Farm type[b]	57	2	1.000
Effectiveness index	18	2	0.528
Constraints index	32	2	0.696
Diffusion[c]	58	2	0.270
Size of yam production[d]	58	5	0.887
Number of heaps treated	58	7	0.273

[a]Trial participants, farmers who have been exposed to demonstrations, and those who have never heard about it.

[b]Subsistence or commercial farmers.

[c]Whether information on the technique is passed on to other farmers or not.

[d]Measured by the number of yam heaps grown.

A similar analysis of subsets of farmers with respect to yam production experience showed that those not willing to adopt the technique have an average of 27 years' experience, relatively longer than the 22 years experience of the other subgroup. As one would expect, there is a fairly high correlation (0.74) between farmers' age and experience. Accordingly, younger farmers should be targeted for promotion and trial of the hot-water technique.

Conclusions and recommendations

The fact that trial participants in Oyo North and Kwara State were not using the metallic tank for the hot-water treatment remains the main challenge for further development of the technique. Research efforts should focus on improving the capacity of treatment with local materials, and on designing more efficient heating equipment recommendable to farmers. It is necessary to revise the design of the metallic tank to achieve energy saving, lighter weight, and optimal size that could be easily handled by farmers. Increasing the number of farm-level demonstrations and expanding farmer-managed trials will contribute to a better appreciation and acceptability of the technique by farmers in nematode infested areas.

5.1.6 Economic viability and acceptability of legume fallow for soil fertility maintenance in yam production

A.V. Houndekon (Universite Nationale du Benin), K N. Amegbeto

Yam production is economically and financially viable, generating substantial revenues to producers, and thus contributing to poverty reduction in Benin. Nevertheless, the crop is demanding in soil fertility and producers shift production to virgin or fallowed land on a yearly basis. Improved fallowing techniques based on legume crops developed and tested on farmers' fields in the Zou-Nord region of Benin in 1994 and yam production followed in 1997. The objectives of this study were to (1) evaluate farmers' perception of the technique; (2) identify factors explaining adoption and nonadoption; and (3) evaluate farm-level economic benefits of the technique. A total of 134 farmers including 55 adopters of intercropping yam and *Gliricidia sepium* were selected and interviewed. Results provide evidence that adopters of the technique acknowledge its contribution to soil fertility improvement, reduction of fallow periods, production of stakes, and prevention of soil erosion. Yet, a number of constraints namely competition between yam and *Gliricidia sepium* trees, high labor requirement, and difficulties in the provision and growth of young plants restrict its adoption. Among nonadopters, lack of information regarding the technique and lack of interest are the constraints identified, respectively, with 53% and 20% of farmers. The likelihood of adoption increases with farmer's age and security over farmland. Results from a partial budget analysis show that intercropping yams with *Gliricidia sepium* is economically viable with a marginal rate of return of 705% that is slightly more than double farmers' minimum acceptable rate of return. In view of the high profitability compared to adoption rates, research efforts need to evaluate the technology within the context of whole farm planning where many crops compete for limited resources. Further dissemination efforts should consider seriously and address the constraints identified above.

5.2 Strategies for integrated management of pests and soil fertility in yam-based systems developed

Background

Pests and diseases during growth and postharvest tuber storage have a major influence on productivity of yam cultivation. It is generally acknowledged that most pathological

causes of losses in storage can be attributed to an interplay of nematodes (principally *Scutellonema bradys* and *Meloidogyne* spp.) fungi, and bacteria, moderated by physical factors of the storage environment such as temperature and humidity. It is also widely known that most of these losses originate from preharvest invasion or infection and/or damage during harvest and transit. The practice in many countries of placing yams first in the cropping sequence and avoiding continuous yam cultivation on the same field in West Africa may have as much to do with avoidance of pest and pathogen build-up (nematodes, mealybugs, scales, etc.) as with loss in soil fertility per se. Hence intensification of yam cultivation would benefit immensely from selection and breeding for host-plant resistance to damage caused by prevalent pests in addition to other elements of crop productivity. The success of this research will, however, depend on the development and utilization of efficient and accurate screening methodologies. Modification of cultural practices can also form an important component of integrated control. For example, the utilization of clean planting material can markedly reduce the populations of pests and pathogens in yam-based systems, since yam setts often represent a source of inoculum for viruses, fungi, and nematodes. While tissue culture provides a means for the elimination of viruses and fungi, hot-water treatment (thermotherapy) can significantly reduce populations of nematodes from ware and seed tubers. Strategic and adaptive research is, however, required before these technologies can be recommended to farmers.

The traditional long fallows that characterized yam-based systems have become impossible in many yam-growing areas owing to pressure on the land from increased human population. Alternative strategies that are compatible with the trends in socioeconomic and physical conditions in these areas are important to the sustainability of yam production. As yam-based production systems become more intensified, the management of soil fertility and the control of weeds are becoming more challenging.

Ongoing and future activities

5.2.1 Screen yam germplasm (*D. alata, D. rotundata*) to identify sources of resistance to major field and storage pests (viruses, nematodes, and anthracnose disease)

J.d'A. Hughes, S.A. Soyinka, R. Asiedu, N.Q. Ng - in collaboration with B. Odu, A. Oladiran

The reactions of 24 *Dioscorea rotundata* genotypes to infection by three yam viruses other than *yam mosaic virus* (YMV) genus *Potyvirus* were investigated. None of the *D. rotundata* infected with *Dioscorea alata virus* (DAV) genus *Potyvirus* showed any symptom associated with DAV-infected plants. The implication of this is that infected plants serve as reservoir for the virus thus becoming foci of infection to susceptible *D. alata* genotypes and cowpea cultivars, which are alternate hosts. DAV-latent *D. rotundata* genotypes could also serve as the medium of recombination between DAV and other potyviruses infecting yam especially with YMV. Cucumber mosaic virus (CMV) genus *Cucumovirus* was mechanically and vector transmissible to six out of the 23 *D. rotundata* genotypes inoculated. This shows that there may be a low rate of infection by CMV compared to DAV and *Dioscorea alata bacilliform* virus (DaBV), genus *Badnavirus*, which infected more of the inoculated *D. rotundata* genotypes. *D. rotundata* genotype TDr 1640 showed resistance to DAV, CMV, and DaBV, while TDr 1621 was not infected by CMV and DaBV, but was infected by DAV. These genotypes are recommended as sources of resistance in yam breeding.

Dioscorea mild mottle virus (DMV), genus *?Comovirus* is a new virus, partially characterized, infecting yams in Nigeria. There are two strains of the virus that exhibit slightly different biological properties and are tentatively identified as S95 and S121. Fifty-eight *Dioscorea rotundata* and 26 *D. alata* landraces from the IITA yam germplasm collection were screened and 31 accessions (19 *D. rotundata* and 12 *D. alata*) that expressed virus-like symptoms were tested using triple-antibody sandwich (TAS) and protein-A sandwich (PAS) enzyme-linked immunosorbent assay (ELISA). Ten of the 19 *D. rotundata* were infected with yam mosaic virus (YMV), genus *Potyvirus* while one further accession was infected with *Dioscorea alata* virus (DAV), genus *Potyvirus*. TDr 93-22, TDr 608, TDr 99-3, TDr 99-12, TDr 99-13, TDr 99-14, and TDr 99-15 failed to react with antisera raised against YMV, DAV, CMV, genus *Cucumovirus, Dioscorea alata* virus (DABV), genus *Badnavirus* or DMV (strains S59 and S121). Of the 12 *D. alata* accessions tested, only TDa 95-14 tested negative for these viruses. All the other accessions tested positive for DAV and eight of the accessions were also positive for at least one of YMV, CMV, and DABV.

5.2.2 Conduct vector studies on known yam viruses and characterize new ones

J.d'A. Hughes - in collaboration with L. Dongo, G.I. Atiri, G.G. Adebayo, P. Keese, A. Mackenzie, A. Gibbs, M. Gibbs

Dioscorea mottle virus (DMV), a new virus of yams with three distinct strains (mottle strain, mild strain, and necrotic strain) was found within the major yam-growing areas of Nigeria. The virus with isometric particles measuring between 20 and 28 nm is serologically related to cowpea mottle virus genus *Carmovirus* by enzyme-linked immunosorbent assay (ELISA), oucherlony diffusion tests, and immunosorbent electron microscopy (ISEM). It readily infects members of the *Amaranthaceae* and *Fabaceae* by mechanical transmission. The virus is also seed transmissible. DMV mild chlorotic strain had a seed transmissibility of 97% in *Vigna unguiculata* cv. Tvu 2657. The molecular weight of the coat protein is 18 ± 0.1kd as determined by polyacrylamide gel electrophoresis (PAGE). Further work is needed to fully characterize the virus.

5.2.3 Study nutrient requirements of yams and efficient use of fertilizers in yam-based systems

*Determination of critical nutrient levels in plants and soils for yam (*Dioscorea rotundata *and* D. alata*) in West Africa*

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Index leaf nutrient levels are used to guide fertilizer application in modern agriculture. Therefore an effort is being made to gather data on yam nutrient levels and to link those with yam yield to provide a diagnostic tool for yam plant nutrition in the future. Trials were initiated by NARS collaborators in Benin, Côte d'Ivoire, Ghana, Nigeria, and Togo to study response to fertilizer with support of the IFAD yam project. These trials are being used to develop the database of nutrient contents in index leaves of yam (youngest fully expanded leaves at peak vegetative biomass stage). A sampling and analysis protocol for index leaves was developed by email communication between resource persons.

Index leaves from trials conducted in 2000 were analyzed for N, P, K, Ca, and Mg. Nutrient concentrations in index leaves were variable and depended on site (climate and soil),

fertilizer treatment, yam variety, and sampling technique (Table 8). Corresponding yield data were received from all countries. Substantial responses to fertilizer were observed at six out of eight sites (Table 9). Fertilizer responses are necessary to use the data for estimation of critical levels. Yields in trials conducted in Nigeria and Togo in 2000 were too low to show responses to fertilizer.

For the sites at which a fertilizer response was observed, there was rarely a clear connection with any one nutrient (Table 10). This is in part due to the confounding effect of several nutrients being applied simultaneously. After the 2000 season, most of the countries agreed to include some treatments in which N, P, or K are withheld compared to a full N-P-K treatment. This will help to isolate the effect of individual nutrients and improve our ability to

Table 8. Range of nutrient contents (%) in index leaves of yam in 2000.

Country	Site (varieties)	N	P	K
Nigeria	Umudike(3)	2.5–3.7	0.11–0.36	0.3–0.8
Benin	Ina(2)	3.4–5.2	0.18–0.54	1.2–3.7
Togo	Sotouboua(1)	1.6–3.8	0.31–0.55	3.1–6.0
Ghana	Atebubu(2)	2.9–3.9	0.36–0.55	3.2–4.6
Ghana	Ejura(2)	2.6–3.6	0.29–0.49	3.0–4.9
Ghana	Kwadoso(2)	3.2–3.7	0.27–0.52	3.6–5.1
Côte d'Ivoire	Bringakro(4)	2.2–5.0	0.27–0.56	2.3–4.8
Côte d'Ivoire	Dikodougou(4)	2.3–4.9	0.24–0.50	2.5–4.9

Table 9. Summary of nutrient responses in IFAD (yam) supported fertilizer trials in 2000.

Country	Site (varieties)	Factors (levels)	Overall mean	Responses
Nigeria	Umudike(3)	N(3) × K(4)	4.87	All non sig.
Benin	Ina(2)	NPK(3) ×K(2)	16.6 (10.9)	Sig. (0.064)
Togo	Sotouboua(1)	N(3) × P(3) M K(3)	2.9	All non. sig.
Ghana	Atebubu(2)	NPK(6)	17.8	Sig. (0.0001)
Ghana	Ejura(2)	NPK(6)	22.3	Sig. (0.0028)
Ghana	Kwadaso(2)	NPK(6)	21.6	Sig. (0.052)
Côte d'Ivoire	Bringakro(4)	NPK(3)	11.0	Sig. (0.0051)
Côte d'Ivoire	Dikodougou(4)	NPK(3)	11.4	Sig. (0.0007)

Table 10. Summary of preliminary analysis of critical nutrient levels in yam.

Country	Relationship between yield and nutrients	Possible cause
Nigeria	None	Limited response, no unamended treatment
Benin, Côte d'Ivoire, Ghana (P & K)	No clear responses	At or above critical level for N, P, and K
Togo	None	Response limited by causes other than nutrient supply
Ghana (N)	Positive response for Dente and negative response for Puna	Possibly below critical level for Dente and above critical level for N in Puna

estimate critical levels. For the trials conducted in 2001, index leaves have been collected and we are awaiting yield data before submitting index leaf samples for analysis.

5.3 Development and dissemination of improved yam genotypes

Background

Genetic improvement of yams at IITA focuses on Guinea (*Dioscorea rotundata* and *D. cayenensis*) and water (*D. alata*) yams. Guinea yams are indigenous to West Africa. They are the most preferred yams and also those with the highest market value owing to the organoleptic properties of their tubers that suit the most prevalent food use for the crop in the region. *D. alata*, introduced to Africa from Asia during the 16th century, is next in terms of volume of production and extent of utilization to the Guinea yams but it is the most widely distributed *Dioscorea* species in the world.

Primary geographical focus of IITA's yam improvement work is on the dominant yam-production zones of coastal West and Central Africa (WCA). It is however recognized that yam cultivation has continued outside those zones in many countries of Africa, often as a minor component of the farming systems. Annual and perennial wild/semidomesticated *Dioscorea* species continue to serve as important reservoirs of food in Africa during periods of food shortage. Yams bring a lot of flexibility to the annual cycle of food availability in many areas through the multiplicity of cultivars, agroecological adaptation, maturity periods, as well as options for storage and utilization. Moreover the crop has high commercial value that can be exploited for alleviation of poverty. It is important to understand the minor, but significant, role that the crop plays outside the main production belt in WCA and explore opportunities for expansion of production and utilization of the crop, where relevant, with the aims of enhancing food security and income generation for farmers and consumers.

The objectives for yam improvement at IITA include high yield of dry matter per unit area and unit time; resistance to diseases (e.g., anthracnose, viruses, tuber rots) and pests (e.g., nematodes, beetles); and tuber characteristics that are valued by consumers (e.g., size, shape, culinary quality, and shelf life). Farmers have been relying on natural genetic variation for their selection of suitable yam cultivars to cope with the deteriorating resource base in the major yam producing areas. The pace of this is not compatible with the increasing challenges in the physical and socioeconomic environment. Farmer-participatory testing, which combines farmers' indigenous knowledge and long experience with the expertise of breeders, is one of the approaches being used for the selection of new cultivars that are more suited to the current challenges as well as opportunities.

Planting materials for production of ware yams (large tubers for market or home consumption) are derived from the edible portion, the tuber, which is expensive and bulky to transport. Farmers often use small tubers from the previous harvest or cut portions of large tubers as planting materials. For early maturing varieties of *D. rotundata*, harvesting of tubers about two thirds into the growing season without destroying the root system ("milking") provides early yams for home consumption and market. This also allows the regeneration of fresh small tubers from the corm at the base of the vine. These small tubers are harvested at the end of the season and used as planting materials for the next season. The multiplication ratio for seed yam production in the field is very low (less than 1:10) compared, for instance, to some cereals (1:300). The technique of rapid multiplication using small tuber pieces (e.g., 25 g weight, called a minisett) in field nurseries has been developed and used for acceleration of the multiplication process. Meristem culture and

micropropagation in vitro offer even higher multiplication rates and healthier propagules. For bulbiferous cultivars of *D. alata* there is another option for propagation through the bulbils, while the use of botanic seeds and vine cuttings require more research effort to become viable alternatives in the future.

The yam tuber remains dormant during the unfavorable agroclimatic period between one harvest and the next planting season. This relatively long tuber dormancy ensures longer shelf life of the fresh tuber than in other root and tuber crops. The tuber dormancy also permits flexibility in harvesting period and in-ground storage with the consequent benefits to labor utilization. In traditional farming in West Africa it is quite common to plant yams immediately after harvest thus obviating the need for storage of seed yams in a barn. The tuber sprouts after a dormancy period of two to four months. However, the long tuber dormancy in yams poses a powerful restriction to efforts at increasing the number of crop cycles in a year.

Ongoing and future activities

5.3.1 Develop broad-based populations for improved performance of yams in the moist savanna of West Africa

R. Asiedu

A total of 4237 flowers of *D. alata* were individually pollinated at Ibadan. This involved eight female and four male parents. Fruit set ranged from 0 to 100% while seed set ranged from 0 to 54%. Seeds were also collected from open-pollinated flowers of 24 females. A total of 19 456 seeds were thus generated for sowing in year 2002. In *D. rotundata*, hand pollination involved seven female and ten male parents. A total of 6685 flowers were individually pollinated. Fruit set ranged from 0 to 60% while seed set ranged from 0 to 81%. Seeds were also collected from open-pollinated flowers of 11 females and a total of 5713 seed were obtained for sowing in year 2002.

A total of 1490 seedlings of *D. alata* representing seven full sib and 20 half-sib families were evaluated at Ibadan for reaction to pest and diseases. Seedlings showing extreme susceptibility to anthracnose disease were rejected. The tuber shape was also considered in selecting the tubers for clonal evaluation in 2002. In the *D. rotundata* nursery, a total of 1168 seedlings, made up of 21 full sib and 19 half-sib families were also evaluated.

Breeding lines of *D. alata* and *D. rotundata* were evaluated in comparison with local check cultivars in preliminary, advanced, and uniform yield trials at Ibadan (forest/savanna transition zone), Ikenne (forest zone), and Ubiaja and Abuja (southern Guinea savanna). Selections were made on the basis of tuber yield; reaction to viruses, anthracnose (leaf scorch) disease, leaf spot, leaf blight, and nematodes; and tuber quality (dry matter content, culinary attributes). In preliminary yield trials of the 1996, 1997, and 1998 series of *D. rotundata*, the top test lines yielded at least twice as much as the check cultivars. For instance, test clones TDr 98/01737, TDr 98/00328, and TDr 98/01946 yielded from 26.41, 20.94, and 20.45 t/ha, respectively, compared to local cultivar TDr 93-31 (8 t/ha) at Ibadan under trial conditions of no fertilizer and no staking and with planting sett size of

300 g. Similarly, test clones TDr 96/02445 and TDr 97/00793 yielded 17.38 and 27.33 t/ha, respectively, compared to the local cultivar (TDr 93-31) yield of 8.44 t/ha.

