Project 6

Improving cassava-based systems

Annual Report 2000

International Institute of Tropical Agriculture

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 6
Improving Cassava-based Systems

by V. Aggarwal, M. Andrade, M.T. Ajayi, M. Bokanga, R. Carsky, D. Chikoye, K. Dashiell, A. Dixon (project coordinator), A. Ebert, S. Ferris, M. Gedil, O. Ghebreyesus, R. Hanna, J. d'A Hughes, I. Kasele, S. Kolijn, D. Keatinge, W. Khizzah, A. Larbi (ILRI), J. Legg, V. Manyong, B. Maziya-Dixon, H. Mignouna, S.Y. Ng, S. Nokoe, N. Sanginga, J. Teri, G. Tian, M. Toko, J. Wendt, J.A.Whyte.

Project Goal

To develop, evaluate, and promote improved and adapted cassava germplasm, for the lowland and mid-altitude agroecological zones of sub-Saharan Africa, to develop agronomic and other practices to ensure sustainable cassava production and utilization, and to develop, evaluate and promote improved postharvest technologies for expanded utilization and commercial systems. Interaction with national programs is fostered through long-established links in West and Central Africa, two root crop research networks (EARRNET and SARRNET) covering East and Southern Africa, and cassava research at the East and Southern Africa Regional Center (ESARC) in Uganda.

Project Highlights

Additional 30 selected genotypes of cassava with multiple resistance to cassava mosaic disease (CMD), bacterial blight (CBB), anthracnose (CAD) and green mite (CGM) as well as acceptable agronomic and end-users characteristics for various agroecologies were pathogen-tested and certified for distribution. Currently a total of 438 virus-tested genotypes are available for international distribution, representing about two-fold increase from that of 1995. Eighteen other genotypes are at various stages of the cleaning up process.

More than 20,000 cassava in vitro plantlets were produced for distribution, ministake production, and use as stock cultures. Over 3,500 of the plantlets were distributed in 10 shipments to NARS collaborators in five countries and to CIAT in Colombia, and more than 1,000 certified ministakes were delivered to Sierra Leone, marking the first delivery of certified cassava ministakes from IITA. In addition, 219,733 seeds, covering 1,120 families of broad-based and special trait populations were distributed to national programs in 6 countries. IITA also received 2,923 seeds collected from local landraces constituting 61 families from Mozambique as part of an effort to exploit favorable traits in African landraces, including resistance to CMD and cassava green mite.

Sourcing seeds from the broad-based germplasm at IITA headquarters, Ibadan, EARRNET/ESARC continues to identify increasing number of clones with high dry matter (>40%) and low cyanogenic potential at its major regional evaluation sites of the midaltitude agroecology. Clones MH97/2006, MM96/3474 and MH97/1395 had DM of 50% while MH97/1463, MH97/1690, MH97/2257 and MH97/2471 had CNP score of 1. At Mtwapa, Kenya (the lowland ecology), two thousand four hundred and one clones showing multiple resistance to the major diseases and pests including cassava brown streak disease (CBSD), and good quality characteristics were selected for further evaluation.

The Government of Uganda officially released three additional CMD-resistant cultivars of IITA origin as NASE 10, NASE 11 and NASE 12 (MH95/0414). NASE 12, a selection under high CMD and the Ugandan variant of CMD (UgV) infection pressure at the ESARC regional germplasm program for the mid-altitude ecologies, has consistently shown no symptom of the diseases (score of 1) indicating near immunity, and it has excellent cooking quality, low cyanogenic potential and good agronomic characteristics in addition to multiple pest resistance. Over 100,000 ha of improved CMD-resistant cultivars of IITA origin is now grown by farmers in Uganda. In Western Kenya, cultivars SS4 and Migyera continued to be multiplied at primary (79ha.), secondary (31ha), and tertiary (339ha), respectively. A total 2,395,000 planting stakes required to plant about 450 hectares have been distributed from the 7 initial primary sites. In Rwanda, cassava planting material has been generated from five secondary sites to plant about 200 ha.

In collaboration with the Institute of Plant Sciences (ETH), Switzerland, organogenesis based-cassava regeneration system has been successfully transferred to IITA and used to regenerate for the first time a wide range of African cassava germplasm. Cyclic somatic embryogenesis, organogenesis, and plant regeneration were achieved in more than 10 selected African cassava germplasm (8 African cassava landraces and 4 improved genotypes). In addition, the highest transient GUS expression was obtained with the combination of the landrace TME 8 and GV3101 when the compatibility of four *Agrobacterium* strains with three African cassava landraces was screened. The regenerated plantlets have successfully been established in the field with a survival percentage ranging from 60% to 100%, and so far, no abnormalities were observed in these plants. Antibiotic sensitivity study using five cassava genotypes also showed that at 15 mg/l hygromycin in the culture medium, both callus and shoot bud formation were arrested. Information obtained from these studies will serve as a basis for future transformation studies.