5.3.2 Produce virus-tested propagules of yams for international distribution

S.Y. Ng, J.d'A. Hughes - in collaboration with Nigerian Plant Quarantine Service

A total of 111 yam samples were submitted for virus indexing as part of the production of virus-tested plantlets or for quarantine purposes for import of germplasm. Out of the 111 samples, 25 tested positive for YMV, 13 for CMV, 14 for DABV, and 15 for DAV. Only CMV and DABV were found in samples from Sierra Leone whereas YMV, which is considered the most prevalent virus infecting yams in West Africa, was not detected.

Pathogen elimination

S.Y.C. Ng - in collaboration with N.Q. Ng, R. Asiedu, J. d'Hughes, M. Ayodele, Nigerian Plant Quarantine Service

Tubers of 20 genotypes of the species were planted in soil in screenhouses for pathogen elimination through meristem culture. Tubers of all genotypes of *D. alata* except one sprouted and meristems were dissected and cultured. Apical and axillary buds were collected from the sprouted genotypes as from six weeks after sprouting for two to three times at monthly intervals. The buds were treated with surface disinfectants (ethanol and clorox) and meristems with 1–2 leaf primordia were dissected, excised, and placed on an appropriate culture medium. Cultures were incubated in a culture room with a 12-hour photoperiod and temperature of 27–30 °C. Approximately 40 to 60 meristems were cultured for each genotype. Meristems from seven genotypes formed plantlets and those of ten genotypes showed green growth. Those that had formed plantlets are either in the process of initial multiplication or of being transplanted and established in an isolation room for virus indexing (Table 11).

During 2001, 32 plants of 15 yam genotypes derived from meristem culture were successfully established in pots in the isolation room. Virus indexing and certification were carried out on these plants based on visual symptom observation, mechanical inoculation to *Nicotiana benthamiana*, and enzyme-linked immunosorbent assay (ELISA). Out of the 15 genotypes, plants of 11 genotypes tested negative for all known viruses affecting yams in Nigeria and were certified by the Nigerian Plant Quarantine Service. These included Muchumudu (a local variety from Ghana), nine *D. rotundata*, and two *D. alata* genotypes from IITA selections.

Micropropagation of in vitro plantlets

S.Y.C. Ng - in collaboration with N.Q. Ng

More than 35 000 in vitro plantlets were produced during the year. Materials included for mass propagation were twenty selected genotypes, which will be used for the 2002 minituber production and three genotypes targeted for East Africa. A large proportion of these plantlets was transplanted to humidity chambers and further transplanted to protected screenhouses for minituber production under the IFAD and the USAID-OFDA supported projects. Some were delivered to collaborators upon request or used as stock cultures in preparation for the 2002 planting season.

Table 11. Status of *Dioscorea alata* genotypes from IITA subjected to meristem culture for pathogen elimination.

Genotype	No. M.C.	Dev. M.C.	Status
TDa 95/00197	65	Plantlets regenerated	I.M.
TDa 95/00010*	–	–	–
TDa 98/00167	60	Plantlets regenerated	I.M.
TDa 98/01168	65	No growth	–
TDa 98/01184	60	Plantlets regenerated	I.M.
TDa 98/01191	40	Green growth	–
TDa 98/01183	40	Plantlets regenerated	Transplanted
TDa 98/01187	45	Plantlets regenerated	I.M.
TDa 98/01169	65	Plantlets regenerated	I.M.
TDa 98/01177	45	Green growth	–
TDa 98/01176	45	Green growth	–
TDa 98/00562	40	Green growth	–
TDa 98/01170	60	Green growth	–
TDa 98/01186	50	Green growth	–
TDa 98/01166	45	Green growth	–
TDa 98/01181	45	Green growth	–
TDa 98/01174	45	Plantlets regenerated	Transplanted
TDa 98/01190	40	Green growth	–
TDa 98/00591	50	Green growth	–

No. M.C. = Number of meristems cultured

Dev. M.C. = Developmental stages of meristem cultures

I.M. = Initial multiplication

* = Tubers did not sprout

Production of minitubers

S.Y.C Ng - in collaboration with N.Q. Ng, M. Ayodele, Nigerian Plant Quarantine Service

More than 22 000 in vitro plantlets of 63 genotypes were transplanted to humidity chambers for acclimatization. Percentage survival after acclimatization in the humidity chambers ranged from 0 to 97% among the genotypes. Overall average percentage survival for all genotypes was 53.4%. Percentage survival of 15 out of 63 was between 10 and 30% (Table 12). Such low percentage survival at the postflask management stage is very unusual. This could be due to the use of cultures (plantlets) that were poor in growth, poor handling of the plantlets during and after transplanting to humidity chambers, and/or poor management of the plants after the humidity chambers were opened. The surviving plantlets were transplanted to sterile/treated soil in protected screenhouses for minituber production. About 80% of the surviving plants were successfully established in soil (over 9500 plants). The percentage establishment ranged from 0 to 100% with 18 genotypes having establishment of 90% and above and 18 having establishment below 10% (Table 12). The poor establishment in some of the genotypes was due to the attack by caterpillars and late transplanting in one of the screenhouses. Minitubers will be harvested early in 2002.

Table 12. Distribution of yam genotypes based on the percentage survival in humidity chamber and percentage establishment in a screenhouse of tissue culture plantlets.

Percentage survival/ establishment	No. of genotypes	
	Humidity chamber	Soil in screenhouse
≥ 90	6	18
80–89	7	9
70–79	8	5
60–69	8	2
50–59	8	0
30–49	9	8
10–29	15	3
< 10	2	18

Minitubers were harvested at the beginning of 2001 from the plants planted in protected screenhouses in 2000 either in sterile mixtures of soil and coco-peat in pots or in ridges of treated soil. More than 12 600 minitubers of 52 genotypes, weighing a total of more than 12.6 kg, were harvested from the screenhouses. The average tuber weight per tuber ranged from as low as 3 g to above 60 g depending on the genotype with an overall average of 10.6 g per tuber. Minitubers were washed in tap water and then soaked in a mild solution of Clorox for 30 minutes. They were then air-dried overnight, packed in bags, and stored. They were later inspected for defects and the accepted ones were certified for distribution.

We reported in the year 2000 that over 10 000 plants of 13 yam genotypes were transplanted to seedbeds in the field for minituber production under the USAID-Nigeria project. The plants, after acclimatization in humidity chambers in August/September, were transplanted to seedbeds in the field from September to October 2000. Bamboo poles were erected and spreading shade-cloth over the bamboo poles shaded the plants. This provided about 50% shading. Overhead sprinkling or manual watering was provided once-a-week. Seedbeds were mulched with dried grasses. Minitubers were harvested in March and April 2001. A total of 6209 minitubers weighing more than 145 kg was harvested (Table 13). Average weight of minitubers varied depending on the genotypes. It ranged from 1.4 g to 56.3 g with an overall average of 23.4 g per tuber. This showed that, with appropriate management, minitubers could be produced on a large scale from in vitro plantlets in the field even during off-season.

It was observed that, for the same genotypes, tubers produced in seedbeds in the field were larger than those planted in protected screenhouse either on ridges or in pots (Table 14). In some cases, tubers harvested from the field were six to eight times larger. The lower tuber weight of the tubers harvested from plants established in sterile/treated soil in the screenhouses could be due to the lower light intensity, planting density, and absence of mycorrhizal association.

Table 13. Number and weight of *Dioscorea rotundata* minitubers produced on seedbeds under field conditions (2000/2001 planting).

Genotype	No. minitubers harvested	Tuber weight (kg)
TDr 131	57	0.50
TDr 179	625	15.26
TDr 205	66	3.19
TDr 608	361	5.52
TDr 93-2	404	4.66
TDr 93-23	252	1.75
TDr 93-31	1183	1.75
TDr 93-69	359	5.20
TDr 93-83	1236	69.53
TDr 93-89	227	5.88
TDr 98-138	297	2.65
TDr 84/00625	569	18.68
TDr 89/02526	573	10.82
Total	6209	145.39

Table 14. Comparison of weight of minitubers of *Dioscorea rotundata* produced in a screenhouse and in the field.

	Mean Tuber weight (g)	
Genotype	Screenhouse	Field
TDr 131	11.0	8.8
TDr 179	8.3	24.4
TDr 205	7.4	48.3
TDr 608	9.7	15.3
TDr 84/00625	20.6	32.8
TDr 93-2	9.8	11.5
TDr 93-69	8.9	14.5
TDr 93-83	11.8	56.3
TDr 93-89	3.0	25.9
Average	10.1	26.4

Exchange germplasm with collaborators and obtain feedback

S.Y. Ng

More than 1300 in vitro yam plantlets in ten consignments were distributed to collaborators in five countries throughout the world. These included Canada, Germany, Ghana, Japan, and United Kingdom (Table 15). The materials were mainly used for studies on tuber dormancy, development of plant regeneration and transformation systems, and methods for nematode screening. More than 7000 of the yam minitubers harvested from the screenhouses and certified were delivered to NARS in Sierra Leone and Togo (Table 15). Minitubers (6209) harvested from the seedbeds in the field were delivered to the National Root Crop Research Institute, Umudike, Nigeria for further multiplication under the USAID-Nigeria project.

Table 15. Distribution of virus-tested in vitro yam plantlets and minitubers during 2001.

	In vitro plantlet		Minituber	
Country	No. genotypes	No. plantlets	No. genotypes	No. minituber
Canada	10	40	–	–
Germany	19	1.9	–	–
Ghana	5	50	–	–
Japan	4	40	–	–
Nigeria	–	–	13	6209
Sierra Leone	–	–	30	4044
Togo	–	–	2	2958
United Kingdom	1	1078	–	–
Total		1317		13 211

5.3.6 Conduct regional varietal trials with NARS

Three IITA-derived genotypes of *Dioscorea rotundata* (TDr 89/02461, TDr 89/02565, and TDr 89/02677) were formally released as new varieties in April by the National Root Crops Research Institute (NRCRI). This is the first such release of new yam varieties in the country and in Africa.

Populations of *Dioscorea rotundata* developed for high yield and pest resistance formed the basis for identification of superior new clones by partners in the seven major yam producing countries of West Africa (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Nigeria, and Togo). These trials were characterized by active participation of resource-limited smallholder farmers at whom the improved varieties are targeted. New clones, superior in yield and pest resistance to popular local yam varieties, were identified among the introductions in each of these countries.

Fifty-two new clones of *D. rotundata* were provided for farmer-participatory evaluation in six states of Nigeria and a set of twelve leading clones were delivered to partners in each of the seven key countries for a regional collaborative trial. New clones of *D. alata*, selected for high tuber yield and food quality as well as anthracnose resistance, were also delivered to, and evaluated on-station with partners in Nigeria (18 clones) and Côte d'Ivoire (36 clones). Selections from earlier introductions are under on-farm evaluation with farmers in Côte d'Ivoire.

5.3.7 Study the inheritance of resistance to YMV in *D. rotundata*

B. Odu, R. Asiedu, J.d'A. Hughes, N.Q. Ng

Controlled crosses were made between male and female parents (total of 11) selected from the *D. rotundata* landraces evaluated in multisite and screenhouse trials. A total of 1688 plants (F_1 progenies) derived from the controlled crosses were artificially inoculated with YMV in the screenhouse for the study of inheritance of resistance to the virus. Classification of plants in the segregating families into susceptible or resistant genotypes was possible due to the presence of symptoms and also to the reliability of triple antibody sandwich enzyme-linked immunosorbent assay (TAS-ELISA) for the detection of YMV in infected symptomless F_1 plants. Genetic analysis of resistance to YMV in the *D. rotundata* genotypes suggests control by two dominant genes.

5.3.8 Develop methods for the control of flowering in yams and for artificial sprout induction in dormant yam tubers

H. Shiwachi, R. Asiedu - in collaboration with I.A. Acha, M. Akoroda (University of Ibadan, Ibadan, Nigeria)

Rapid propagation techniques

The effects of IBA [4-(3-indolyl) butyric acid] and gibberellin inhibitors on the development of bulbils on and establishment of vine cuttings from *D. rotundata* varieties TDr 131, TDr 93-31, TDr 99-12, TDr 93-49, TDr 335, TDr 99-21, TDr 1975, TDr 3598, TDr 1640, and TDr 99-9 were investigated from April to October 2001.

Vine cutting

Leafy vine cuttings with 4–6 nodes and about 20 cm long were cut from plants on 27 July. The epidermis of each node was peeled with a razor blade and IBA was applied on the pealed surface area. The treated vine cuttings were then planted in boxes filled with coco-peat (shredded coir) in a slanted position. Boxes were covered with a plastic sheet, and the whole area of the experiment was further covered with shade cloth. Six cuttings were planted in each box, and this was replicated four times.

Four weeks after planting of vine cuttings, TDr 99-21 had the highest percentage rooting of 66% while TDr 1975 and TDr 3598 had low values of 30% and 27%, respectively.

Layering of plants

Application of IBA to nodes of lateral branches, which were then covered with soil, led to root formation on seven out of ten accessions of *D. rotundata* five weeks from layering. TDr 335 had the highest percentage (30%) of rooting while TDr 1640, TDr 1975, and TDr 3598 did not form roots.

Obstruction of photosynthesis products

Incisions were made on the vines of *D. rotundata* accessions in an effort to induce bulbil formation through interruption of the flow of photosynthate. Half of the diameters of vines were cut off with the razor blade in a wedge shape at a height of 10–15 cm from the ground on 12–13 July. No bulbils were formed.

Induction of bulbils by inhibitors of gibberellins

Foliage of *D. rotundata* accessions was sprayed with 20 ppm of uniconazole-P (UP) or 50 ppm of prohexadione-calcium (PC) on 16 August. No bulbils were observed.

Introduction of carbonized rice husk for presprouting nursery on minisetts

Members of *D. rotundata* varietal group Kponan are known for poor sprouting ability. Carbonized rice husk was used as a medium for presprouting minisetts from a popular member of the group, cultivar Puna from Ghana, in comparison with shredded coir. One hundred and eighty minisetts were buried in each of the two media and moisture was added as required. No minisett germinated in the shredded coir whereas 61% of them sprouted in the carbonized rice husk.

Artificial sprout induction in dormant yam tubers

The effects of two gibberellin inhibitors, uniconazole-P (UP) and prohexadione-calcium (PC), on the dormancy of yam tubers were investigated under different storage conditions. The tubers were harvested before full senescence of the plants and treated with UP. Tuber dormancy was shortened in TDa 99/00049 by 56 days compared to the control in response to uniconazole-P (UP) and tuber storage at 30 °C, but not in TDr 131. Variable responses were shown when UP and PC were applied to tubers of seven varieties of yam at four weeks after harvest. The results suggest that the effects of UP and PC vary with the depth or intensity of dormancy in yam varieties.

Effect of day length on flower bud emergence in D. rotundata *and* D. alata

The effects of day length on the development of flower bud in TDr 89/02665, TDr 95/01924, TDa 87/01091, and TDa 95/00328 were investigated from April to October 2001. Fifty-day-old plants were exposed to ten-hour day lengths (short days) for 15 days from 24 May, fourteen-hour day lengths (long days) for 30 days, and moved out to natural day length conditions.

Short-day treatment delayed flower bud emergence in TDr 89/02665 and TDr 95/01924. Flower bud emergence with long-day treatment was earlier than the control in TDr 95/01924, but not in TDr 89/02665. TDa 87/01091, and TDa 95/00328 did not flower.

Induction of flowering by vine grafting in D. alata

Grafting was performed between the flowering accessions TDa 92-2, TDa 93-36, TDa 85/00250, TDa 87/01091, TDa 95/00328, TDa 95/01176, and TDa 98/01166 and nonflowering accessions TDa 95-23, TDa 95-75, and TDa 95-102. The flowering accessions were used as rootstock and nonflowering ones as scion. About 50% of the grafted plants survived to flowering time after grafting. However, no flowering was observed in nonflowering accessions. Control plants also did not flower and the experiment will be repeated and expanded to include wild *Dioscorea* species that flower profusely.

5.3.9 Improve in vitro tuberization in yams

S.Y.C. Ng N.Q. Ng - in collaboration with H. Schiwachi, I. Fawole, M. Balogun (University of Ibadan, Ibadan, Nigeria)

Studies carried out in 2000 indicated that microtubers could be formed from cultures of nodal cuttings made from in vitro plantlets of both *D. rotundata* and *D. alata* in medium containing α-naphtalene acetic acid (NAA) and incubated under complete darkness. Though this culture system has potential the percentage tuberization was very low and erratic. Systematic studies are planned to improve the production system and study dormancy of the microtubers.

Two yam genotypes from each of *D. alata* and *D. rotundata* were selected from the germplasm collection based on our previous studies on their response to microtuberization. These were TDr 608, TDr 93-23, (*D. rotundata*) TDa 297, and TDa 92-2 (*D. alata*). TDr 608 and TDa 297 were most responsive to microtuberization while TDr 93-23 and TDa 92-2 were intermediate. Yam tubers of these four genotypes were planted in pots in a screenhouse. At ten-node stage, the 1st to 8th nodes from the apex were collected, surface disinfected, and cultured in Murashige and Skoog basal medium supplemented with 60 g/l sucrose, 1mg/l NAA, and 8 g/l agar. Cultures were incubated in the dark. At four months after culturing,

data on number of nodes and tubers per plantlet, stage of tuber development, and position of tuber relative to the medium were recorded. At six months after culturing tubers were harvested, and the weight of tubers per plantlet was recorded.

Results obtained at four months after culturing showed that there were no significant differences in position of microtubers among the four genotypes studied. However there were significant differences among genotypes in the developmental stages of the microtubers. TDa 92-2 had predominantly (80.2%) well recognizable primary nodal complex with obvious tuber initials. This was followed by TDa 297, TDr 608, and TDr 93-23 with values of 57.3%, 40.6%, and 28.2%, respectively. Though TDr 608 had low percentage nodal cuttings with well recognizable primary nodal complex, 9.4% of the explants produced well-developed microtubers at this stage. Nevertheless at harvest (6 months after culturing) the other three genotypes also had visible tubers produced. Hence, TDr 608 was more responsive to the culture medium and produced microtubers earlier whereas the other three genotypes were slower in response and microtubers formed at a later stage of plant growth. The early formation of well-developed microtubers in TDr 608 might be related to early bulking in the field as compared to the other genotypes tested.

The number of tubers per plantlet ranged from 1 to 3, and was significantly different among genotypes. TDr 608 had the highest mean value (1.53), followed by TDa 297 (1.50), TDa 92-2 (1.35), and TDr 93-23 (0.83). TDa 92-2 and TDr 608 had the highest mean tuber weight per plantlet, followed by TDa 297 and TDr 93-23. The above results indicate that the tuber induction medium could be further improved and that culture conditions should be examined to promote multiple tuber formation and increase the frequency of tuberization.

5.3.10 Develop regeneration and transformation systems for yams

S.Y.C. Ng - in collaboration with S.H. Mantell, S. Kohalmi

Induction of embryogenic callus

Nine yam genotypes (five of *D. alata* and four of *D. rotundata*) were screened for their ability to undergo somatic embryogenesis. Active growing root segments of 1 cm length (1 mm root-tip was cut off) were obtained from three-week-old yam cultures. Root segments were cultured in callus induction medium developed for *Arabidopsis*. The medium used was Murashige and Skoog basal medium supplemented with 3% sucrose, 0.5 mg/l 2,4 dichlorophenoxyacetic acid (2,4-D), 2 mg/l indole acetic acid (IAA), 0.5 mg/l 6-(γ,γ-dimethylallylamino)-purine riboside (IPAR), and 0.8% agar. Cultures were incubated in the dark. Embryogenic calli were obtained from one *D. alata* genotype, TDa 289, at a frequency of 50% and none from *D. rotundata*.

Studies were conducted to investigate the effects of 4-amino-3, 5,6-trichloropicolinic acid (picloram) at two concentrations (4 mg/l and 8 mg/l) on three types of explants, young leaves, meristems with leaf primordia, and root segments in terms of callus formation and somatic embryogenesis. In these studies, *D. alata* genotype TDa 289 and *D. rotundata* genotype TDr 93-69 were used. Single node cuttings from in vitro plantlets were cultured in yam multiplication medium for three weeks. The young leaves, meristems with leaf primordia, and root segments were dissected from the plantlets and inoculated in the induction media. Murashige and Skoog basal medium with 2% sucrose and 0.7% agar was used and two levels (4 and 8 mg/l) of picloram were added after the medium was sterilized. Each medium and explant treatment was replicated thrice. Each replicate had 2–6 pieces of explant depending on the availability of plant materials. Cultures were incubated in the

dark at 30 °C. Cultures were observed weekly and data were recorded. Callus was induced in both media with all the three types of explants in both genotypes. A hundred per cent callus induction were obtained with young leaf and meristems with leaf primordia in both culture media. However only 37.3% and 17.8% of root segment explants formed callus in medium containing 4 mg/l and 8 mg/l picloram, respectively in TDa 289 and 17% and 6% in TDr 93-69, respectively. At 50 to 55 days after culturing, globular embryos were observed in cultures of root segments in medium containing 4 mg/l picloram (19.4%) and 8 mg/l (8.3%) in TDa 289 and none in TDr 63-69.

Induction of proliferation of existing meristem

The effects of Thidiazuron (TDZ) in the culture medium on the proliferation of meristems were examined in *D. alata* genotypes TDa 297 and TDa 95/00005. Media containing 0, 1, 2, and 5 mg/l TDZ were used. Each treatment had four replications and each replicate had 4 to 5 meristems. Enlargement of the meristems was observed in all treatments. However shoots were not obtained. This indicates that TDZ might not be suitable for use in the induction of proliferation of existing meristems.

The effects of various concentrations of 6-benzyl amino purine (BAP) at 0.4, 2, 4, and 8 mg/l on proliferation of existing meristems of yam were investigated in *D. alata* genotypes TDa 289 and TDa 95/00005. Each treatment was repeated four times with 4–6 nodal explants per replicate. Highest percentage explant that formed multiple shoots was obtained at BAP 0.4 mg/l in both genotypes. TDa 289 was more responsive (63% multiple shoot formation) to BAP treatment than TDa 95/00005 (46%). As the concentrations of BAP increased, percentage explants forming multiple shoots decreased. Highest average number of shoot obtained per explant (3.0) was also obtained in BAP 0.4 mg/l. This suggests that BAP at low concentration could induce proliferation of existing meristems. This medium was used in an electroporation experiment in order to recover transgenic plants.

Transformation by electroporation

The plasmid used for transformation studies was pRD410 carrying the neomycin phosotransferaseII (nptII) and β-glucuronidase (uidA) gene driven by the 35S promoter. The kanamycin-killing curve was established with *D. alata* genotype TDa 289 that will be used in the transformation studies. Meristems with leaf primorida were used as explants and inoculated to media containing 0, 60, 120, and 240 mg/l kanamycin. At one month after culturing, 71.4% of explants remained viable and green in medium without kanamycin whereas only 14.3%. 7.2%, and 0.0% remained viable and green in medium containing 60, 120, and 240 mg/l kanamycin, respectively. At two months after culturing, 35.8% of explants grown in medium without kanamycin formed shoots whereas those in media containing 60 and 120 mg/l kanamycin turned white and no shoots were formed. Based on this result, kanamycin at 60 mg/l will be used in the selection medium for the selection of putative transformants.

E. coli, which contained the plasmid pRD410, was obtained from glycerol stock culture stored at –20 °C and cultured in LB medium containing kanamycin and incubated at 36 °C on a shaker for 12 to 16 hours. Plasmid DNA was isolated from *E. coli* cells using alkaline-lysis SDS procedure followed by a phenol-chloroform, and chloroform extraction to remove the contaminating proteins and carbohydrates. DNA was digested overnight with RnaseA at 37 °C after resuspension in sterile distilled water. After digestion with RnaseA, cabenicillin and PPM (preservative for plant tissue culture media) were also added into the plasmid

DNA suspension. The DNA concentration was quantified by pipetting 1 µl of the DNA suspension and mixed with 1 µl of ethidium bromide and observed under Gel Doc 1000. This was compared with a series of known DNA concentration solutions under the same conditions.

For electroporation, meristems with leaf primordia of TDa 289 were dissected and transferred to an electroporation curvet (gap size 4 mm) filled with 200 ul electroporation buffer containing two concentrations of plasmid DNA (10 and 20 ng/µl). Each treatment was replicated three times with 5 explants in each replicate. Meristems with leaf primordia placed in electroporation curvets filled with electroporation buffer without plasmid DNA were used as control. The electroporation curvets were left at room temperature for one hour. They were then incubated on ice for 5 minutes. Electroporation was performed using the Gene PulserII electroporation system set at 0.25 kv. The curvets after electroporation were put on ice for 5 minutes. The explants were then transferred to shoot proliferation culture medium containing 0.4 mg/l BAP (SPM) and incubated in the dark for two days. They were then transferred to selection medium containing 60 mg/l kanamycin in SPM for observation. As for the controls, half of the explants were transferred to medium containing kanamycin and the other half to normal SPM. Ten days after culturing in selection medium, two and five explants of those electroporated with 10 ng/µl and 20 ng/µl plasmid DNA, respectively, showed growth (with leaf primordia elongated). Two of the explants of the control cultured in selection medium showed growth and all of the explants of the control cultured in normal SPM (medium without kanamycin) showed growth. However at four weeks after transferring to kanamycin selection medium, all the explants (control and treatments) were either bleached or turned black, whereas those that were cultured in SPM without kanamycin formed shoots. This indicated that none of the explants electroporated with plasmid DNA was transformed. The potential of this transformation system could be further explored by varying factors such as the electroporation voltage and the DNA concentrations, or adding spermidine to increase the transformation efficiency.

5.4 Technologies for improved postharvest systems developed and disseminated to NARS

Background

Quality of the tuber for the preparation of yam-based foods is a major criterion for acceptance of new yam varieties by farmers and consumers. Yam tubers are mostly consumed with sauce directly after boiling, frying in oil, or roasting. They may also be cooked into pottage with added protein sources and oils. One major method of preparation that is well appreciated in coastal West Africa is the boiling and pounding of the tuber pieces into a thick dough (called *fufu* or *pounded yam*) that is consumed with soup. Another popular dough (called *amala* in Nigeria and Benin and *konkonte* in Ghana) is prepared in hot water from flour derived from dried yam tubers. The popularity of this product is increasing in urban areas owing to the convenience in its preparation. The product has also been introduced to processors and consumers in Burkina Faso, Cameroon, and Côte d'Ivoire through the same project entitled: Raising the value of yams on the urban market. A few commercial products based on dry flakes or flours from the tuber are produced in Côte d'Ivoire and Nigeria for export and sale in urban areas. These are produced by peeling, dicing, sulphite bathing, cooking, mashing, drying, and flaking followed by packaging. However, the yam

sector currently needs additional innovative processing technologies that could reduce food losses and create new products with higher added value. In order to address this efficiently it is necessary to understand the properties of the tuber that relate to the high quality of food products.

Ongoing and future activities

5.4.1 Characterize chemical and physical components affecting food quality and industrial processing quality of primary yam products

M. Bokanga, R. Asiedu - in collaboration with A. Abass

Tuber storage and the qualities of yam foods

In West Africa, it is quite common to plant yams shortly after harvest (e.g., in November or December) thus obviating the need for storage of seed tubers in a barn. This is possible because yam tubers remain dormant during the unfavorable, agroclimatic period between one harvest and the next growing season. The tubers normally germinate at the beginning of the rainy season. The dormancy also permits flexibility in harvesting period and ensures longer shelf life of the fresh yam tuber than in other root and tuber crops. These flexibilities in planting and harvesting periods for yams are important in the management of farm labor. The reduced cost of production and the extended availability of fresh ware tubers in the market lead to enhanced increased access to yams especially for low-income families.

Two popular cultivars of *Dioscorea rotundata* (Lasirin and Olodo) that were planted in December 1999 by a farmer in Oyo State, Nigeria were harvested in two batches—September and December of 2000. The tubers were stored at ambient conditions in a barn until March 2001. The weight loss, spoilage, sprouting rate, edible food loss, chemical composition, and food qualities of the boiled yam, pounded yam, and fried yam chips were evaluated monthly during the storage period. The objective was to investigate the influence of the period of storage and the month of harvesting on the qualities of major yam foods.

Tuber weight loss, spoilage, and edible food loss were consistently greater in yam tubers harvested in September but the tubers harvested in September and those harvested in December started sprouting at the same time. The moisture content of the tubers decreased and peeling loss increased with storage time. The amylose contents and pasting properties of the yam tubers did not exhibit any particular trend during storage. There were no drastic changes in the color of the tuber parenchyma or the fried chips made from them during storage. However, the moisture content of fresh yams and oil absorption of fried yam chips reduced as storage progressed. Changes in overall quality index (OQI) observed during storage suggest that better quality foods are made from the tubers harvested in December. The food quality increased two to three months after harvest and then declined.

Screening advanced breeding lines for food quality

An experiment was carried out to assess genotypes of *D. alata* and *D. rotundata* for organoleptic quality of their tubers. A nine-member sensory evaluation panel assessed the quality of two popular food products ("boiled yam" and "pounded yam") prepared from tubers of 67 genotypes of *D. rotundata* and boiled yam from 104 genotypes of *D. alata*. The *D. rotundata* tubers were obtained from advanced yield trials (AYT) while the *D. alata* ones were from advanced and uniform yield trials (UYT). The attributes scored with respect to pounded

yam were color, sheen, smoothness, consistency, elasticity, and hardness. For boiled yam, taste, color, softness, mealiness, and wetness were scored. Subjective evaluation of quality of boiled *D. alata* tubers showed that 5% of the genotypes screened were liked extremely, 55% moderately, and 9% were disliked. Regression analysis showed that smoothness accounted for 60% of the variation of general acceptability. In *D. rotundata*, boiled yam from 6% of the genotypes screened were liked extremely, 78% moderately, and 2% were disliked. Taste accounted for 64% of the variation in general acceptability. Pounded yam from 19% of genotypes from the same species were liked extremely, 64% moderately, and 6% were disliked. Smoothness contributed 68% of total variation in general acceptability of pounded yam.

5.4.2 Develop technologies for improved storage and expanded utilization of yams

Evaluation of the presence of aflatoxin in the yam chip production system in Benin

K. Hell, K.F. Cardwell, P. Vernier (CIRAD) - in collaboration with C. Mestres (CIRAD), J. Hounhouigan (CERNA-FSA, Benin)

Dry pieces of the yam tuber, termed chips, are stored for milling into flour when required for reconstitution into a dough that is consumed with soup in West Africa. A survey was initiated in 2000 to study the prevalence of aflatoxin in yam chips. The HACCP (Hazard Analysis Critical Control Point) System was used to elucidate the points in the production system that predisposes the chips to aflatoxin contamination. Several points were identified that contributed to the high prevalence of aflatoxin in the samples. Only 6% of the samples exceeded the minimum residue level of the WHO, whereas nearly 97% of the samples exceeded the proposed level of the EU of 4 ppb.

Points at which increased toxin levels were found are:

1. The storage of yam chips in rooms leads to increased moisture content of chips, which could lead to the development of fungi and toxigenesis especially during the rainy season.

2. Actors in the production system commonly wash and re-dry chips that are infected by molds leading to further development of molds and toxins.

3. Producers, retailers, and consumers have to be informed to the dangers of aflatoxin contamination in the yam production system and ways to reduce the risks of toxin development.

5.5 Developing the capacity of human resources for research on yams

Background

Development of the capacity for research and development is crucial to the drive towards improvement and sustainability of yam-based production systems.

5.1 Supervise degree-related research of NARS personnel

Research fellows who were advised by members of Project 5 on activities related to the project area listed below together with their research topics and degree-awarding institution:

Egesi, Chiedozie

The effects of some environmental factors on the flowering of water yam (*Dioscorea alata* L.).

PhD, University of Ibadan, Nigeria

Funding—Self

University advisor: J. Egunjobi

Project 5 advisor: R. Asiedu

Ile, Elsie Ihuakwu

Influence of provenance and ecology on flowering and dormancy in white yam (*Dioscorea rotundata* Poir.).

PhD, University of Reading

Funding—DFID

University advisor: T. Wheeler

Project 5 advisor: R. Asiedu

Odu, B.O.

Identification of resistance to yam viruses in *Dioscorea* species and genetic analysis of resistance to yam mosaic potyvirus in *Dioscorea rotundata* Poir.

PhD, University of Ibadan, Nigeria

Funding—Gatsby Charitable Foundation, UK

University advisor: S. Soyinka

Project 5 advisors: J.d'A. Hughes, R. Asiedu, Q. Ng

Sangoyomi, T.E.

Postharvest deterioration of yams due to fungi.

PhD, University of Ibadan, Nigeria

Funding—self

University advisor: E. Ekpo

Project 13 advisor: R. Asiedu

Claudius-Cole, Abiodun

Cultural control of *Meloidogyne* spp. and *Scutellonema bradys* on edible yams.

PhD, University of Ibadan, Nigeria

Funding—self

University advisor: B. Fawole

Project 5 advisor: R. Asiedu

Onibokun, Adefoyeke

Resistance to anthracnose disease in *Dioscorea alata* (water yam).

PhD, University of Ibadan, Nigeria

Funding—IITA

University advisor: A.C. Odebode

Project 5 advisor: R. Asiedu

Onibokun, Adefoyeke

Resistance to anthracnose disease in *Dioscorea alata* (water yam).

PhD, University of Ibadan, Nigeria

Funding—IITA

University advisor: A.C. Odebode

Project 5 advisor: R. Asiedu

Acha, Ivo Atabong

Suitability of yam (*Dioscorea* spp.) clones for rapid multiplication

MSc, University of Ibadan, Nigeria

Funding—Self

University advisor: M.O. Akoroda

Project 5 advisor: H. Shiwachi, R. Asiedu

Abstracts of completed theses

Dongo, Lelia Nkechinyere

Partial characterization of isometric particles found in *Dioscorea alata* in Nigeria

PhD, University of Ibadan, Nigeria

Funding—IITA

University advisor: G.I. Atiri

Project 5 advisor: J. d'A. Hughes

Abstract

Farmers' yam fields and backyard gardens in major yam growing areas of Nigeria were surveyed for characterized and unknown viruses of yams. Apparently healthy and diseased

yam leaves were collected and tested for known yam viruses (*Dioscorea alata* virus (DaV), genus Potyvirus; Yam mosaic virus (YMV), genus Potyvirus, *Dioscorea dumetorum* virus (DdV), genus Potyvirus; *Dioscorea bulbifera* virus (DbV), genus Badnavirus; *Dioscorea alata* virus (DBV), genus Badnavirus; and Cucumber mosaic virus (CMV), genus Cucumovirus using enzyme-linked immunosorbent assay (ELISA) of extracted sap. The results showed that approximately 92% of cultivated yams express virus-like symptoms (mosaic, mottling, chlorosis, shoe-stringing, green vein-banding, leaf distortion). YMV was the most prevalent of the known viruses infecting about 31% of *Dioscorea alata* samples and 36% of *D. rotundata* samples, followed by DaV and DBV, DbV, DdV and CMV. Yam plants were commonly infected with more than one virus. Infections with YMV, in combination with other viruses such as DaV, were most common. CMV did not occur as mixed infections.

A new yam virus, *Dioscorea mottle* virus (DMV), with strong strain differentiation was found in *D. alata* leaves exhibiting symptoms of mottling, mild chlorosis, and necrosis using herbaceous test plants. Sap from yam leaves exhibiting symptoms of mottling induced leaf bleaching and distortion on leaves of *Vigna unguiculata* cv. IT84s-2114 after mechanical inoculation while those from yam leaves exhibiting mild chlorosis and necrosis caused symptoms of chlorotic mosaic and green vein-banding on leaves of *V. unguiculata* cv. 2657 and vein clearing and mottling on leaves of *Glycine max* cv. Malayan. The mild chlorosis strain of DMV incited pinpoint lesions on inoculated leaves of *Chenopodium murale* and chlorotic lesions on systemically infected leaves of *C. amaranticolor* and *C. quinoa*. The mottle and necrosis strains of DMV could not infect these species.

Electron microscopic observation of purified preparations of DMV strains revealed isometric virus-like particles 17–28 nm in diameter. Purified preparations of the mottle strain of DMV appeared as "strings of beads" whereas particles of the other two strains remained discrete and were not clumped. Antisera prepared against the DMV strains had titers of 1:12 000, 1:8000, and 1:1000 for DMV mottle strain, DMV mild chlorosis strain, and DMV necrosis strain, respectively. Serological relationships of DMV were determined using protein A sandwich (PAS) ELISA, Ouchterlony double diffusion test and immunosorbent electron microscopy (ISEM). DMV was found to be closely related to *Cowpea mottle* virus (CPMoV), genus Carmovirus.