Collaborative work with the International Center for Tropical Agriculture (CIAT) has shown that a dominant gene (*CMD 2*), controlling a new source of resistance to CMD and different from the most extensively used gene for resistance to CMD derived from interspecific hybridization, is flanked by the SSR and a RFLP marker, *rGY11* and *rSSRY28*, at 9 and 8cM, on linkage group R of the male-derived molecular genetic map of cassava. The groundwork to isolate *CMD2* by positional cloning, using candidate genes and BAC contigs in Nigerian cassava land races is being undertaken.

Bulk segregant analysis made up of 10 most resistant and 10 most susceptible F1 progenies derived from the cross TMS 30555 (susceptible) x TME 7 (resistant) were screened with 140 RAPD, 150 SSR, and 104 AFLP primer combinations (64 combinations of EcoR1/Mse1 +3 primer pairs and 40 combinations of Apa 1/Taq 1 +3 primer pairs), and only one SSR primer consistently showed distinct differences between the resistant and susceptible plants, after screening the members of each bulk, the parents and the entire mapping population. Regression analysis indicated that this marker contributed 59% of the total variation in the population for resistance to CMD. The primer was then used to screen 23 cassava clones with varying levels of resistance to the disease, to confirm its usefulness as a marker associated with resistance to CMD, and the results showed difference between some resistant clones and TME7 with respect to that marker. The resistant clones 58308 and TMS 30572 (extensively used sources of resistance in the breeding program) and TME 8 did not have this marker suggesting that different genes may control resistance to CMD.

Six genotypes (30572, 30001, 91/02324, 92/0427, 92/0057 and TME 1) evaluated in the field for resistance to root rot disease under natural infestation at 6, 9, 12 and 15 months after planting showed that at 6 and 9 months, there was no significant difference in the reaction of the genotypes to root rot. At 12 and 15 months the genotypes differed significantly in their reactions to root rot and there was a significant increase in the percentage root rot with increase in plant age. The rate of increase in percentage root rot was higher in TME 1 and 92/0057 than for the other genotypes.

Two components of the cassava market survey (market chain and industrial uses) in Uganda were completed and the result are being used to devise the research agenda in Uganda based on market opportunities and potential to engage partners in new areas of research such as collective marketing with producers, development of trade associations and also public-private sector consortia. In addition, the cassava-based processing equipment developed at ESARC were technically reviewed in collaboration with FAO and a web-based catalogue on prices, fabricators, output, numbers of equipment sold and technical drawings of these equipment are being compiled.

To expand the marketing opportunities available to smallholder farmers, reduce their dependence on traders, improve the quality of intermediate cassava products and encourage take-up of cassava as input by a variety of end-users, a pilot processing plant in western Kenya has been initiated with the installation and testing of five processing equipment (manual chipper, manual and motorized graters, screw press, hammer mill) and tested.

A website (www.cgiar.org/foodnet) established for the food network of East Africa (FOODNET) to avail regional partners with information about current events in the network and to provide a site for collating project and associated research and development (R&D) information has been taken as the template for the recent construction of 14 regional network websites, which comprise the ASARECA portfolio.

The capability of NARS and NGOs to undertake cassava research and development was enhanced through three training workshops on cassava processing techniques; report and proposal writing; and cassava mosaic disease monitoring and diagnostics; as well as courses on rapid multiplication of cassava; commercialization and enterprise development for cassava and sweet potato planting materials production and distribution; cassava and sweet potato processing, products and market development; monitoring and impact assessment of root crop technologies; and virus elimination and detection for 123 technicians, extension workers and researchers in East and Southern Africa.

Project Rationale

Cassava provides more than half of the dietary calories for over 200 million people in sub Saharan Africa (about half of the total population). It also contributes substantial amounts of protein, minerals (iron and calcium) and vitamins (A and C) through consumption of the leaves. It is Africa's food insurance: it gives stable yields even in the face of drought, low soil fertility and low intensity management. It can remain in the soil until needed, spreading out food supply over time, helping avert the tragic "boom and bust" cycle of oversupply that is followed by famine. The low input requirements of cassava in particular and its ability to survive the devastation of drought and armed conflicts have made it thrive where other crops have failed. As a low cost carbohydrate source, cassava thus plays a food security role. In addition, data collected by the Collaborative Study of Cassava in Africa (COSCA) in 563 villages scattered across 11 countries, which account for over 80% of cassava production in Africa, have shown that cassava generates cash income for the largest number of households in comparison with other staples. Potentially, cassava is therefore a cash crop rather than a subsistence crop in Africa.

IITA's founders invested in crop improvement on the premise that tropical food crops, had received insufficient research attention and would probably show a large response to dedicated efforts in crop improvement. This hope was borne out in cassava, as much higher yielding, pest-resistant cultivars (particularly to bacterial blight and mosaic disease) were quickly developed and rapidly adopted by farmers wherever planting material became available.

However, the increase in population and competition for land in SSA calls for innovations in food production and utilization technologies. The trends in the socio-economic as well as the physical environment in Africa favor the increased production of cassava. As cassava production expands, there is equally the need for expansion of utilization and commercialization to make a range of food, feed, and industrial products from cassava quantitatively and qualitatively competitive with other high energy foods and imported items. Increased reliance on it as an energy food and its entry in the animal feed and in other industrial applications will provide incentives that will motivate farmers, processors and consumers to expand production and utilization, respectively.

Despite the proven track record in cassava improvement, many challenges remain. Diseases (cassava mosaic disease, bacterial blight), insects (mealybug, grasshoppers, termites), mites (green spider mite, red spider mite) and nematodes still take their toll, occasionally in epidemic proportions in both traditional and new areas of production. As environments in which cassava could be cultivated are impoverished by overuse or devastated by new diseases or pests, there is the urgent need to protect and broaden its genetic base in order to ensure food security in the future. The early introductions made by the Portuguese in the 1500's in West Africa and in the 1700's in East Africa were not ample enough to transfer into Africa the wide genetic base existing at the center of origin of the species. Germplasm introductions from Latin America and its utilization in partnership with CIAT are needed to further broaden the germplasm base of cassava by providing unique sources of variability not currently available in Africa. There is even more need than ever to tap available gene pools, particularly those adapted to harsh environments. In addition, most of our earlier breeding work was carried out in the lowland humid tropics. Germplasm adapted to the other agroecologies is also needed, particularly the cool mid-altitude and the dry savannas. Also, the considerable diversity of African cassava cultivars is yet to be fully exploited, particularly to tap on the genes for resistance to the major pests and diseases as well as the preferred food quality characteristics and plant architecture.

The high water content of the root, and associated spoilage and high transport costs make post-harvest processing laborious and costly. Also, the cyanogenic potential of the crop could pose a health risk if the content is high and the roots are not properly processed before consumption, and if the nutritional status of the population is poor. Availability of high quantity and quality dry and safe products with long shelf life is necessary to support the development of cassava-based agro-industries.

The biochemical and biophysical basis of biotic and abiotic stresses, culinary and nutritional quality and cyanogenesis, yield physiology and stability, as well as attributes of adaptation need further investigation. The genetic basis and inheritance, as well as the mechanisms and environmental influences of these important attributes are also largely unknown. Specific genotypes targeting end-uses in the animal, starch, confectionery, textile and pharmaceutical industries are yet to be identified and adopted in Africa. Cassava genotypes with different flour characteristics for various end-uses are needed. Cassava leaves are also preferred vegetable in many countries but lack of continuous assessment for their food and feed quality attributes has slowed efforts for improvement. The suitability of the leaves (foliage yield and digestibility) of cassava genotypes, and utilization of residues (e.g. leaves, peel) for the livestock sector need to be exploited. Increased utilization in animal feed, starch, confectionery, textile and pharmaceutical industries can reliably be ascertained with improved and constant supply of cassava. In addition, biotechnological tools, where appropriate, would be applied for more rapid and efficient cassava improvement.

Finally, our system of germplasm exchange, building institutional capacity and collaborative research with the National Agricultural Research Systems (NARS) and Advanced Research institutes, as well as a sustainable system of multiplication and distribution of clean planting materials need to be intensified in order to align better with our partners and ultimate beneficiaries, the African farmers.

Outputs

6.1 Source populations for traits of major importance to cassava production and food systems in sub-Saharan Africa

Background

Using new diversity effectively requires extensive intercrossing and selection. The wide range of target agro-ecologies, farming systems, utilization patterns and consumer preferences for cassava in SSA demands that a number of different recombining populations will have to be handled. Back-up special populations are essential as feeders of agroecologically broad-based populations.