Protein A sandwich ELISA (PAS-ELISA) detected the three strains of DMV better although double antibody sandwich (DAS) ELISA was found to detect DMV mild chlorosis strain and DMV mottle strain. The coat protein of DMV mottle and necrosis strains had an apparent molecular weight of 18 ±1 Kd while DMV mild chlorosis strain had three protein bands of molecular weights of 21.5, 18, and 11.5 ± 1 Kd when estimated by polyacrylamide gel electrophoresis. Based on the effects of the three virus isolates on herbaceous test plants, they were thought to be different viruses, but serological studies and virus protein molecular weight determination indicate they are strains of a single new virus, DMV.

Odu, Babajide

Identification of resistance to yam viruses in *Dioscorea* species and genetic analysis of resistance to yam mosaic potyvirus in *Dioscorea rotundata* Poir.

PhD, University of Ibadan, Nigeria

Funding—Gatsby Charitable Foundation

University advisor: A.O. Oladiran

Project 5 advisors: R. Asiedu, J.d'A. Hughes, N.Q. Ng

Abstract

Studies on the identification of sources of resistance to yam viruses in *Dioscorea* species and genetic analysis of resistance to Yam mosaic virus (YMV) genus Potyvirus in *Dioscorea rotundata* were carried out. Seventy-two *D. rotundata* genotypes collected from the yam-growing areas of West Africa were used in this study. Twenty-two of these were selected for evaluation in the field and screenhouse on the basis of the following criteria: they had exhibited a high level of field resistance to leaf diseases in past evaluations at the IITA; they are the major yams planted in the "yam belt" of West Africa; they are high yielding; and they have end-user acceptability. They were evaluated for virus resistance and for the study of stability of performance in relation to virus symptom severity in four agroecological zones over two cropping seasons (1998–1999). Controlled crosses were made between 5 male and 9 female plants classified as resistant, moderately resistant, or susceptible, and selected from the *D. rotundata* genotypes under evaluation. The resultant F_1 progenies were transplanted into a screenhouse for assessment of inheritance of resistance to YMV. Also used in the study were 40 genotypes of *D. alata*, which were evaluated in both the field and in the screenhouse. *D. cayenensis* and wild yam relatives of different species were evaluated in the screenhouse. The following are the wild and semidomesticated species evaluated with numbers of accessions in parentheses: *D. dumetorum* (2), *D. praehensilis* (3), *D. togoensis* (1), *D. bulbifera* (1), *D. abyssinica* (3), *D. mangenotiana* (2), *D. librchtsiana* (1), *D. burkilliana* (1), and *D. hirtiflora* (1). Screenhouse evaluations were also carried out to confirm the results from the field trials as well as for the genotypes not included in the multisite trials. This involved mechanical and vector transmission studies. These 22 *D. rotundata* genotypes evaluated in the multisite trials were also inoculated with other yam viruses, which are known in West Africa to infect yams. These are *Dioscorea alata* virus genus Potyvirus (DAV), *Dioscorea alata* badnavirus genus Badnavirus (DaBV) and cucumber mosaic virus genus Cucumovirus (CMV). This was done to determine the reactions of these genotypes to these yam viruses.

Significant variation in disease incidence and symptom severity in respect of YMV, DAV, CMV, and DaBV were established at different intervals of field evaluation of the 22 *D. rotundata* genotypes. Results of sampling done at all the locations for all the yam viruses showed incidence of 41.5% for YMV and 20.8% for DAV. Other yam viruses were not detected. There was variation in resistance of the genotypes to virus diseases.

Additive main and multiplicative interaction (AMMI) analysis of virus symptom severity scores from the four agroecological locations showed that TDr 1621, TDr 1640, TDr 35, TDr 2224, and TDr 93-48 had low symptom severity scores indicative of resistance to field infection of yam virus diseases. Screenhouse evaluation of all the collected genotypes confirmed these results and that of other *D. rotundata* genotypes not included in the multisite trials as resistant to YMV.

Field and screenhouse evaluation of *D. alata* genotypes showed TDa 291, a landrace cultivar from Puerto Rico; TDa 297 and TDa 289 (DAN 087) from Nigeria; TDa 95-23; and TDa 95-14, a landrace cultivar from Ghana, to be resistant to YMV. Also, a genotype of *D. bulbifera* was found to be resistant to YMV in the screening of wild yam relatives.

Vector transmission studies confirmed the transmissibility of *Aphis gossypii*, *A. craccivora*, *Toxoptera citricidus*, and *Rhopalosiphum maidis* as previously reported and established *Pentalonia nigronervosa*, *A. spiraecola*, *R. nymphaea*, and *T. aurantii* as vectors of YMV for the first time.

Genetic analysis of resistance to YMV in the *D rotundata* genotypes strongly suggests that resistance is a dominantly inherited trait. Segregation ratios obtained from the families indicate that at least two dominant genes are involved.

5.5.2 Organize workshops in collaboration with NARS: Methodology workshop on modeling technology adoption and assessing economic viability and impact of yam technologies

N.K. Amegbeto, V.M. Manyong, O. Coulibaly, V. Okoruwa, B. Nkamleu

An important built-in mechanism of the ongoing IFAD-sponsored subregional project on yams in West Africa is the enhancement of human capacity through training. As the project is NARS-centered with emphasis on end-user participation in the execution of activities, it is expected that the NARS personnel and other groups will take the lead in solving yam production problems. In particular, the socioeconomists are expected to bridge the gap between yam technology development through research and stakeholders' preferences, acceptability, and adoption of these technologies. They are also expected to assess the resulting impact on livelihoods and poverty alleviation. However, it is the case that the human capacity within most NARS is inadequate either in terms of number or expertise to undertake the necessary research activities.

The socioeconomic themes in the current phase of the project relate to the analysis of economic viability/profitability of new yam technologies and their acceptability for adoption by end-users. A set of harmonized questionnaires have been prepared and distributed by the project economist to NARS colleagues for use in data collection. At their request, a methodology workshop was organized at Parakou, Benin Republic from 29 October to 2 November 2001 on the analytical tools most relevant to the studies. K.N. Amegbeto and V.M. Manyong (IITA Ibadan); O. Coulibaly (IITA Benin); B. Nkamleu (IITA Cameroon); and V. Okoruwa, (University of Ibadan) served as resource persons.

The objective of the workshop was to strengthen the analytical skills of NARS colleagues in anticipation of upcoming data analysis and reporting required for the socioeconomic studies within the IFAD project. The specific objectives were to:

- Provide the theoretical background underlying Probit, Logit, and Tobit models used in technology adoption studies.
- Familiarize participants with the Limdep software and the econometrics of Probit, Logit, and Tobit models.
- Discuss the analytical framework (types, steps, sensitivity considerations) for assessing profitability and economic viability of agricultural technologies based on budgeting techniques.
- Discuss the elements (concept, levels, types, tools, and indicators) of impact assessment and how they apply to yam technologies being developed.
- Review the applicability of the above tools and models towards the questionnaires and data being collected this year.
- Enhance practical skills of participants through hands-on numerical applications on Limdep and on Microsoft Excel using both country specific and more general data sets.

A total of 13 participants attended the workshop. These include two NARS economists

from each of the following countries: Benin, Ghana, Nigeria, and Togo; and one economist from Côte d'Ivoire. In addition, two research assistants and two auditors from IITA Benin who were interested in the workshop also attended. All the participants except the two auditors were sponsored by the IFAD yam project.

In addition to the Limdep software and manuals, the following documents were distributed to the participants:

Alimi, T. and V.M. Manyong. 2000. Partial budget analysis for on-farm research. International Institute of Tropical Agriculture, Research Guide No. 65.

Coulibaly, O., G.B. Nkamleu, M. Tamo, and J.M. Ngeve, (unspecified year). Adoption of storage pest control technology by cowpea traders in Western Cameroon : Probit Model Application. Unpublished manuscript.

Nkamleu, G.B. and O. Coulibaly. 2000. Le Choix des methodes de lutte contre les pestes dans les plantations de cacao et de café au Cameroun. Economie Rurale No. 259, Septembre–Octobre.

Nkamleu, G.B. 1999. Etat des lieux de l'agroforesterie au Cameroun : cas des provinces du centre, du sud-ouest et du nord-ouest. secheresse, No. 3, Vol. 10, Septembre.

Nkamleu, G.B., D.M. Mbila, and D. Endamana. 2000. Study of socioeconomic factors influencing investment into agrochemical in Cameroon: a survey in periurban and urban agriculture.

Nkamleu, G.B. and A.A. Adesina. 1999. Determinants of chemical input use in periurban lowland systems : bivariate probit analysis in Cameroon. Agricultural Systems 63: 111–121.

LIMDEP sample programs.

Completed studies

Abang, M.M., S. Winter, K.R. Green, P. Hoffmann, H.D. Mignouna, and G.A. Wolf. (forthcoming). Molecular identification of* Colletotrichum gloeosporioides *causing yam anthracnose in Nigeria. Plant Pathology.

Four forms of *Colletotrichum* representing three distinct virulence phenotypes were found associated with foliar anthracnose of yam in Nigeria: the aggressive, slow-growing gray (SGG), the moderately virulent, fast-growing salmon (FGS), the weakly virulent, fast-growing gray (FGG), and the moderately virulent, fast-growing olive (FGO) morphotypes. Isolates of the four forms were identified as *C. gloeosporioides* based on morphology. Reaction of monoconidial cultures on casein hydrolysis medium (CHM), PCR-RFLP, and sequence analysis of the internal transcribed spacer region of the ribosomal DNA (ITS 1 -5.8S- ITS 2) were used to establish the identity of the yam anthracnose pathogen(s). All yam isolates were distinguished from *C. acutatum* by the absence of protease activity on CHM. Upon ITS PCR and enzymatic digestion of PCR products, all FGS, FGO, and SGG isolates produced RFLP patterns identical to those of *C. gloeosporioides* reference isolates while FGG isolates revealed unique ITS RFLP banding patterns. Sequence analysis of the ITS 1 region and of the entire ITS region revealed that SGG, FGS, and FGO isolates were highly similar (98–99% nucleotide identity), with a 97 to 100% identity to *C. gloeosporioides*. Less than 93% similarity of these fungal isolates to reference *C. acutatum* and *C. lindemuthianum* isolates was observed. The molecular study confirmed that foliar

anthracnose of yam is caused by *C. gloeosporioides*. While a high similarity was found among most *C. gloeosporioides* fungi from yam, isolates of the FGG form did not cluster with any previously described *Colletotrichum* species and probably represent a distinct species.

Mignouna, H.D., M.M. Abang, K.R. Green, and R. Asiedu. 2001. Inheritance of resistance in water yam (*Dioscorea alata*) to anthracnose (*Colletotrichum gloeosporioides*). Theoretical and Applied Genetics 103: 52–55.

Colletotrichum gloeosporioides causes anthracnose, the most severe foliar disease of field-grown water yam (*Dioscorea alata*). The inheritance of resistance to a moderately virulent (FGS) strain of the pathogen was investigated in crosses between tetraploid *D. alata* genotypes: TDa 95/00328 (resistant) × TDa 95-310 (susceptible) (cross A), and TDa 85/00257 (resistant) × TDa 92-2 (susceptible) (cross B). Segregation of F_1 progeny fitted genetic ratios of 3:1, 5:1 (crosses A and B), and 7:1 (cross A) resistant:susceptible when inoculated with the FGS strain, indicating that resistance is dominantly inherited and suggesting that more than one gene controls the inheritance of resistance to this strain in the accessions studied. When parental and progeny lines of cross A were inoculated with an aggressive (SGG) strain of the pathogen, all plants expressed a susceptible phenotype, indicating strain-specific resistance in TDa 95/00328. Screening of 20 cultivars/landraces confirmed the high susceptibility of *D. alata* accessions to the SGG strain and revealed the presence of apparent strain nonspecific resistance in TDa 85/00257. TDa 85/00257 and TDa 87/01091, which were resistant to the SGG strain, will be useful both as sources of resistance and in the development of a host differential series for *D. alata*.

Mignouna, H.D., P. Njukeng, M.M. Abang, and R. Asiedu. 2001. Inheritance of resistance to yam mosaic virus, genus Potyvirus, in white yam (*Dioscorea rotundata*). Theoretical and Applied Genetics 103: 1196–2000.

Yam mosaic virus (YMV) causes the most widespread and economically important viral disease affecting white yam (*Dioscorea rotundata*) in West Africa. The genetic basis of resistance in white yam to a Nigerian isolate of YMV was investigated in three tetraploid *D. rotundata* genotypes: TDr 93-1, TDr 93-2, and TDr 89/01444. F_1 progeny were produced using TDr 87/00571 and TDr 87/00211 as the susceptible parents. Segregation ratios indicated that a single dominant gene in a simplex condition governs the resistance in TDr 89/01444, while the resistance in TDr 93-2 is associated with the presence of a major recessive gene in duplex configuration. Segregation of progeny of the cross TDr 93-1 × TDr 87/00211 fitted a genetic ratio of 2.48:1 resistant:susceptible, which can be expected when two simplex heterozygotes are crossed, indicating the possible modifying effect of the susceptible parent. Triple antibody immunosorbent assay (TAS-ELISA) was used for virus detection in inoculated plants. Slight mosaic symptoms appeared on most resistant individuals, while asymptomatic resistant genotypes with high ELISA (A_{405}) values were observed in all crosses. Such a heterogeneous response suggests the influence of additional modifier genes that segregate in the progeny. The finding that resistance can be inherited as a dominant or recessive character has important implications for YMV resistance breeding.

Mignouna, H.D., M.M. Abang, A. Onasanya, B. Agindotan, and R. Asiedu. (Forthcoming). Identification and potential use of RAPD markers linked to yam mosaic virus resistance in white yam (*Dioscorea rotundata *Poir.). Annals of Applied Biology.

Resistance to yam mosaic virus (YMV) in tetraploid white yam (*Dioscorea rotundata*) is inherited differentially as a dominant and recessive character. Elite *D. rotundata* breeding lines with durable resistance to YMV can be developed by pyramiding major dominant and

recessive genes using marker-assisted selection (MAS). The tetraploid breeding line, TDr 89/01444, is a source of dominant genetic resistance to yam mosaic disease. Bulked segregant analysis was used to search for random amplified polymorphic DNA (RAPD) markers linked to YMV resistance in F_1 progeny derived from a cross between TDr 89/01444 and the susceptible female parent, TDr 87/00571. The F_1 progeny segregated 1:1 (resistant: susceptible) when inoculated with a Nigerian isolate of YMV, confirming that resistance to YMV in TDr 89/01444 was dominantly inherited. A single locus that contributes to YMV resistance in TDr 89/01444 was identified and tentatively named *Ymv-1*. Two RAPD markers closely linked in coupling phase with *Ymv-1* were identified, both of which were mapped on the same linkage group: $OPW18_{850}$ (3.0 ± 0.5 centiMorgans [cM]) and $OPX15_{850}$ (2.0 ± 0.5 cM). Both markers successfully identified *Ymv-1* in resistant genotypes among 12 *D. rotundata* varieties and in resistant F_1 individuals from the cross TDr 93-1 ×, TDr 87/ 00211, indicating their potential for use in marker-assisted selection. $OPW18_{850}$ and $OPX15_{850}$ are the first DNA markers for YMV resistance and represent a starting point for the use of molecular markers to assist breeding for resistance to YMV.

Egesi, C.N., M. Pillay, R. Asiedu, and J.K. Egunjobi. (Forthcoming). Ploidy analysis in water yam,* Dioscorea alata *L. germplasm. Euphytica.

Poor reproductive development in yams (*Dioscorea* spp.) has often been attributed to the polyploid nature of the crop. In this study, flow cytometry was used to determine the ploidy level of 53 accessions of *Dioscorea alata*, mostly from West African countries, Chad, and Puerto Rico. Nuclei were isolated from young leaf material and stained with DAPI (4,6-diamidino-2-phenylindole). The nuclear genome size (2C) was measured as an indicator of the ploidy level. *Dioscorea rotundata* genotypes with known ploidy levels were used as standards. The results showed that the majority of plants were hexaploid (84.9%) with a smaller percentage of tetraploids (15.1%). A higher number of male plants were hexaploid than tetraploids. This is at variance with earlier findings, which reported that hexaploid male plants are rare. Higher ploidy levels were not directly related to sparse or erratic flowering as previously reported, as profuse flowering occurred in some male hexaploid accessions. These findings have important implications for yam breeding in relation to yam genetic resources.

Carsky, R.J., N. Wolo, V.M. Manyong, and G. Tian. 2001. Nutrient balance model for design of sustainable yam cropping systems. Pages 198–209* in *Root crops in the 21st century, edited by M.O. Akoroda and J.M. Ngeve, Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, October 1998. ISTRC-AB, IITA, Ibadan, Nigeria.

A simple balance sheet was used to identify nutrient limitations in yam production and to predict changes in soil nutrient stocks as a result of adoption of soil improvement systems for yam, using *Gliricidia sepium* agroforestry (cut-and carry and in situ) systems as examples. Fixed nutrient inputs taken from the literature include weathering, atmospheric deposition, nonsymbiotic BNF, and those present in the yam seed while fixed exports are leaching and runoff/erosion. Variable inputs are nutrients in *Gliricidia sepium* mulch and crop residue return. Variable exports consist of nutrients in the yam tubers and uptake by trees when grown in the same field with yam. Literature review has provided estimates of yam tuber nutrient concentrations, expected amounts of *G. sepium* mulch and its nutrient content. Sensitivity analysis using the model suggests that nutrient contents of yam and *G. sepium* mulch are important terms in the equation and therefore should be locally measured. The model predicts N depletion in an in situ system except for yam yield of 10

Mg/ha or less and *G. sepium* mulch application of 4.5 Mg/ha or more. Higher yields of yam tubers (15 to 20 Mg/ha) are attainable without soil depletion in a cut-and-carry system with 3 to 4.5 Mg/ha of mulch. Without K fertilizer, the model predicts potassium mining under all scenarios of an in situ system and even in a *G. sepium* cut-and-carry system unless 3 to 4.5 Mg/ha of mulch is applied. The results suggest that for long-term sustainability, K must be applied either directly to the yam crop or to the associated *G. sepium* when the two are grown in association.

Houndekon A.V. and V.M. Manyong. 2001. Indigenous knowledge and domestication of wild yams in West Africa: experience from Benin Republic. Paper presented at the Symposium on Participatory plant breeding in Africa: an exchange of experiences, 7–10 May 2001, WARDA, M'bé, Bouaké, Côte d'Ivoire.

Domestication of wild yams is an indigenous, traditional breeding technique applied by farmers of the yam belt in West Africa. This paper reports partial results of a research sponsored by the CGIAR Systemwide Program on Participatory Research and Gender Analysis (PRGA), implemented by IPGRI/IITA and their partners in West Africa, and titled: Farmers practice of domestication and their contribution to improvement of yam in West Africa. Results from a survey on a sample of 80 domesticators in Benin Republic indicated that the domestication of wild yams is a variant of participatory plant breeding (PPB) whereby only farmers are involved in the selection process of a new crop variety. The main reasons for the domestication of wild yams were to develop new varieties that are more productive than the existing ones, create a source of cheap planting materials, and perpetuate an ancestral practice. Domesticators used well-defined parameters to identify wild yam candidate for domestication such as similarity of leaves of wild yams to those of cultivated varieties, thorny stems, and similarity of flowers. Domesticators applied specific techniques during the domestication such as the use of obstacles, cutting of tubers, or milking. Domesticators had developed indicators to monitor the success or failure of the domestication process such as change in the flesh color of tubers, disappearance of thorns on the stems, absence or reduction of the small roots from the surface of tubers, change in the shape and size of tubers, and reduction or absence of the bitter taste from tubers.

Results from cost analysis indicated that yam domestication is time-consuming, requires long-term investments, is expensive, and remains a marginal activity that is practiced by a limited number of yam growers

Abang, M.M., H.D. Mignouna, K.R. Green, and R. Asiedu. Development of a tissue culture-based whole plant method for assessing anthracnose disease reactions in water yam (*Dioscorea alata*). Presented at the 5th All Africa Conference of African Crop Science Society, 21–25 October 2001, Lagos, Nigeria.

There is an urgent need for a rapid and standardized method for the large-scale screening of the available water yam (*D. alata*) germplasm to identify sources of anthracnose resistance and for genetic studies. The method should take account of the variability within populations of *C. gloeosporioides* and allow for the variation in host response due to variables such as leaf age, inoculum type and concentration, as well as application method. Experiments were conducted to determine optimal conditions for inoculation of yam plants with *C. gloeosporioides*, and subsequent incubation and evaluation of disease response. Best results were obtained by paintbrush inoculation of whole young leaves with a conidial suspension (1×10^6 spores ml^{-1}) amended with Tween® 80 (1.2 % v/v). Based on these results, a rapid, tissue-culture based, whole plant screening method was developed which is now used routinely for large scale screening of *D. alata* mapping populations

for anthracnose resistance in genetic studies. Optimal conditions include inoculation of plantlets raised up to the 3 to 5 fully expanded, leaf stage following postflask establishment, incubation in a containment facility (maintained at 27±1 °C, 98–100 % R.H., and 12 hr daylight/night natural cycle), misting of plants two times a day postinoculation, and the use of a standard quantitative method of disease evaluation after seven days. The tissue-culture based method uses little inoculum and space, allows the use of whole plants of uniform age, shows good correlation with field screening, and can be carried out under controlled conditions with selected isolates.

Claudius-Cole, A.O., B. Fawole, and R. Asiedu. The role of cover crops in the management of* Meloidogyne incognita *and other plant parasitic nematodes. Presented at the 5th All Africa Conference of African Crop Science Society, 21–25 October 2001, Lagos, Nigeria.

Ten cover crops were assessed in 2000 for their ability to control *Meloidogyne incognita* (the root-knot nematode) with the aim of recommending their inclusion in cropping systems for soil maintenance. *Aeschynomene histrix, Cajanus cajan, Centrosema pubescens, Crotalaria ochroleuca, C. juncea, Lablab purpureus, Mucuna pruriens (utilis), Pueraria phaseoloides, Stylosanthes guianensis, Tagetes erecta*, and *Vigna unguiculata* were used in the study. They were planted in pots containing sterile soil in the screenhouse at IITA Ibadan, Nigeria and inoculated with eggs/juveniles of root-knot nematode. Nematode counts were taken from plant roots and the soil of each pot after eight weeks. Counts from *Aeschynomene histrix, Centrosema pubescens, Crotalaria ochroleuca, C. juncea, Mucuna pruriens (utilis), Pueraria phaseoloides, Stylosanthes guianensis*, and *Tagetes erecta* were not significantly different from the control (uninoculated) and therefore showed some promise. *Lablab purpureus, Cajanus cajan*, and *Vigna unguiculata* supported significantly higher numbers of nematodes than the control showing that they have the undesirable ability to build up nematode populations in the soil. The same species, growing in the field and under natural infestation, were sampled for nematodes associated with their roots four times during the year. *Meloidogyne* spp., *Pratylenchus* spp., *Helicotylenchus* spp., *Hoplolaimus* spp., *Scutellonema* sp., *Aphelenchus* sp., and *Criconemoides* sp. were observed. The following species were ranked based on their ability to sustain populations of the various nematodes in the following increasing order: *Tagetes erecta, Aeschynomene histrix, Centrosema pubescens, Crotalaria juncea, Stylosanthes guianensis, Mucuna pruriens (utilis), Crotalaria ochroleuca, Pueraria phaseoloides, Vigna unguiculata, Cajanus cajan*, and *Lablab purpureus.*

Egesi, C.N., R. Asiedu, J.K. Egunjobi, and S. Ogunyemi. Processing characteristics and sensory analysis of water yam (*Dioscorea alata *L.) Germplasm. Presented at the 5th All Africa Conference of African Crop Science Society, 21–25 October 2001, Lagos, Nigeria.

Development of low-cost, processed products can help farmers avoid losses, increase incomes, and improve consumer acceptability of a crop. The problems of yam flour processing are hinged on the supply of suitable yam varieties because each gives a different quality of flour. Evaluation of the processing characteristics of forty water yam (*Dioscorea alata* L.) accessions collected from Benin, Ghana, Nigeria, and Puerto Rico is reported. Different accessions were assessed for tuber dry matter content. Sliced samples were evaluated for flesh color and rates of browning for possible processing into flour. Boiled tuber pieces of the accessions were evaluated for mealiness, color, taste, and general acceptability. "Pounded yam" (dough from boiled and pounded tubers) of accessions were evaluated for consistency, color, stickiness, and general acceptability. Accessions were identified that possessed a high tuber dry matter content making them suitable for use as a boiled vegetable and as

pounded yam. These accessions are also useful for processing into chips and flour. The tuber dry matter content, which varied from 18.5% to 40.0%, was within the acceptable range. There was significant variation in flesh color and rate of browning, indicating that some accessions would be more suitable for sun drying and flour production. Flesh color of accessions ranged from white to deep purple. There were significant differences in acceptability of the boiled and pounded tubers of accessions for the different textural attributes evaluated. The accessions have shown great potential for direct utilization in meals and processing for flour production.

Aduramigba-Modupe, A.O., R. Asiedu, A.C. Odebode, and A.O. Oladiran. Resistance of water yam (*Dioscorea alata*) to anthracnose disease in Nigeria. Presented at the 5th All Africa Conference of African Crop Science Society, 21–25 October 2001, Lagos, Nigeria.

Water yam (*Dioscorea alata* L.) is the most cosmopolitan of all food yams grown in the tropical and subtropical regions of the world. Anthracnose disease, caused by *Colletotrichum gloeosporioides* Penz. is a major constraint to water yam production in Nigeria. Five breeder lines and eighteen landraces of *D. alata* from IITA's germplasm collection were subjected to field screening for their reactions to anthracnose disease in three agroecological zones (southern Guinea savanna, derived savanna, and humid forest) in Nigeria during 1999 and 2000. Incidence and severity of foliar symptoms were scored on three occasions during the growing season. Data analysis, using the additive main effects and multiplicative interaction (AMMI) model, revealed significant effects of genotype (G) and environment (E) as well as G and E interactions. Parallel studies on variability of the pathogen, based on collections of isolates from various locations in Nigeria, would help in interpreting these responses. The severity scores were highest in the humid forest zones and also higher in 1999 than 2000 across the three locations. Differences between locations indicated that disease was more severe in areas of higher rainfall. Six genotypes (TDa 289, TDa 294, TDa 291, TDa 92-3, TDa 85/00250, and TDa 94-73) out of the 23 evaluated showed significantly lower levels of infection. These six could serve as sources of resistance to this major disease in yam breeding programs.

Odu, B.O., R. Asiedu, J.d'A. Hughes, S.A. Shoyinka, and A.O. Oladiran. Potential of West African white yam (*Dioscorea rotundata *Poir.) genotypes as sources of resistance to yam mosaic virus (genus Potyvirus; family Potyviridae). Presented at the 5th All Africa Conference of African Crop Science Society, 21–25 October 2001, Lagos, Nigeria.

Yam, a multispecies crop, is a major source of food and income for millions of people especially in West and Central Africa. This region produces about 95% of the world total. Several cultivars of *Dioscorea rotundata* Poir. (white guinea yam), the most important species, are susceptible to yam mosaic virus (YMV) genus Potyvirus; family Potyviridae. Infection leads to reduction in plant vigor.

Twenty-two accessions were selected from the yam germplasm collection based on their apparent field resistance to leaf diseases in previous evaluations and planted in four agroecological zones of Nigeria, and also in an insect-proofed screenhouse at one of the locations. The genotypes were evaluated for virus symptom severity in the four locations, and for their response to mechanical and vector transmission of YMV. Symptom severity rating and absorbency values obtained from enzyme-linked immunosorbent assay (ELISA) were used as parameters to assess resistance.

There was considerable variation among the genotypes with respect to virus symptom severity. Additive main and multiplicative interaction (AMMI) analysis of virus symptom severity ratings from the four agroecological zones showed that the yam accessions TDr 1621, TDr

1640, TDr 35, TDr 2224, and TDr 93-48 had low virus symptom severity scores indicative of resistance to field infection by yam viruses. Screenhouse evaluation by mechanical and vector transmission showed that of all the genotypes inoculated with YMV, only the five previously listed remained symptomless. These are therefore potential sources of useful resistance genes that can be exploited for the genetic improvement of *D. rotundata*.

Sangoyomi, T.E., R. Asiedu, and E.J.A. Ekpo. Influence of storage methods on tuber losses in white yam (*Dioscorea rotundata *Poir.). Presented at the 5th All Africa Conference of African Crop Science Society, 21– 25 October 2001, Lagos, Nigeria.

The tuber storage facilities traditionally used by farmers in the major yam growing areas of Nigeria vary in design, depending on agroecological and sociocultural factors. Loss of yam tubers in storage, up to 40% reported in Nigeria, is a major constraint in yam production and marketing. Four popular varieties of white yam (*Dioscorea rotundata* Poir.) were purchased from farmers' fields and stored for six months in three types of traditional barns commonly used in Abakaliki, Lafia, and Gabi as well as the barn of IITA's yam program at Ibadan. Tubers were assessed on a monthly basis for rot incidence and severity as well as weight loss. Rot incidence was significantly higher ($P \leq 0.05$) using Gabi (5.83%) and Lafia barns (6.23%) compared to IITA-Ibadan (2.78%) and Abakaliki barns (2.78%) during the first month of storage. This same trend was observed in the second and third months. At the end of the storage period, the highest rot incidence was recorded in Gabi barns (45.37%). Rot severity was consistently lowest in Abakaliki barns. Tubers weight loss was highest at IITA (54.67%) and least at Abakaliki (42.33%). This resulted from a combination of physiological weight loss, rots, and rodent damage in decreasing order of importance. These in turn are related to the differences in environmental factors and vulnerability to pest attack of the various barn designs. The foregoing are key elements for consideration in any programs aimed at optimizing yam preservation.

Abang M.M., R. Asiedu, H.D. Mignouna, K.R. Green, S. Winter, and G.A. Wolf. Anthracnose disease of yams in West Africa: recent advances in research and future perspectives. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

Water yam (*D. alata*) is the most widely cultivated yam species globally and is superior to white yam (*D. rotundata*) in terms of factors such as yield potential, adaptability to low fertility soils, ease of propagation, early vigor for weed suppression, and storability of tubers. The major limitation to stable and reliable production of the species is its susceptibility to anthracnose disease caused by *Colletotrichum gloeosporioides*. Early research emphasized chemical and cultural control measures, and programs for the systematic breeding of yams for anthracnose resistance were largely nonexistent. Chemical control measures are inappropriate for resource-poor farmers while cultural methods are inadequate under conditions of high disease pressure. The availability of resistant varieties could potentially be the cornerstone of an integrated management strategy for yam anthracnose. Recent research at the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria has contributed immensely to knowledge on the molecular taxonomy of *Colletotrichum* strains associated with yam anthracnose, and on the phenotypic and genetic diversity of *C. gloeosporioides* from yams. Isolates with complex virulence capability have been identified for anthracnose resistance screening of yams using rapid detached leaf or whole plant assays. Mapping populations have been developed for studies on the genetics of resistance and the inheritance of resistance to a widely prevalent strain of *C. gloeosporioides* has been elucidated. Two RAPD markers linked to anthracnose resistance were recently identified using bulked segregant

analysis. Recent studies have also led to the development of the first genetic linkage map of *D. alata* and to the identification of one QTL with minor effect on anthracnose resistance. Current research efforts and suggestions for future work on anthracnose disease of yams in West Africa are presented.

Claudius-Cole, A.O., R. Asiedu, and B. Fawole. Cultural control of* Scutellonema bradys *on edible yams. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

Root and tuber crops are important because many of the developing world's poorest and most food insecure households depend on these crops as their principal source of food and cash income. Yam ranks as the second most important tuber crop in the humid tropics. Plant-parasitic nematodes seriously limit yam production in many areas of the world. Up to 40% of tuber damage has been reported to be associated with dry rot caused by *Scutellonema bradys* in Nigeria resulting in a reduction of tuber weight. Cover crops have been reported to influence nematode populations when used in rotation or as intercrops. In order to evaluate their potential, five cover crops *Aeschynomene histrix, Cajanus cajan, Centrosema pubescens, Pueraria phaseoloides*, and *Mucuna pruriens (utilis)* were intercropped with yam on the field and in pots in a screenhouse. There were two control plots/pots for this treatment, cowpea *(Vigna unguiculata* Ife-Brown*)* as the positive control and plots/pots without cover crop as the negative control. Yam varieties TDa 294 (water yam) and TDr 608 (white yam) were used for the study. Except for the control, artificial inoculation of *S. bradys* was done with yam peels containing 10 000 nematodes for each plant. Nematode populations in the tubers and soil in plots/pots where yam was associated with *Aeschynomene histrix, Pueraria phaseoloides*, and *Mucuna pruriens (utilis)* were significantly lower compared to those resulting from intercropping yams with cowpea. These three cover crops hold promise for inclusion in yam-based cropping systems for soil maintenance. Yam intercropped with *Centrosema pubescens* supported more nematodes than when associated with the other species but less than those with the cowpea control. *Cajanus cajan,* however, was similar to cowpea in its effect on the nematode population in tuber and soil and is therefore not recommended as a cover crop in *S. bradys* infested soil to be used for yam production.

Egesi, C.N., R. Asiedu, J.K. Egunjobi, and S. Ogunyemi. Evaluation of phenotypic variation in water yam (*Dioscorea alata *L.) germplasm using multivariate analysis. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

A multivariate study based on agrobotanical traits of 40 water yam (*Dioscorea alata* L.) accessions was carried out to evaluate individual and group variations and to identify the most relevant characters for distinguishing them. The accessions were originally obtained from Benin, Ghana, Nigeria, and Puerto Rico. The first five principal components (PCs) were identified which together explained 63% of the total variation. The first PC (27% of the variation) was associated with distribution of anthocyanin on leaves and stems and with tuber characteristics. The second PC (12% of the variation) was associated with leaf and stem dimensions. The third PC (10% of the variation) was associated with severity rating of foliar disease symptoms and percent tuber dry matter content. Cluster analysis revealed the differentiation of the accessions into two major groups, with nine subgroups. Grouping was not related to geographic origin of the accessions. The level of variation observed in this study indicated that an expanded germplasm collection might be necessary to ensure a broader genetic base for the improvement of water yam.

Aduramigba-Modupe, A.O., R. Asiedu, and A. . Odebode. Effect of anthracnose disease on yield of* Dioscorea alata. *Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

Anthracnose disease caused by *Colletotrichum gloeosporioides* Penz. is a major constraint to the production of *Dioscorea alata* in Nigeria. The disease reduces the effective photosynthetic surface of the plant thus resulting in yield loss of about 80 to 90%. Field experiments were conducted during 1999 and 2000 at Umudike, Ibadan, and Mokwa representing the forest, forest/savanna transition, and southern Guinea savanna zones of Nigeria, respectively. Twenty-three genotypes were evaluated, some with known differential resistance to the disease. Correlation analysis was conducted to investigate the relationship between disease severity and tuber yield of *D. alata* genotypes. Regression analysis was used to determine models for estimation of yield loss caused by anthracnose disease on water yam genotypes with various levels of resistance. Negative correlations were established between yield and the disease, with Umudike, Ibadan, and Mokwa having –0.70, –0.63, and –0.55 correlation coefficients, respectively. Multiple point regression models were more suitable for explaining the variation in yield attributed to anthracnose disease. Genotypes TDa 289 and TDa 294 showed the highest level of resistance at the three locations.

Odu, B.O., J.d'A. Hughes, R. Asiedu, S.A. Shoyinka, and O.A. Oladiran. Reactions of white yam (*Dioscorea rotundata *Poir.) genotypes to three viruses infecting yams. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

Reactions of 24 white yam (*Dioscorea rotundata* Poir.) genotypes to three viruses mechanically and vector transmitted were studied. The viruses were *Dioscorea alata* virus (DAV) genus Potyvirus; family Potyviridae, *Dioscorea alata* bacilliform virus (DaBV) genus Badnavirus, and cucumber mosaic virus (CMV) genus Cocumovirus, family Bromoviridae. The results were confirmed by enzyme-linked immunosorbent assay (ELISA) and symptom development. Of all the infected genotypes, only TDr 95-128, a landrace cultivar from Nigeria, developed symptoms of infection to both CMV and DaBV in mechanical and vector transmission, respectively. Of the 24 *D. rotundata* genotypes inoculated with the three viruses, ELISA showed that nine remained uninfected by DAV and 11 were uninfected by CMV, or by DaBV. Genotypes TDr 747 and TDr 1640 showed extreme resistance to all three viruses.