On-going and future activities

6.1.1 Development and improvement of special trait populations

by A.D., J.A.W., W.K. - in collaboration with M.B. and B. Maziya-Dixon

Satellite back-up populations for multiple pest resistance, low cyanogenic potential (CNP) and culinary quality (mealiness), nutritional quality (zinc, iron and ß-carotene enriched roots) and high dry matter (DM) continue to be improved through hybridization, evaluation, selection and recombination. Several crosses and backrosses were made for these special trait populations in Nigeria in 2000 (Table 1) for evaluation in the 2001 seedling nursery. In addition, the introduction, evaluation, and utilization of germplasm from Latin America continued in 2000, in collaboration with CIAT. Several crosses, incorporating resistance to cassava mosaic disease (CMD), were made between African adapted gene pools and earlier introductions from Latin America. Selected individuals or families from each cycle of selection can be used as sources of new cultivars at any stage in the selection program or incorporated into elite breeding populations.

Table 1. *Seeds obtained from controlled hybridization in Nigeria in 2000*

Crosses	No.of seeds	No. of families
African adapted germplasm x Latin American Germplasm		
Latin American germplasm x IITA's earlier and newly improved germplasm	19 099	1102
IITA's earlier and newly improved germplasm x Latin American germplasm	2780	162
African Landrace introgression		
African landraces (2*x*) x African landraces (2*x*)	5273	29
African landraces (2*x*) x IITA's improved clones (2*x*)	7886	212
Poundable crosses		
IITA's improved clones x Low cyanide and poundable African landraces	179	10
IITA's improved clones x Low cyanide and poundable African landraces	261	16
Low cyanide and poundable African landraces x IITA's newly improved clones	74	8
IITA's earlier improved clones x Low cyanide and poundable African landraces	1927	128

6.1.2 Improvement of polyploid population

by A.D. - in collaboration with J.A.W., W.K.

Ploidy manipulation gives breeders versatility in moving genes between ploidy level and between related species. Polyploid breeding in cassava has opened up new and often unexpected avenues in plant breeding and genetics with new chromosomal structures, new genetic expressions, new breeding methods and new cultivars. Since cassava is a vegetatively propagated crop, polyploid cassava can take advantage of vigor due to heterosis effects which can be optimized by maximum degree of heterozygousity at three of four different alleles at a locus, and last permanently, provided that no somatic mutation occurs in the cultivars.

Hybridization between spontaneous cassava tetraploids with low dry matter percentage (DM%) and improved diploid cassava genotypes with high DM% have resulted in the selection of triploid genotypes with very high fresh root yield, but low DM%. The success of polyploid breeding in cassava, lies in the efficient production of improved triploids with desirable traits. This can be achieved by crossing the improved sexual and asexual tetraploids with improved diploids of different genetic backgrounds. Such combination exploits high heterosis and brings about the optimum ploidy level required for high yield potential. Ploidy manipulation through unilateral and bilateral polyploidization and somatic polyploidization continues to be implemented for the diversification of the polyploid gene pools of cassava to enhance further improvement. In 2000, additional tetraploid x tetraploid crosses resulting in 28 families and 388 seeds were made in Ubiaja among somatic and sexual tetraploids of improved clones and African landraces for evaluation in 2001.

6.1.3 Evaluation for storage root formation and screening for high protein content in cassava

by A.D. A.L. M.G. - in collaboration with M. Fregene.

Cassava root is a major source of energy in human and livestock diets in the tropics, while protein is the most limiting nutrient. Identifying cassava clones with higher storage root protein content could improve the protein to energy ratio in diets of millions of people and their livestock.

Hybridization between a low cyanide cultivar 94/0239 and a wild *Manihot* species (*Manihot tristis*), known to contain about 6 to 8%, provided 6,000 true seeds which were evaluated in the seedling nursery in 1999. In January 2000, the seedlings were harvested, and only 74 plants, which produced storage roots, were planted in a clonal trial and harvested at six month after planting. Samples of peeled storage root of the genotypes were oven-dried and ground to pass through 1 mm screen for N determination and conversion to protein content. Total storage root protein content among the genotypes ranged from 1.4 to 5.8%. Nine of the genotypes had protein content greater than 3 %. Of these 9 genotypes, fresh root yield ranged from 1.6 to 17.6 t/ha, DM% ranged from 21 to 39%, root size ranged from small to big, and CMD reactions ranged from a score of 1 (resistant) to 3 (moderately susceptible), while and CGM reactions ranged from a score of 2 (moderately resistant) to 5 (highly susceptible). These genotypes were planted for further evaluation.