Adeniji M.O. and R. Asiedu. Screening yams (*Dioscorea spp.*) for organoleptic quality. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

An experiment was carried out at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, to assess genotypes of *D. alata* and *D. rotundata* for organoleptic quality of their tubers. A nine-member sensory evaluation panel assessed the quality of two popular food products ("boiled yam" and "pounded yam") prepared from tubers of 67 genotypes of *D. rotundata* and boiled yam from 104 genotypes of *D. alata*. The *D. rotundata* tubers were obtained from advanced yield trials (AYT) while the *D. alata* ones were from advanced and uniform yield trials (UYT). The attributes scored with respect to pounded yam were color, sheen, smoothness, consistency, elasticity, and hardness. For boiled yam taste, color, softness, mealiness, and wetness were scored. Subjective evaluation of quality of boiled *D. alata* tubers showed that 5% of the genotypes screened were liked extremely, 55% moderately, and 9% were disliked. Regression analysis showed that smoothness accounted for 60% of the variation of general acceptability. In *D. rotundata*, boiled yam from 6% of the genotypes screened were liked extremely, 78% moderately, and 2% were disliked. Taste accounted for

64% of the variation in general acceptability. Pounded yam from 19% of genotypes from the same species were liked extremely, 64% moderately, and 6% were disliked. Smoothness contributed 68% of total variation in general acceptability of pounded yam.

Sangoyomi, T.E., R. Asiedu, and E.J.A. Ekpo. Control of postharvest fungal rot of white yam (*Dioscorea rotundata *Poir.) with botanicals. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

Crude extracts from ten plants common in Nigeria were screened for their effects on major fungal pathogens of the yam tuber in order to identify suitable botanicals for control of rots during storage. The effects of the extracts on growth of mycelia and production of spores/sclerotia by fungal pathogens were studied in vitro using the food poisoning technique. Agar plates containing crude extracts from specific plant species were inoculated at the center with 4-mm diameter of the respective fungal mycelia. All plates were incubated at 28 °C and radial growth was measured daily for four days. Crude extract from *Allium sativum* caused 100% inhibition of the growth of *Botryodiplodia theobromae*, *Penicillium oxalicum*, *Rhizoctonia solani*, *Sclerotium rolfsii*, *Aspergillus niger*, and *Aspergillus flavus*. It also reduced radial growth of *Fusarium moniliforme*, *Fusarium oxysporum*, *Fusarium semisectum*, *Setosphaeria rostrata*, *Colletotrichum gloeosporioides*, and *Sphaerostilbe repens* compared to growth on the control. Crude extract from *Zingiber officinale* completely inhibited the growth of *Setosphaeria rostrata*. *Hibiscus rosa-sinensis* caused 75% reduction in growth of *Fusarium oxysporum* and *Fusarium semisectum* while *Ocimum gratissimum* caused about 80% reduction in growth of *Rhizoctonia solani* and *Sphaerostilbe repens*. Extracts from the other plant species (*Cymbopogon citratus*, *Chromolaena odorata*, *Azadirachta indica*, *Acalypha wilkesiana*, *Cassia alata*, and *Enantia chlorantha*) were not effective in reducing growth of the pathogens. Subsequent in vivo studies have confirmed the effectiveness of crude extract from *Allium sativum* in protecting yam tubers from fungal rots. Boiling destroyed the functions of the active ingredients in all the plant species if used during extraction.

Vernier, P. and R.A. Dossou. Some aspects of evolution of yam-based systems in Benin. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

The Republic of Benin is a very important yam producer in West Africa and the fourth largest producing country worldwide. The production showed a noteworthy dynamism during the past 30 years with an annual rate of increase of more than 3% from 530 000 tonnes in 1961–1963 to 1.5 million tonnes in 1996–1998. This expansion is mainly due to the increase of cultivated area on cleared land, which grew from 61 000 to 135 000 ha. Average yield shifted very little and cultivation techniques remained very traditional. This situation is very similar in the rest of the subregion. Nevertheless, beyond the traditional status of yam cultivation, some important changes have occurred, driven by market-demand oriented producers. Examples include the development of the sun-dry chip subsector, the integration of yam into cotton based cropping systems, and a certain degree of intensification (or sedentarization). For yam cultivation traditionally based on slash-and-burn practices, this is a new situation in Africa.

Abass, A.B, A.O. Olorunda, R. Asiedu, and M. Bokanga. Effect of age of yam tuber at harvest on the qualities of yam foods. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

Two *D. rotundata* landraces (Lasirin, Olodo), popular in western Nigeria, planted in December 1999 by a farmer located north of Oyo State, Nigeria, were harvested in two batches (September and December 2000) and stored at ambient conditions in the barn till March 2001. The weight loss, spoilage, sprouting rate, edible food loss, chemical composition, and food qualities of the boiled yam, pounded yam, and fried yam chips were evaluated monthly.

Tuber weight loss, spoilage, and edible food loss were consistently greater in yam tubers harvested in September but sprouting of the September batch was lower. Both the tubers harvested in September and those harvested in December started sprouting at the same time. The moisture content of the tubers decreased and peeling loss increased with storage time. The amylose contents and pasting properties of the yam tubers did not exhibit any particular trend during storage. There were no drastic changes in the color of yam tubers and the fried chips during storage.

Changes in overall quality index (OQI) observed during storage suggest that better quality foods are made from the tubers harvested in December; the food quality increased two to three months after harvest and then declined. Moisture content of fresh yams and oil absorption of fried yam chips reduced as storage progressed.

Otegbayo, B.O., A.U. Achidi, R. Asiedu, and M. Bokanga. Food quality attributes of the Kponan varietal group of white yam. Presented at the 8th Symposium of the International Society for Tropical Root Crops—Africa Branch, 12–16 November 2001, Ibadan, Nigeria.

Pona or Puna (Ghana), Kpouna (Togo and Benin), or Kponan (Ivory Coast) are the names given to a group of highly appreciated cultivars of *D. rotundata* (white yam) that are rated superior to other yams in cooking quality attributes (mealiness, taste, and texture). These sensory attributes and the physicochemical composition of 35 accessions in the varietal group obtained from Ghana and five popular Nigerian cultivars of *D. rotundata*, as checks, were investigated. Puna accessions contained 39.33%. 74.20%, 4.61%, 4.30%, 0.32%%, and 2.29% of dry matter, starch, sugar, protein, fat, and ash on a dry weight basis, respectively. The average phosphorous content was 110.27 mg/100 g and the amylose ratio was 35.80%. For the check cultivars, the average dry matter, starch, sugar, protein, fat, ash, were: 31.25%, 77.24%, 5.57%, 3.64%, 0.39%, 2.76%, respectively; the average phosphorous content was 104.79 mg/100g and the amylose ratio 33.11%.

With respect to pasting characteristics, the Puna accessions had a higher peak viscosity, breakdown, final viscosity, and setback, but lower holding strength and pasting temperature compared with the check cultivars. Sensory evaluation revealed that boiled tubers of the Puna accessions were sweet, soft, and mealy and were more preferred than those of the check cultivars for their taste and texture. Significant correlations were found between dry matter and mealiness ($r = 0.57$), amylose and mealiness ($r = 0.37$), and fat and mealiness ($r = 0.32$). The high dry matter and amylose are thought to contribute to the good texture of the Puna accessions and may also be responsible for their superior cooking qualities compared to other yams. However other indicators of yam food quality need to be identified.

Staff

Principal scientific staff	Project research time allocation
K. Amegbeto, socioeconomist	90
R. Asiedu, PhD, breeder/geneticist (project coordinator)	80
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M. Bokanga, PhD, biochemist and food technologist	20
K. Cardwell, PhD, plant pathologist	5
R. Carsky, PhD, agronomist	20
D. Chikoye, PhD, weed scientist	10
J. d'A. Hughes, PhD, virologist	20
P. Keese, molecular biologist	20
V. Manyong, PhD, agricultural economist	5
J. Meerman, nematologist	25
H.D. Mignouna, PhD, molecular geneticist	30
N.Q. Ng, PhD, genetic resources specialist	5
S. Ng, MSc, tissue culture specialist	25
S. Nokoe, PhD, biometrician	10
C. Nolte, PhD, agronomist	C*
H. Shiwachi, physiologist	100
S. Soyinka, virologist	20
G. Tian, PhD, agronomist	10
B. Van der Meer, GIS specialist	5
P. Vernier, PhD, agronomist#	100
N. Wanyera, PhD, breeder/agronomist	100
Total	700

* C means complementary member

CIRAD scientist

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Publications 2000 and 2001

2000

Journal articles and book chapters

*Dansi, A., H.D. Mignouna, J. Zoundjihékpon, A. Sangaré, R. Asiedu, and N. Ahoussou. 2000. Using isozyme polymorphism to assess genetic variation within cultivated yams (*Dioscorea cayenensis/Dioscorea rotundata *complex) of the Republic of Benin. Genetic Resources and Crop Evolution 47: 371–383.*

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2001

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Asiedu, R. 2001. Improving cassava- and yam-based systems. Paper presented at Workshop on Improved production and storage of root and tuber crops in West Africa, 22 June 2001, ETH Research Station, Eschikon, Switzerland,. ETH, Zurich and CSRS, Côte d'Ivoire.

Donors

Department for International Development (DFID), United Kingdom

Directoraat Generaal Internationale Samenwerking (DGIS), The Netherlands

Gatsby Charitable Foundation, UK

International Fund for Agricultural Development (IFAD), Italy

Japan International Research Center for Agricultural Sciences (JIRCAS), Ministry of Agriculture, Forestry and Fisheries, Japan

Ministere de la Cooperation, France

United States Agency for International Development (USAID), USA

Acronyms and abbreviations

AEZ	agroecological zones
AYT	advanced yield trials
CGIAR	Consultative Group on International Agricultural Research
CMV	cucumber mosaic virus (CMV), genus Cucumovirus
DbBV	*Dioscorea bulbifera* virus (DbBV), genus Badnavirus
DaV	*Dioscorea alata* virus (DaV), genus Potyvirus
DaBV	*Dioscorea alata* virus (DaBV), genus Badnavirus
DDV	*Dioscorea dumetorum* virus (DDV), genus Potyvirus
DFID	Department for International Development, UK
DLV	*Dioscorea* latent virus (DLV), genus Potexvirus
DMCV	*Dioscorea* mild chlorotic virus
DMV	*Dioscorea* mottle virus
DNV	*Dioscorea* necrosis virus
ELISA	enzyme-linked immunosorbent assay
ESARC	East and Southern Africa Regional Center
GCF	Gatsby Charitable Foundation
IFAD	International Fund for Agricultural Development

ISTRC	International Society for Tropical Root Crops
NAARI	Namulonge Agricultural and Animal Research Institute, Uganda
NARES	national agricultural research and extension system
NARS	national agricultural research system
NCRP	Nationally Coordinated Research Project
NRCRI	National Root Crops Research Institute, Umudike, Nigeria
UYT	uniform yield trial
WCA	West and Central Africa
WECARD	West and Central African Council for Research and Development
YMV	yam mosaic virus (YMV), genus Potyvirus

IITA Research Project 5: Improving yam-based systems

Objectives

- Characterize farmers' management strategies in yam-based systems and the potential for the acceptance of improved technologies.
- Develop strategies for integrated management of pests and soil fertility in yam-based systems.
- Produce yam genotypes with high and stable yield of tubers with good food and storage qualities and disseminate them to NARS.
- Develop technologies for improved postharvest systems and disseminate them to NARS.
- Strengthen research, training, and leadership skills for NARS scientists and personnel working on yam-based systems.

Activities

- Survey farmers' perceptions of the resource management constraints in intensified yam-based systems.
- Conduct economic analysis of the yam seed sector and ex-ante adoption studies of improved varieties.
- Assess the economic viability and acceptability of planted legume fallows for soil fertility maintenance.
- Conduct ex-ante adoption studies on hot-water therapy for disinfection of yam seed tubers.
- Investigate the domestication of wild yams in Benin and Nigeria.
- Establish the geographic distribution of yam nematodes in Benin and yam viruses in Ghana.
- Improve the methodologies for screening of yam host-plant response to nematodes and viruses.
- Screen yam germplasm for resistance to major field and storage pests.
- Conduct vector studies on known yam viruses and characterize new ones.
- Identify herbaceous and woody legumes for integration into yam-based systems.
- Estimate nutrient requirements of yams and promote efficient use of fertilizers in yam-based systems.
- Develop broad-based populations for improved performance of yams in the moist savanna of West Africa and in the midaltitude ecologies of East Africa.
- Develop special populations for improved tuber quality and anthracnose resistance.
- Produce virus-tested propagules of yams for export and exchange germplasm with collaborators.
- Conduct regional varietal trials with NARS.

- Study differential responses to abiotic environmental stresses in yams.
- Identify factors controlling the cooking quality of yams and develop screening methods.
- Develop screening methods and control measures for enzymatic browning of yam tubers.
- Develop methods for artificial sprout induction in dormant yam tubers and for the control of flowering.
- Improve in vitro mass propagation and postflask management of yam plantlets.
- Develop regeneration and transformation systems for yams.
- Establish molecular markers for genes conferring resistance to yam viruses, nematodes, and anthracnose disease.
- Develop molecular maps for *D. alata* and *D. rotundata.*
- Characterize chemical and physical components affecting food quality and industrial processing quality of primary yam products.
- Develop technologies for improved storage and expanded utilization of yams.
- Improve and promote processing of yam tubers into dry food products in West Africa.
- Supervise degree-related research of NARS personnel.
- Provide technical backstopping to specific NARS-centered projects.
- Establish a database for geographic information, manpower resources, projects, and improved technologies relevant to yam research and development in Africa.

Expected outputs

- Understanding of farmer management strategies and potential for acceptance of new technologies.
- Better knowledge of yam pests and diseases and the strategies for their integrated control.
- Appropriate strategies for management of soil fertility and weeds for yam producing areas.
- Stable, high-yielding genotypes with good quality tubers, suited to relevant cropping systems.
- Protocols for artificial induction of flowering and tuber sprouting.
- Modern tools for increasing efficiency of genetic improvement.

Annex 1

Research Projects

1. Conservation and use of plant biodiversity
2. Improving plantain- and banana-based systems
3. Improving cowpea–cereal systems in the dry savannas
4. Improving maize–grain legume system systems in West and Central Africa
5. Improving yam-based systems
6. Improving cassava-based systems
7. Biological control and functional biodiversity
8. Integrated management of legume pests and diseases
9. Integrated management of maize pests and diseases
10. Integrated management of cassava pests and diseases
11. Protection and enhancement of vulnerable cropping systems
12. Improvement of high intensity food and forage crop systems
13. Integrated perennial and annual cropping systems
14. Impact, policy, and systems analysis

CGIAR Systemwide and Ecoregional Projects

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

Systemwide Program on Integrated Pest Management (SP-IPM)

Annex 2

Project 5 Logframe

Project planning matrix (PPM)	Project ref. no: 5	Project title: Improving yam-based systems	Estimated project duration: 10 years	PPM prepared: December 2000

Summary of objectives/activities	Objectively verifiable indicators	Means/sources of verification	Important assumptions
Goal Adoption of improved technologies by farmers, contributing to a sustainable increase in productivity of yam-based systems	• Productivity of yam-based systems significantly increased and sustained above year 2000 level • Yam production expanded into new areas in West and East Africa • Expanded utilization of a broader range of food products from yam	• Annual project reports • National statistics • FAO statistics	• Favorable political and socioeconomic environment
Purpose Improved technologies targeted at enhanced productivity of yam-based systems evaluated and disseminated by NARS	• Collaborative trials with NARS on improved genotypes and propagation practices conducted in at least four countries in West Africa annually • Collaborative trials with NARS on strategies for management of pests and soil fertility conducted at pilot sites in three countries in West Africa annually during 2001–2003 • Farmer participatory evaluation of improved technologies (genotypes, propagation practices, and strategies for management of pests and soil fertility) conducted at pilot sites in three countries in West Africa by 2003 • Evaluation of improved genotypes and propagation practices conducted with at least 2000 farmers in one country of East Africa by 2003 • Effective network of scientists in yam research and extension	• NARS reports • Annual project reports • Proceedings of meetings/ workshops/ symposia/ conferences • Training course documentation • Journal articles	• Funding, logistical support, and manpower continue to be available • Effective systems for dissemination of improved technologies to farmers

Project planning matrix (PPM)	Project ref. no: 5	Project title: Improving yam-based systems	Estimated project duration: 10 years	PPM prepared: December 2000

Summary of objectives/activities	Objectively verifiable indicators	Means/sources of verification	Important assumptions
Results/Outputs 1. Farmers' management strategies in yam-based systems and the potential for the acceptance of improved technologies characterized	• Farmers' perceptions of the resource management constraints in intensified yam-based systems in Nigeria documented in 2000 • Economic benefits and potential for adoption of planted legume fallows, hot water therapy of seed yams, and improved varieties established in at least two countries in West Africa by 2003 • Economic analysis of the yam seed sector in two countries in West Africa completed by 2002 • Domestication of wild yams characterized in the Republic of Benin by the end of 2001 in terms of stakeholders, methodologies used, costs, initial germplasm, and end-products • Surveys on yam domestication in Nigeria completed by mid-2001	• Survey reports • Annual project reports • Publications	• NARES have effective mechanisms for using diagnostic information for research planning
Results/Outputs 2. Strategies for integrated management of pests and soil fertility in yam-based systems developed	• At least five yam selection programs in Africa using the methods developed for screening of yams for resistance to nematodes, viruses, and fungi by 2002 • Geographic distribution of yam nematode pests in the Rep. of Benin documented by 2001 • At least four new viruses characterized by 2002 • Critical nutrient requirements of yams established by 2002 • Symptoms of deficiency for at least three major nutrients and influence of fertilizer application on foliage diseases documented by 2003 • Losses attributed to yam viruses quantified by 2003 • Potential of herbaceous legumes and other crops intercropped with yams to reduce soil populations of parasitic nematodes established by 2001 • At least two fallow legumes confirmed as promising for soil fertility maintenance and reduction of pests (especially parasitic nematodes) in at least two countries in West Africa by 2002 • Stable productivity of yam-based systems demonstrated over a 10-year period at pilot sites in the SGS of at least one country in West Africa • New practices for intensive yam cultivation tested in the moist savanna and forest zones of Nigeria • One manual on major pests and diseases of yams published by 2001	• IITA annual reports • Journal articles • NARS reports	• Facilities and trained personnel available in NARS to apply the new techniques

Project planning matrix (PPM)	Project ref. no: 5	Project title: Improving yam-based systems	Estimated project duration: 10 years	PPM prepared: December 2000
Summary of objectives/activities	**Objectively verifiable indicators**		**Means/sources of verification**	**Important assumptions**
Results/Outputs 4. Improved postharvest systems developed (Linked to activities in Project 14)	• Principal food and processing qualities in yams characterized by 2002 • Improved storage techniques for yams developed by 2003 • New modes of utilization of yams developed and disseminated in West and East Africa by 2003 • Improved techniques for processing yam chips (ensuring reduced discoloration and bitterness) tested by the end of 2001 • Yam "chip technology" and food products based on yam chips promoted in urban areas in at least 3 countries in West Africa where such foods are relatively new		• NARS reports • IITA reports • Journal publications	Continuation of funding for the Yam Valorization Project by the French Ministry of Foreign Affairs in 2001
Results/Outputs 5. Research, training, and leadership skills strengthened for NARS personnel working on yams	• At least one NARS staff pays a study visit (2 to 4 weeks) to project scientists each year • At least four African postgraduate students conduct research for MSc/PhD theses under supervision of project scientists each year resulting in a minimum of two completed theses per year during 2000 to 2003 • Workshop on GIS and database management for personnel from 5 NARS conducted by mid-2000 • Database for geographic information, manpower resources, projects, and improved technologies relevant to yam research and development in Africa established by mid-2001 • Backstopping visits to project sites, participation in project meetings and communication with NARS collaborators by Project scientists with respect to the IFAD/IITA/WECARD Yam Project in West Africa, the Ghana Root and Tuber Improvement Programme, and the USAID/OFDA Project (Community-based promotion of food security crops) in West and East Africa during 2000–2003		• Training reports • MSc/PhD theses • Training materials • Travel reports	

Project planning matrix (PPM)	Project ref. no: 5	Project title: Improving yam-based systems	Estimated project duration: 10 years
Summary of activities *Activities specified for each output*			**Specification of inputs/costs**
Output 1: Farmers management strategies in yam-based systems and the potential for the acceptance of improved technologies characterized			**Input of time (SY) per project member to this output**
1.1 Study farmers' practices for domestication of wild yams in Benin and Nigeria			
1.2 Conduct cost analysis in the domestication of wild yams in West Africa: case studies			
1.3 Study the process of domestication in partnership with practising farmers			
1.4 Characterize germplasm (morphology, protein, DNA) involved in the domestication process			P. Vernier (.30)
1.5 Survey farmers' perceptions of the resource management constraints in intensified yam-based systems in Nigeria			V. Manyong (.05) H. Mignouna (.02)
1.6 Survey management practices in slash-and-burn versus short-fallow systems in the Rep. of Benin			C. Nolte (C*)
1.7 Conduct economic analysis of the yam seed sector			J. Meerman (.05)
1.8 Conduct ex-ante adoption studies of improved varieties			K. Amegbeto (.50)
1.9 Assess the economic viability and acceptability of planted legume fallows for soil fertility maintenance			S. Nokoe (.05)
1.10 Assess the economic benefits of using healthy seed tubers for yam cultivation			
1.11 Conduct ex-ante adoption studies on hot-water therapy for disinfection of yam seed tubers (linked to Activity 2.2)			

Project planning matrix (PPM)	Project ref. no: 5	Project title: Improving yam-based systems	Estimated project duration: 10 years	PPM prepared: December 2000
Summary of activities *Activities specified for each output*			**Specification of inputs/costs**	**Important assumptions**
Output 2: Strategies for integrated management of pests and soil fertility in yam-based systems developed			**Input of time (SY) per Project member to this output**	
2.1 Establish the geographic distribution of yam nematode pests in the yam growing areas of Republic of Benin				
2.2 Assess the impact of hot water therapy of seed yams on yield and storage of yam tubers				
2.3 Improve the methodologies for screening for resistance to yam viruses			D. Chikoye (.08)	
2.4 Screen yam germplasm (*D. alata*, *D. rotundata*) to identify sources of resistance to major field and storage pests (viruses, nematodes, anthracnose disease)			J. Meerman (.20) J. Hughes (.17)	
2.5 Conduct vector studies on known yam viruses and characterize new ones			M. Ayodele (C*)	
2.6 Study the influence of storage environment on storage rot of *D. rotundata* tubers			R. Asiedu (.15)	
2.7 Evaluate botanicals for control of tuber rots of *D. rotundata* during storage			G. Tian (.07)	
2.8 Quantify yield losses associated with yam virus infection			R. Carsky (.15)	
2.9 Evaluate herbaceous legumes and other crops intercropped with yams for potential to reduce populations of parasitic nematodes			P. Vernier (.20) K. Cardwell (.05)	
2.10 Study the influence of fertilizer nutrients on necrosis, silvering and/or surface blackening of *D. alata* leaves			Q. Ng (C*)	
2.11 Study the prevalence of leaf nutrient deficiency symptoms on farmers' fields in Nigeria			H. Shiwachi (.20)	
2.12 Study nutrient requirements of yams and efficient use of fertilizers in yam-based systems			S. Soyinka (.17)	
2.13 Study integration of woody legumes in yam-based systems in SGS			K. Amegbeto (.10)	
2.14 Evaluate the potential of reduced tillage (direct planting in mulch) for planting of yams in the Republic of Benin				
2.15 Assess profitability of fertiliser use in intensified yam-based systems in the Republic of Benin and in two major yam producing areas in Nigeria				

C*: complementary

Project planning matrix (PPM)	Project ref. no: 5	Project title: Improving yam-based systems	Estimated project duration: 10 years	PPM prepared: December 2000
Summary of activities *Activities specified for each output*			**Specification of inputs/costs**	**Important assumptions**
Output 3: Yam genotypes with high and stable yield of tubers with good food and storage qualities developed and disseminated to NARS			**Input of time (SY) per project member to this output**	
3.1 Develop broad-based populations for improved performance of yams in the moist savanna of West Africa				
3.2 Develop broad-based populations for improved performance of yams in the midaltitude ecologies of East Africa				
3.3 Develop populations for improved tuber quality and virus resistance in *D. rotundata*				
3.4 Develop a population for improved resistance to anthracnose disease in *D. alata*				
3.5 Produce virus-tested propagules of yams for export, exchange germplasm with collaborators, and obtain feedback			R. Asiedu (.55) N. Wanyera (.80)	
3.6 Conduct regional varietal trials with NARS			M. Bokanga (.07)	
3.7 Study the inheritance of resistance to YMV in *D. rotundata*			S.Y.C. Ng (.23)	
3.8 Conduct on-farm trials aimed at farmer-participatory selection of superior varieties of *D. alata* and *D. rotundata* in Nigeria and Uganda			J. Hughes (C*) Q. Ng (.03)	
3.9 Identify factors controlling the cooking quality of yams and develop screening methods			H. Shiwachi (.70)	
3.10 Develop screening methods and control measures for enzymatic browning of yam tubers			H. Mignouna (.28)	
3.11 Evaluate the effect of growth regulators on aerial tuberization in yams			P. Vernier (.10)	
3.12 Develop methods for the control of flowering in yams and for artificial sprout induction in dormant yam tubers			S. Soyinka (C*)	
3.13 Improve in vitro tuberization in yams				
3.14 Develop regeneration and transformation systems for yams				
3.15 Establish DNA fingerprints of elite yam genotypes				
3.16 Establish molecular markers for genes conferring resistances to yam viruses and anthracnose disease				
3.17 Develop molecular maps for *D. alata* and *D. rotundata*				

Project planning matrix (PPM)	Project ref. no: 5	Project title: Improving yam-based systems	Estimated project duration: 10 years	PPM prepared: December 2000
Summary of activities *Activities specified for each output*			**Specification of inputs/costs**	**Important assumptions**
Output 4: Improved postharvest systems developed 4.1 Characterize chemical and physical components affecting food quality and industrial processing quality of primary yam products 4.2 Develop technologies for improved storage and expanded utilization of yams 4.3 Improve and promote processing of yam tubers into dry food products in West Africa 4.4 Document the market orientation of yam production in West Africa			**Input of time (SY) per project member to this output** M. Bokanga (.10) P. Vernier (.35) N. Wanyera (.10) K. Amegbeto (.10)	
Output 5: Research, training, and leadership skills strengthened for NARS personnel working on yams 5.1 Train NARS personnel on short-term attachment to project scientists 5.2 Supervise degree-related research of NARS personnel 5.3 Organize workshops in collaboration with NARS 5.4 Provide technical backstopping to specific NARS-centered projects 5.5 Establish a database for geographic information relevant to yam cultivation and utilization in West Africa 5.6 Document available manpower resources for yam research and development in West Africa 5.7 Document yam research and development projects, and improved technologies on yams available in West Africa 5.8 Update and disseminate information in 5.5, 5.6, and 5.7 to yam research and development programs on a regular basis			**Input of time (SY) per project member to this output** R. Asiedu (.10) M. Bokanga (.03) K. Cardwell (C*) R. Carsky (.05) D. Chikoye (.02) K. Amegbeto (.20) J. Hughes (.03) V. Manyong (C*) J. Meerman (.05) H. Mignouna (C*) Q. Ng (.02) Y. Ng (.02) S. Nokoe (.05) C. Nolte (C*) H. Shiwachi (.10) G. Tian (.03) P. Vernier (.05) N. Wanyera (.10) S. Soyinka (.03)	

C*: complementary

Annex 3

Project 1: Conservation and use of genetic biodiversity

A core collection of cowpea comprising 1926 accessions which are representative of morphological diversity and geographical origin was selected from over 12 000 accessions of the world cowpea collection.

Introduced 127 local cultivars of cassava and 44 yam cultivars collected in Sierra Leone.

Experiments on cryopreservation of cassava shoot-tips, using encapsulation-vitrification and fast freezing method, gave recovery rates of about 60% in certain genotypes.

Studies on population growth and stability of in situ wild yam populations in a forest reserve in Ibadan, monitored over a 3-year period, showed a slight increase in population sizes, but no significant change in the gene frequency of selected morphological markers.

Studies on segregation patterns of mutants in crosses between cowpea varieties confirmed the existence of transposable elements that inhibit or excite gene expression.

Musa genetic diversity studies showed amplified fragment length polymorphism (AFLP) as more powerful than random amplified polymorphic DNAs (RAPDs) in the discrimination of genotypes and the identification of genetic relationships. Plantains from Cameroon were genetically distinct from those of West Africa. Genome composition of all breeding lines and African landraces of Musa has been determined. Sukali Ndizi considered a diploid is a triploid with AAB genome composition.

Germplasm material from genebanks and breeders were provided to national agricultural research and extension systems (NARES) on request. The West and Central Africa Collaborative Maize Research Network (WECAMAN) dispatched 169 kg of maize seed to NARS based on superior performance of varieties tested in 2000. Fifty-eight sets of maize regional uniform variety trials and 26 sets of the regional Striga variety trials in the extra-early maturity groups were also distributed to NARS collaborators in West, Central, eastern, and southern Africa. Forty sets of soybean international trials were supplied to 21 NARS collaborators in Africa, 3 in Asia, and 1 in the US. Over 10 000 disease-free cassava in vitro plantlets were given to NARS in 6 African countries, 2 European countries, and the US. In addition, 1400 disease-free in vitro yam plantlets and 13 211 yam mini-tubers were given to NARS worldwide.

Staining techniques for the isolation and identification of the rust fungi and other microorganisms from infected leaf surfaces of soybean were standardized. *Colletotrichum gloeosporioides* strains causing foliar infection of *Dioscorea* species were classified.

Project 2: Improving plantain- and banana-based systems

Tetraploid (4x) × diploid (2x) crosses mostly produce triploid (3x) progeny while 2x–4x crosses mostly produce 2x progeny, showing that ploidy in offsprings is controlled by paternal microsporogenesis.

A secondary 3x cooking banana hybrid (TM3x30456 [612-74 × 8075-7]) with excellent plant and fruit traits was selected in Nigeria. Another 3x selection was obtained from 2x parents (TMB2x 9722-1 × TMB2x 9128-3) in Uganda, demonstrating that unilateral sexual polyploidization can be used to improve East African highland bananas (EAHB).

Total DNA analysis revealed 3 genetic subspecies in *Musa acuminata* and 2 forms in *M. balbisiana*, suggesting that there are at least 3 A genomes and 2 B genomes. A

quantitative assay based on AFLP analysis of ribosomal RNA genes for discrimination of A and B genomes was developed.

Transmission of *Beauveria bassiana* from infected to uninfected banana weevils was demonstrated while resistance to the pest was identified in Calcutta 4, TMB2x7197-2, and TMB2x8075-7.

Long-lasting reduction in nematode infestation by hot-water treatment (HWT) of planting materials was demonstrated. Fertilizer application also suppressed nematodes, particularly without HWT. Resistant progenies (TMHx 660K-1 and TMHx 917K-2) from crosses between Enzirabahima (susceptible) and Calcutta 4 (resistant) were identified, increasing prospects for breeding resistance in EAHB.

Stable integration of reporter genes was achieved for the control of banana viruses in prelude to genetic transformation against banana streak virus (BSV) and putative nematode vectors of banana die-back virus (BDBV) were identified.

Significant progress was made in establishing *Musa* breeding operations in the Cameroon benchmark and in the duplication of hybrid propagation for distribution at Ibadan, marking a major shift in the operational mode of plantain research in West and Central Africa (WCA). *Musa* breeding and nematology research capacity in Uganda for East and Southern Africa (ESA) was restored.

Three workshops were held to facilitate the delivery of improved hybrids to farmers and large-scale, on-farm variety demonstration plots were established in 11 states across the Nigerian plantain belt.

Project 3: Improving cowpea–cereal systems in the dry savannas

A total of 595 new cowpea breeding lines were developed and tested in the moist savanna, dry savanna, and the Sahel. Over 60 promising lines combining high yield potential and resistance to diseases, insect pests, and *Striga* were selected. Of these, IT97K-568-11, IT97K-568-18, IT568-19, IT98K-491-4, IT98K-128-3, IT98K-131-1, IT98K-506-1, IT98K-589-2, IT98K-598-4, IT99K-381-6, IT99K-453-1, IT99K-718-6, IT99K-856-19, IT99K-1152-28, and IT99K-1258 were most promising.

Improved *Striga* resistant cowpea variety IT97K-499-38 yielded 50% to 300% higher than the local varieties in *Striga* infested fields in Benin Republic. It also caused high percentage of suicidal germination of *Striga hermonthica* seeds.

Bruchid resistant cowpea varieties showed 3–5 eggs/g seed and 12–18% adult emergence compared to 10–20 eggs/g seed and 55%–68% adult emergence in the susceptible varieties. Seed size, color, and texture had no effect on oviposition and adult emergence.

Drought-tolerant cowpea varieties such as IT97K-499-39, IT97K-1075-7, IT97K-634, and IT97K-819-118, and heat tolerant varieties such as IT99K-1058, IT99K-1059, IT99K-1060, IT88D-643-1, IT88D-867-11, and TVu 4552 were developed.

Some cowpea varieties were screened for shade tolerance. A 60% reduction in light caused a 56% reduction in grain yield. IT90K-277-2, IT93K-452-1, and IT89KD-391 were more shade tolerant than other varieties.

A multiple cropping system involving a wheat crop from November to March, heat-tolerant cowpea from March to June, and rice from July to October was developed and tested at Kadawa (Nigeria) irrigation scheme for 2 years with an annual food production of 8 to 9 t/ha.

The IITA/ICRISAT/ILRI improved crop–livestock system was adopted by a large number of farmers. Supplementary feeding of only 200 g cowpea haulms per day along with sorghum stover to young rams doubled their weight gain compared to feeding them sorghum stover alone.

Significant genetic differences were observed among cowpea varieties for seed quality. The Aloka local cowpea had the hardest seed (9 kg crushing weight) and took longest to cook (57.5 minutes).

A total of 294 sets of cowpea international trials comprising over 100 improved breeding lines were sent, on request, to national collaborators.

Project 4: Improving maize–grain legume production systems in West and Central Africa

To identify varieties high in micronutrient content, 20 early-maturing maize varieties grown in 3 diverse locations were evaluated for iron, zinc, and ß-carotene content. One of these varieties grown at Ikenne showed 45% more iron bioavailability than a control variety widely grown in Nigeria. The results indicate that the potential exists to breed early-maturing maize varieties for high and stable mineral content across diverse growing conditions.

In collaboration with the United States Department of Agriculture (USDA) and various universities and institutions in Nigeria, IITA conducted a national food consumption and nutrition survey. Data were collected on household composition, socioeconomic characteristics, food security, household food consumption expenditure, and health care issues. Nutrition status was assessed and biological samples collected. Data entry and laboratory analysis of biological samples are in progress.

An experiment was conducted at Ikenne to compare the performance of 24 early maturing improved maize varieties developed at IITA and CIMMYT with 25 early maturing farmers' ecotypes from Senegal under controlled drought stress and sufficient moisture supply. As a group, the improved open-pollinated (OP) varieties outyielded the local ecotypes by 112% under drought stress and by 94% under sufficient moisture supply.

A trial consisting of 15 maize varieties was evaluated at 3 levels of nitrogen (N) application in Mokwa and Zaria, Nigeria. The top ranking four varieties, DTSR-W, LNPC3, ACR8328C7, and LNTP produced higher yields than a widely grown open-pollinated variety, TZB-SR, at 30 kg/ha N application. They did not differ from other varieties at 90 kg/ha N.

Three soybean breeding lines (TGX1909-7F, TGX 1910-10F, and TGX 1910-11F) which fix about 10% more nitrogen than the current best variety (TGX 1448-2E) were developed. Also, 15 dual-purpose soybean lines with 2–2.5 t/ha grain and 2.5–3.5 t/ha stover yields were identified for distribution to the NARS.

Extra-early (2000 Syn EE-W) and early (EV DT 97 STR C1) maturing *Striga* resistant varieties evaluated at Férkessedougou outyielded the respective best non-*Striga* resistant varieties by as high as 46% under artificial *Striga* infestation.

Project 5: Improving yam-based systems

Farmers in Oyo and Kwara states of Nigeria were satisfied with the hot-water (53 °C) therapy of seed yams for reducing nematode symptoms and improving germination, tuber quality, and market value. Under high infestation the therapy more than doubled net profit. Users' constraints were evaluated.

Dioscorea rotundata Poir. (white yam) accession TDr 1640 as well as *D. alata* L. (water yam) accessions TDa 291 and TDa 289 are resistant to *D. alata* virus (DAV); *D. alata* bacilliform virus (DaBV); and cucumber mosaic virus (CMV).

Two gibberellin inhibitors, uniconazole-P (UP) and prohexadione-calcium (PC), coupled with tuber storage at 30 °C, shortened tuber dormancy in *D. alata* accessions TDa 99/00049 and TDa 95/00328.

Three IITA-derived clones of *D. rotundata* (TDr 89/02461, TDr 89/02565, and TDr 89/02677) were formally released as new varieties in Nigeria.

About 30 000 seed tubers of new *D. rotundata* varieties were delivered to over 300 farmers of 10 districts in Uganda for farmer-participatory testing.