The extent of variation in storage root protein content was also assessed in the cassava breeding collection and advanced trials. Total storage root protein concentration varied widely among the genotypes of the various trials. The mean, minimum, maximum and standard deviation of the various trials are shown in Table 2. Three of the trials (UYT (Multiple Pest Resistance 1), UYT (Poundable), and UYT (Yellow Roots) had the highest mean and maximum protein content. The genotypes in these specific trials will be further assessed in 2001 to confirm the results of 2000.

Table 2. Variation in protein content (%) of storage roots of cassava in various trials (1999/2000)

Trial	N	Min	Max	Mean	SD	Skewness
Improved germplasm collection	375	0.00	6.63	2.13	0.95	1.57
Local germplasm collection	181	0.00	4.13	1.94	0.70	0.01
UYT (Low cyanide)	20	1.28	3.81	2.09	0.59	1.19
UYT (Landraces)	26	0.88	2.50	1.78	0.37	-0.25
UYT (Multiple pest resistance 1)	25	2.13	7.13	4.43	1.25	0.49
UYT (Multiple pest resistance 2)	30	1.19	2.19	1.70	0.24	-0.25
UYT (Multiple pest resistance 3)	20	1.44	3.59	2.18	0.60	0.80
UYT (Poundable)	20	2.81	4.47	3.68	0.47	-0.19
UYT (Tetraploid)	25	0.78	2.53	1.97	0.37	-1.20
UYT (Triploid)	30	1.28	2.78	1.98	0.37	0.11
UYT (Yellow root)	25	1.47	6.06	3.83	0.92	0.03
Genetic Gain	157	0.38	3.88	1.75	0.77	0.91

6.2 Broad-based populations targeted for the major production agroecologies

Background

The specificity, and, or limited adaptation of cassava cultivars due to their high sensitivity to genotype-by-environment (GE) interaction, and the wide environmental variability in the agroecological zones of sub-Saharan Africa called for different objectives in various agroecologies. The development of broad-based populations in different agroecologies would provide the necessary genetic variability with high frequency of desirable genes for agronomic characteristics, consumer quality characteristics, and pest and disease resistance to suit the target systems and end-users. Development of a series of cultivars specifically adapted to different ecological conditions is an efficient breeding strategy that would enhance genetic diversity and expand productivity. Moreover, broad-based gene pools provide sufficient genetic variance in source populations from which selection is practiced for desirable genotypes and progress from selection is maintained.

On-going and future activities

6.2.1 Development and improvement of broad-based populations

by A.D., J.A.W., W.K., I.K. - in collaboration with M.B. and NARS

Drawing on progress made in genotypic adaptation, and the increased capacity of both IITA and National Agricultural Research and Extension Systems (NARES) in the region, emphasis was given to the continuing maintenance and improvement by recurrent selection of broad-based cassava populations through evaluation, selection and recombination of elite genotypes suited for multiple end uses and for adaptation, targeting four major agroecologies (humid forest, forest transition combined with southern Guinea savanna, northern Guinea savanna combined with the Sudan savanna and the midaltitude agro-ecosystems).

In the humid forest zone, selection emphasizes tolerance to high soil acidity, low soil phosphorus and low solar radiation as well as resistance to CGM, CMD, CBB and CAD. In the forest-transition and southern Guinea savanna zones, soil constraints are fewer but selection for resistance to CGM, CMD, CBB and CAD is still important. In the mid-altitudes, initial vigor and rapid growth under cold air temperatures as well as resistance to CBB, CMD and tip die-back take priority. For the Northern Guinea and Sudan savanna zones, types are sought which survive under severe water stress, show high initial vigor and growth rate, and good leaf retention (stay-green) under drought; and secondarily, resistance to pests and diseases. For all agro-ecosystems these desired traits are sought in a background of good agronomic and eating quality. Selected superior individuals or families from any cycle of selection are candidates for advanced testing and distribution to National Agricultural Research Systems (NARS).

The standard selection scheme for germplasm evaluation starts with a seedling nursery at one breeding site within an agroecology. Selections from these nurseries are cloned and evaluated in successive trials - preliminary, advanced and uniform yield trials. With each evaluation, selection is made for performance with respect to ecological adaptation, reaction to pests and diseases and quality of the produce at each site. At the uniform yield trial stage more than one location is used as testing site within the agroecology. The selection scheme also provides for the progressive multiplication of planting material starting from one seedling in the nursery.