Two cultivars of *D. rotundata* planted in December 1999 were harvested in September or December 2000 and stored at ambient conditions until March 2001. Both groups sprouted about the same time but tuber weight loss, spoilage, and edible food losses were greater in the September batch. Better quality foods were made from the December batch. Peeling loss increased, tuber moisture content decreased, and oil absorption of fried yam chips reduced with storage.

Twelve graduate students conducted research on yams and the entries in a yam R & D personnel directory now exceed 200.

The IFAD/WECARD/IITA Yam Project organized a work-planning workshop, a workshop on analytical skills for yam economists, and toured yam research activities in Côte d'Ivoire.

Project 6: Improving cassava-based systems

Over 10 000 tissue culture plantlets of elite cassava germplasm were distributed to collaborators in 5 African and 3 non-African countries, while over 284 000 seeds from 1100 families were distributed to 9 national programs in Africa. In addition, large-scale seedling nurseries with over 100 000 botanical seeds were established at high disease pressure sites at Kenya, Malawi, Mozambique, and Tanzania to intensify the screening effort and accelerate the deployment of improved varieties resistant to cassava brown streak disease in East and southern Africa.

Benefits from the Uganda cassava multiplication project to combat the cassava mosaic disease pandemic using the DREAM impact model of IFPRI were approximately US$36 million over 4 years (1998–2001) for an investment of US$0.8 million.

Cassava plant regeneration efficiency through organogenesis was doubled with the addition of 8 mg/l silver nitrate and an increase (0.8%) of agar concentration in the culture medium. Results from flow cytometry and chromosome counts of field-established cassava regenerants showed few abnormalities.

The assessment of pasting profiles and granular characteristics of starch of 11 cassava

clones indicate considerable differences in starch functionality; peak viscosity (181.9–456.3 RVU), setback viscosity (53.6–111.4 RVU), final viscosity (193.3 and 255.1 RVU), pasting temperature (73.6–75.3 °C), and starch granule sizes (9–20 mm, oval, rounded, and truncated). These results provide directions for cassava selection and improvement for cassava starch-based products, and processing variables.

Cumulative cassava leaf litter dry matter production in southern Benin over two 12-month periods ranged from 2.4 t/ha (in a low rainfall year without fertilizer) to 4.1 t/ha (in an adequate rainfall year with fertilizer), indicating the potential of cassava to contribute to maintaining soil properties.

IITA has expanded its collaboration with CIAT, Colombia, to enhance SARRNET's potential to promote expanded utilization, commercialization, and national and regional trade of cassava and sweetpotato. A public–private sector consortium has been formed to provide linkages between research and private sector partners.

A training course for agro-enterprise development was held for 27 participants in Uganda. Over 100 researchers, technicians, and extension personnel in the region were trained in report and proposal writing, rapid multiplication techniques, and postharvest technology of cassava and sweetpotato. SARRNET has provided 16 cassava processing equipment to its member countries for demonstrations to farmers and the private industry.

Project 7: Biological control and functional biodiversity

A major international workshop on biopesticide regulatory frameworks for African countries, jointly organized by IITA and Virginia Polytechnic Institute (VPI) with financial support from the US Agency for International Development (USAID), was held at the IITA Benin station from 29 January to 2 February. Consequently, Comité inter-Etat de lutte contre la sécheresse dans le Sahel (CILSS) established a framework for the registration of biopesticides and Green Muscle obtained temporary sales permission of Comité Sahélien des Pesticides, the last step before full registration in nine CILSS countries.

Biological Control Products (BCP), the South African commercial partner of Lutte Biologique contre les Locustes et Sauteriaux (LUBILOSA), has shipped the first large Green Muscle order to Niger.

In Mali, several NGOs have committed themselves to the regular use of Green Muscle for grasshopper control. Green Muscle will be ordered on a regular basis with the support of donors.

Plutella xylostella granulovirus has been imported from Kenya to Benin, an important step towards improved control of *P. xylostella* in West Africa.

Scientists and government representatives improved their understanding on aspects of biodiversity, biotechnology, and law of the convention of biological diversity and its implementation during a WAFRINET workshop, coorganized with the Global Biodiversity Institute (GBDI).

More than 250 isolates of fungal pathogens of water hyacinth were collected across 3 major river systems in West Africa in different ecological zones.

The impact of classical biological control of water hyacinth and mango mealybug has been studied, demonstrated, and published.

Results of a survey on the distribution of African root and tuber scale *Stictococcus vayssierei* across a range of different vegetation types and non-crop host plant species indicate that this pest can be controlled through appropriate fallow management.

The acquisition and preservation of 19 000 new specimens from faunistic surveys in Benin, Cameroon, Ghana, Nigeria, and Togo collected by IITA's insect museum strengthens its leading position in the provision of taxonomic support to NARES within West Africa.

Project 8: Integrated management of legume pests and diseases

Synthetic sex pheromones of *Maruca vitrata* were used to monitor field populations at 3 locations. In central Benin, a good correlation was found between adult catches in the traps and larval populations in the field, indicating the possibility of using the traps as a tool to time pest control interventions. However, adult catches from both Tamale and Kano were low in spite of substantial field infestations, indicating possible behavioral/physiological differences in migrating *M. vitrata* populations.

The investigation of natural enemies of the cowpea aphid (*Aphis craccivora*) in southern and central Benin revealed spectacular epizootics of the entomopathogenic fungus *Neozygites* sp. in the Ouémé valley which wiped out aphid colonies. The total absence of hymenopterous parasitoids was confirmed, indicating a potential "off the shelf" bicocontrol project.

During 2 consecutive years, the early maturing soybean line TGX 1835-10E was confirmed as moderately resistant to soybean rust (*Phakopsora pachyrhizi*). Some early varieties with relatively shorter pod filling duration had less yield loss in spite of high disease incidence.

A regional adoption survey (120 farm households per country) showed that neem extracts are being used by 7, 32, and 38% of farmers in Niger, Nigeria and Ghana, respectively, and papaya extracts by 47% of farmers in Benin. The constraint is mainly labor intensive processing of leaves. Key factors affecting adoption of cowpea integrated pest management (IPM) are access to extension, profitability, off-farm incomes, farm labor supply, and level of education.

A study of cowpea IPM technologies in Benin revealed that botanical insecticides are more profitable when applied on improved cowpea varieties (high yielding or pest/disease resistant). The net benefits ranged from US$10/ha (local varieties), to US$110/ha (improved varieties), and up to US$200/ha with improved market access.

Farmer field schools (FFS) trained 1112 farmers and 60 NGO and extension agents in cowpea IPM in the 9 PRONAF countries. In northern Ghana farmer-to-farmer diffusion of knowledge following FFS is increasing.

Project 9: Integrated management of maize pests and diseases

A medical epidemiology survey in the southern Guinea savanna of Benin and Togo revealed that 99% of 479 children were aflatoxin positive, 33% showed stunted growth, and 29%

were underweight. Exposure to aflatoxin was correlated with aflatoxin content of maize, maternal education and socioeconomic status, consumption of maize-based weaning food, and number of L-strain *Aspergillus flavus* colonies in the maize.

Aflatoxin accumulation in selected IITA maize inbred lines was tested using a kernel screening assay in collaboration with the laboratory of the US Department of Agriculture (USDA) in New Orleans, and was found to be much lower (< 50 ng/g) than the best US resistant line (> 200 ng/g).

Public awareness campaigns on aflatoxin were launched in Benin, Ghana, and Togo in collaboration with senior national policymakers, ministers of agriculture and of health, representatives of the diplomatic corps, the FAO Regional Office on Post-harvest, and Rotary International.

Larvae of the maize stem borer *Sesamia calamistis* had a much lower survival rate (1.6%) on new advanced inbred lines 10 days after artificial infestation with 60 eggs/plant.

Three strains of *Trichoderma* species—*T. harzianum*, *T. pseudokoningii*, and *T. hermatum*—persisted in maize stalks co-inoculated with the causal agent of maize stalk rot, *Fusarium verticillioides*, in screenhouse tests. These 3 strains reduced stalk rot and were also effective against the pathogen in in vitro tests. The mechanism appears to be hyperparasitism.

Treating maize plants with neem oil at different concentrations in the greenhouse has showed that oviposition by *S. calamistis* was reduced by three-quarters even at the lowest concentration tested.

Project 10: Integrated management of cassava pests and diseases

The exotic phytoseiid predator *Typhlodromalus aripo* continues to persist and further expand its range in 20 countries in sub-Saharan Africa, and is providing effective management of the cassava green mite.

The preference of *T. aripo* for hairy cassava tips was shown to be widespread and food web surveys in Malawi and Mozambique confirmed that *T. aripo* is restricted to cassava and only affects CGM populations.

Two Brazilian isolates of *Neozygites tanajoae* introduced in 1999 into cassava fields in south-eastern and northern Benin to complement CGM biocontrol by phytoseiid predators continued to persist and produce an average of 25% infection levels in CGM populations in several locations.

In collaboration with the University of Arizona, USA, molecular techniques were used to demonstrate the association of a distinct cassava-colonising genotype of *Bemisia tabaci* with the epidemic of severe CMD in Uganda.

Through an emergency CMD management program in East and Central Africa, IITA, with NARES and NGOs, deployed more than 2000 ha of CMD resistant germplasm, introduced 960 elite CMD resistant clones into open quarantine sites in Kenya and Tanzania and 158 clones in tissue culture to Congo Republic, transferred 7 newly released varieties from Uganda to Tanzania, and evaluated the performance of more than 50 clones with farmers in technology transfer centres in Kenya, Tanzania and Uganda.

A preliminary impact assessment study of CMD management work in 6 districts of Uganda estimated a net present value benefit of US$ 36 million shared roughly equally between producers and consumers.

Surveys of the impact of the released predator, *Teretrius nigrescens*, on beetle pests in cassava chip stores in northern Benin, demonstrated reductions in losses from 45 to 91% in untreated to 15–70% in treated stores.

In addition to cassava, the noncultivated plants *Aframomun danielli*, *Costus afer*, and several wild yam species were identified as common hosts of the African root and tuber scale, *Stictococcus vayssierei*, in fallow and young forest vegetation in western and southern Cameroon.

Project training activities included the completion of 3 MSc and 1 PhD study programs; cassava IPM training of extension workers (and farmers) as follows: 15 (20) in Guinea, 10 (2100) in Kenya, 20 (95) in Malawi, 1000 in Tanzania, 10 (50) in Togo, and 29 (250) inUganda; the distribution of 300 sets of cassava IPM manuals in Kenya, Tanzania, and Uganda; and the development of an educational leaflet for *T. aripo* conservation.

Project 11: Protection and enhancement of vulnerable cropping systems

In the forest margins benchmark area (FMB), annual maize production in a *Mucuna/ Pueraria* cover crop/relay system was sustained for 5 years at 2.5 Mg/ha. Maize grain yields after *Mucuna* var. *jaspaeda* were the highest over 3 consecutive years over other *Mucuna* varieties.

Three soybean varieties were identified for various farmer circumstances in the FMB. High nodulation was observed in shorter fallow areas, with consequent higher yields. Farmers in the northern benchmark, where yields exceed 1000 kg/ha without inputs, are now adopting soybean.

In a study in the northern Guinea savanna and derived savanna benchmark areas to identify target options for herbaceous legumes, farmer participation doubled over the previous year. Four field days involving some 130 farmers were held, and new methodologies tested during farmer workshops.

Some 280 kg of herbaceous legume seed consisting of 117 seedlots were distributed to IARCs, NARS, and NGOs.

Successful stakeholders' workshops on weed management strategies were realized in Zaria and Makurdi. Steering committees on *Striga* and *Imperata* were formed to coordinate research. Two seed companies and the Nigerian Participatory Rural Appraisal Network agreed to assist with workshops and scaling up activities.

Mucuna was shown to suppress speargrass by reducing available solar radiation and other mechanisms.

The Rockefeller Foundation provided a grant to research the effect of genotype and environment on the concentration of L-Dopa in *Mucuna* seed and other plant parts.

For the 2001 growing season, research and development projects in Benin have purchased more than 2000 kg of *Mucuna* from Centre d'information et d'exchanges sur les plantes de

coverture en Afrique (CIEPCA). The CIEPCA newsletter was produced and posted on the Web, and 4 issues of *Mucuna News* have been produced.

A standpoint survey found *Acacia auriculiformis* woodlots to be the most popular soil fertility enhancing technology coming out of 10 to 15 years of work on improved fallows in southern Benin.

Project 12: Improvement of high-intensity food and forage crop systems

On-farm trials conducted from 1999 to 2000 in 19 *Striga hermonthica*-infested fields in the dry savanna agroecozone of Nigeria showed that integrated *S. hermonthica* control was highly effective, in comparison to traditional practices, both in reducing *S. hermonthica* incidence by more than 70% and in increasing maize grain yields by more than 60%.

Maize herbicide evaluation trials conducted in Ibadan and Ilorin showed that postemergence application of nicosulfuron at 50 to 400 g a.i./ha resulted in lower *Imperata cylindrica* biomass (4 to 19 g/m^2) than in the unweeded control plots (63 g/m^2) at crop harvest. The effect of weeding 5 times on *I. cylindrica* biomass was equivalent to that of nicosulfuron at rates of 200 to 400 g a.i./ha.

Comparative economic evaluation and appropriate technology targeting of 10 legume rotation treatments showed that the grain legume and dual-purpose varieties gave cumulative net benefits ranging between US$914 and US$1233, an increase of over 150% above the least profitable system at Ibadan fertile derived savanna (DS) site. The same trends were observed in the northern Guinea savanna (NGS) where the most profitable system outperformed the green manure system economically by over 500%.

The monitoring of N and P in Zouzouvou, DS in Benin, indicates that the N balance was negative. N exports through harvest products and removal/burning of crop residues constituted the largest loss term. The annual P balance ranged between a surplus of 42 kg P/ha and a deficit of 30 kg P/ha.

Preliminary maize yield data for the on-farm, farmer-managed demonstration trials confirmed earlier findings that maize grain yields in the sole fertilizer treatment were similar to yields in the mixture treatment in which about 40% of the fertilizer N was substituted by manure. Farmers' practices led to about 30% lower yields than in both other treatments.

Growing maize after soybean resulted in significantly higher grain yield (1.2 to 2.3-fold increase compared to maize control) except for the maize cultivar Oba Super 2 (8644-27) (an N-efficient hybrid).

Project 13: Integrated perennial and annual cropping systems

Efforts to establish tree-based assets on deforested land in southern Cameroon continued. The cocoa hybrids from Côte d'Ivoire have demonstrated significantly superior establishment vigor and growth and 3 of the 4 hybrids had a significantly greater number of flowers relative to the landraces and local hybrid. The survival of all cocoa seedlings through the second dry season was significantly greater when integrated with shade providing plantain (*Musa* spp.).

In a remote area of the southern Cameroon Atlantic rainforest, the Sustainable Tree Crops Program (STCP) and its partners assisted about 200 small cocoa producers to create a farmers' union of village-based organizations. Cocoa marketed through the union in its initial year yielded 33% higher price than cocoa marketed individually and inputs purchased by the union were bought at a 7% discount. The lessons learned from this are being used by STCP and its partners to reinforce farmer organizations throughout southern Cameroon and West Africa.

An on-farm experiment evaluated the productive capacity of a mature cocoa agroforest after a 2-year abandonment with particular focus on the management of the fungal blackpod disease, the most important constraint to production. Two levels of fungicide treatment were applied and compared to a no fungicide control. A yield of over 300 kg/ha was obtained which is in excess of the average yield for this part of southern Cameroon. Yield at the no fungicide control was less than 50 kg/ha indicating the importance of the constraint.

An on-farm experiment in southern Cameroon compared the decomposition rates in 4 types of land use—the complex cocoa agroforest, forest, *Chromolaena odorata* fallow land, and *Imperata cylindrica* fallow land. The conclusion is that the cocoa agroforest retains more ecosystem functionality when compared to short fallow cropping land-use systems.

Project 14: Impact, policy, and systems analysis

A household expenditure survey in 4 cities of the forest zone of Cameroon confirmed that demand prospects for domestic products (yam, plantain, cassava, maize, and sorghum) are high because they are more desired by urban dwellers than imported products such as rice.

A new micro "Market Information Systems" model developed by FOODNET, with support from the Technical Center for Agricultural and Rural Cooperation (CTA), disseminates the information to about 5 million people in 8 districts of eastern Uganda.

An efficiency analysis of about 560 mixed crop–livestock farms in the northern Guinea savanna of Nigeria showed that the 10% most efficient farms were smaller in size, experienced high pressure on land, were managed by younger farmers, and had higher integration between crops and livestock.

A new, easy, and quick "GPS transect walk" method was successfully tested to quantify the spread and intensity of the adoption and adaptation processes of "best bet" cowpea technologies in the savanna zone of Nigeria.

Positive effects of technological change and policy on the profitability of cowpea systems were found in Couffo département, south Benin Republic. Financial returns for systems with an improved cowpea variety and botanical insecticide (Neem) to control pest in storage generated a bonus of CFA92250/ha over systems without an improved variety. An additional gain of CFA59305/ha was recorded for systems with improved variety and Neem and located in areas with good road infrastructure.

A landscape model of human and land resources for the forest margins was developed in Cameroon. The model links the "human" side and the "land" side through land tenure systems and combines geo-positioning system (GPS), socioeconomic, and biophysical data in a GIS system.

The capability for the application of GIS techniques by IITA and NARS has greatly improved through special training of 61 scientists in eastern and West Africa. Refresher courses were held for 20 NARS scientists in West Africa on advanced methods for impact and economic analyses while 8 local manufacturers in Tanzania were trained in the maintenance and repair of processing equipment.

SP-IPM

Characterized the agronomic, socioeconomic, and epidemiological features of whiteflies and whitefly-transmitted viruses in cassava, legumes, and sweetpotato in Latin America, Africa, the Caribbean, and Mexico, and initiated strategic research to develop appropriate IPM options.

Developed vision of farmer participatory research (FPR) and participatory learning (PL) to advise on what would need to be done differently at the level of farmers, community organizations, extension workers, researchers, and policymakers if FPR/PL were to be successful in IPM.

Recorded significant yield gains by farmers at 6 pilot sites in Africa where intercropping, habitat management, crop rotation schemes, and pest-tolerant crop varieties were introduced as best-bet IPM options to control the parasitic weeds *Striga* and *Orobanche* in maize–legume cropping systems. The participatory approach and processes at the sites assisted organizations to develop effective partnerships to increase the understanding and adoption of IPM options.

Increased public and donor awareness of the benefits of IPM through information materials including news stories, a brochure, and a CD-ROM of information resources.

Annex 4

Map of agroecological zones