Evaluation and selection schemes were established in all breeding sites in 2000. The trials harvested in 1999 were subjected to selections and advanced to the next selection stage. Many clones have reached the most advanced stages. These improved genotypes (in vitro plantlets and seed populations) with acceptable agronomic and end-user characteristics and very high levels of multiple resistance to CMD, CBB, CAD and CGM are distributed to our NARS partners for testing under local environmental conditions.

Increased attention continued to be given to ESARC's cassava germplasm enhancement and development activities of East and Southern Africa. Sourcing from the broad-based germplasm at IITA Headquarters, ESARC in Uganda continues to identify clones with high dry matter (> 40%) and low cyanogenic potential at its major regional evaluation sites of the midaltitude agroecology. Clones MH97/2006, MM96/3474 and MH97/1395 had DM of 50% while MH97/1463, MH97/1690, MH97/2257 and MH97/2471 had CNP score of 1. From a total of 127 clones which were screened for CMD resistance in various trials (clonal evaluation (42), Preliminary Yield Trial (42), and Advanced Yield Trial (43), 28 clones (approximately 23%) did not show any disease symptoms.

Three clones (TME 14, 95/SE-00087 and I91/2327) out of 13 clones evaluated in multilocational trials in 4 locations in Uganda (Namulonge, Masafu, Kumi, and Kigumba) with farmers' participation, combined good storage root quality, high yield and high levels of resistance to CMD, and were selected for more extensive on-farm trials.

At Mtwapa, Kenya (lowland ecology), 2401 clones with multiple resistance to the major diseases and pests, including CBSD and good quality characteristics were selected for further evaluation.

At Alupe, Western Kenya, the fresh root yield ranged from 0.7 t/ha in MM96/2673 to 32.2 in MM96/3665 in the clonal evaluation trial of recent clonal introductions, and from 7.7 in MM96/5739 to 37.6 in MM96/4570 in performance 1 evaluation trial (Tables 3). In the clonal evaluation trial, over 42% of the clones had equal to or higher than 40% dry matter. In the performance 1 evaluation, most clones had % dry matter ranging from 36 to 45%. MM96/3900 had the highest estimate of 46.1%. With regards to cyanogenic potential based on the picrate test and on a scale of 1-9, 70.2 % of the clones were classified as low (score of 1-4), 29.2 % as medium (5-6) and only one clone MM96/2103 was classified as high. Eighty-six clones from the performance 1 trial were advanced to multilocational trials at four locations (KARI-Alupe, Siaya farmer training center at ICIPE station in S. Nyanza, Oyani sub-center of KARI Kisii and RRC Kakamega).

Also in 2000, the Government of Uganda officially released three additional CMD-resistant cultivars of IITA origin as NASE 10, NASE 11 and NASE 12 (MH95/0414). NASE 12, a selection under high CMD and the Ugandan variant of CMD (UgV) infection pressure at the ESARC regional germplasm program for the mid-altitude ecologies, has consistently shown no symptom of the diseases (score of 1) indicating near immunity, and it has excellent cooking quality, low cyanogenic potential and good agronomic characteristics in addition to multiple pest resistance.

About 316 clones were introduced in Zimbabwe in the form of certified tissue culture plantlets (1-10 plantlets per genotype) from IITA in February 1998 and established in the field in August 1998. These were harvested in November 1999 and evaluated for cyanogenic potential. Sixteen cultivars with cyanogenic potential ranging from 1.64-5.08 mg HCN/100 g fresh weight of roots (Table 4) were established in November 1999 in an evaluation plot at two locations (Panmure and Chiredzi). After harvesting, selected cultivars will be established at four locations for participatory evaluation and selection. The same set of cultivars has been established in Swaziland at Big Bend for evaluation and selection. Disease and pest infestation were negligible. However, there was variation in leaf retention and stay green ability during dry and winter periods (Table 1). Five cultivars (I92/0342, I92/0057, I30001, M86/00186, I91/023224) retained most of their leaves with a score of 1, three cultivars (I4(2)1425, I92/0326, and 9102822) scored 2, three cultivars (TME2, 92B/0061, and I60142) scored 3 while others scored 4 or 5.

Table 3. Summary of the yield data collected at Alupe, Western Kenya (1999-2000)

Parameter	Clonal characterization			Performance evaluation		
	Min.	Mean	Max.	Min.	Mean	Max.
PltHt[a]	90.0	151.0	210	127.5	182.4	22.8
BraHt[b]	20.0	54.7	145	32.5	66.2	151.0
BraLvl[c]	3.0	3.6	5	2.0	3.4	5.0
MktNo[d]	2.0	19.4	62	7.0	22.0	40.0
nMktNo[e]	0.0	8.8	38	1.0	10.0	39.0
MktWt[f]	0.7	9.9	29	3.0	9.3	17.3
nMktWt[g]	0.0	1.3	4.9	0.2	1.8	3.9
TbNo[h]	2.0	28.1	96	8.0	32.0	63.0
SRPlt[i]	2.0	6	14	2.0	7.0	13.0
TbWt[j]	0.20	0.41	0.75	0.19	0.36	1.69
DM[k]	27.3	39.6	53.7	32.3	39.7	46.1
Yield (t/ha)[l]	0.7	11.2	32.2	7.7	21.0	37.6
Dyield[m]	0.3	4.6	13.6	3.0	8.3	14.9
Cnp[n]	-	-	-	2.3	3.7	6.3

[a]Plant height; [b]Branch height; [c]Levels of branching; [d]Number of marketable storage roots; [e]Number of non marketable storage roots; [f]Weight of marketable storage roots; [g]Weight of non marketable storage roots; [h]Number of storage roots; [i]Number of storage roots per plant; [j]weight per storage root; [k]Dry matter (%); [l]fresh root yield (ton/ha); [m]Dry yield (ton/ha), [n]Cynogenic potential

Table 4. Cyanogenic potential and leaf retention during winter of selected genotypes from IITA

Genotype	Cyanogenic potential (mg HCN/100 g fresh weight of roots	Leaf retention score during winter*
I 30001	5.06	1
I 60142	1.66	3
I 4(2)1425	4.44	2
I 92/0057	2.28	1
I 91/02327	5.08	4
I 91/02324	3.75	1
I 92/0326	2.02	2
92B/00061	4.33	3
I 92/0067	2.28	1
M 86/00106	3.26	1
I 63397	1.66	5
I 4(2)1443	3.83	5
I 92/0342	1.64	1
TME2	3.51	3
TME1	2.61	3

* 1=high leaf retention and 5 =complete defoliation

6.2.2 Screening breeding populations and local germplasm collections for resistance to relevant pests and diseases in various agroecologies

by scientists named in each subsection

Cassava root rot fungi in Nigeria, variability in *Botryodiplodia theobromae* isolates and evaluation of cassava germplasm for resistance to root rot

by A.D. - in collaboration with E.J.A Ekpo and T.J. Onyeka.

A georeferenced survey of farmers' fields in 16 states across the humid forest and moist savanna agroecological zones (major cassava growing ecologies) was carried out between November 1998 and September 1999 to determine the distribution of cassava root rot disease in Nigeria. Field and laboratory experiments were carried out at IITA, Ibadan to: (i) evaluate the relative importance of the various root rot pathogens associated with cassava, (ii) assess the variability in the population of the most important pathogen of cassava root rot disease, (iii) assess different laboratory assays for evaluating cassava genotypes for resistance to root rot disease, (iv) evaluate the reactions over time of selected cassava genotypes to root rot disease on the field, and (v) evaluate the local and improved cassava germplasm collection for resistance to root rot disease.

Cassava root rot disease symptoms were widely distributed in the two agroecologies. A complex of fungal pathogens were isolated and the pathogenicity of *Botryodiplodia theobromae, Nattrassia mangiferae, Fusarium spp* (*F. solani* and *F. oxysporum*), *Aspergillus niger*, *Rhizopus stolonifer*, *Penicillium oxalicum*, *Sclerotium rolfsii*, *Trichoderma spp* and *Macrophomina phaseolina* was established. Two of the fungi pathogens (*B. theobromae and N. mangiferae*) were identified as the major root rot pathogens of cassava in Nigeria. *B. theobromae* was widely distributed across the two ecologies, and isolated from 74.8% of a total of 115 samples. It was rated highly virulent in the virulence test with root slice assay. The second important pathogen (*N. mangiferae*) was isolated from only 13.04% of the total sample was moderately virulent and spread across the two agroecologies.

Variability was observed in the population of 84 isolates of *B. theobromae*, collected from diseased root samples. Three types of mycelial growth patterns were identified (pale olivaceous grey, olivaceous and leaden black) on potato dextrose agar. Principal component analysis of the data collected on the isolates showed that the first 6 principal components had eigenvalues greater than 1.0 and accounted for 73% of the total variation among the isolates. The early and late growth rates on different culture media and the conidia size of the isolates were the major characteristics for delineating the different isolate groups. Cluster analysis identified five isolate clusters detached at a coefficient of 0.7. The clusters consist of 13 isolates in cluster 1, 45 isolates in cluster 2, 15 isolates in cluster 3, 1 isolate in cluster 4 and 10 isolates in cluster 5. Cluster members were identified across agroecological zones. Cassava dextrose agar (CDA) and cassava agar (CA) compared favorable with potato dextrose agar (PDA) in the support of the growth of *B. theobromae* isolates.

Laboratory assays, root slice, whole root and root piece assay, separated six clones into resistant (30572, 92/0057 and 91/02324) and susceptible (TME1, 92/0427 and 30001) groups. Also the pathogens were separated into highly virulent (*B. theobromae*) and slightly virulent *N. mangiferae* and *F. oxysporum*) in these assays. Genotypes that were resistant to *B. theobromae* were also resistant to *N. mangiferae* and *F. oxysporum*.

The reactions of the six cassava genotypes at different plant ages to root rot disease, and their effects on cassava yield parameters were evaluated in a 15-month field experiment. The genotypes differed significantly for percentage of rotted roots at 12 and 15 months after planting (MAP) but not at 6 and 9 MAP ($P < 0.05$). Genotypes 30572, 91/02324 and 30001 were resistant, and 92/0057, 92/0427 and TME1 were susceptible to the disease. At 12 and 15 MAP, the percentage of rotted roots significantly ($P<0.05$) and negatively correlated with root fresh weight ($r = -0.38, -0.85$), dry yield ($r = -0.37, -0.82$), and total root number ($r = -0.33, -0.38$). The response of the genotypes to root rot depends on the plant age, and field screening should not be done before 12 MAP.

Root rot infection of the genotypes in the lab as determined by the root-slice assay and their reactions to the disease in the field evaluation at 12 MAP were similar, except for 30001, which was found to be resistant in the field, but not in the lab.

Screening of the germplasm collection for resistance showed that in the local germplasm a total of 61 genotypes (21.03%) had highs level of resistance (highly resistant and resistant group) to *B. theobromae*. While in the improved germplasm, 68 genotypes (22.22%) had high levels of resistance to *B. theobromae*.

Cassava bacterial blight in Nigeria: prevalence and evaluation of the cassava germplasm collection for resistance

by A.D. M.G. - in collaboration with O. E. Fagade and A. A. Ogunjobi

A georeferenced field survey of cassava bacterial blight disease (CBB) was carried out in the 36 states of Nigeria, including the Federal Capital between the months of October and December 2000, and CBB-infected leaves and stems samples were collected from 127 farms. Severity of CBB on cassava in the farms was scored on a scale of 1 to 5, where 1 = no symptoms and 5 = severe damage. Morphological and biochemical characterizations of the isolates were also carried out. The severity of the disease on cassava was high (score 4-5), medium (score of 3), and low (score 1-2) in 38.6%, 38.6% 22.8 % of the farms, respectively. Of the farms with high CBB-disease severity of cassava, 43% were from the southern states, 29% from the middle belt, and 27% from the northern part of the country. Gram-staining of the 256 isolates obtained from the samples showed that only 70 of them were gram-negative. Sixty-seven out of the 70 isolates were catalase-positive with mucoidal growth on sucrose-pectone agar (SPA) media, indicating that these were *Xanthomonas campestris*. The sugar utilization and growth characteristics of these bacterial isolates differentiated them into 63 *Xanthomonas campestris* pv *manihotis*, 4 as *Xanthomonas campestris* pv *cassavae*, the causal agents of CBB. Three other isolates out of the 70 were gram-negative and catalase-positive but without mucoidal growth on SPA media and are yet to be identified. Pathogenicity tests and molecular characterization of the isolates will indicate possible strain variation of the two pathovars of *Xanthomonas campestris*. The evaluation of the local, earlier improved and newly improved germplasm will be evaluated for resistance to the pathogenic isolates.

Screening existing improved and local cassava germplasm for resistance to the cassava root scale

by R.H, A.D.

The evaluation the improved and local germplasm of cassava at the Humid Forest Ecoregional Center in Cameroon for resistance to the cassava root scale was initiated in 2000. However, the pest had a clumped distribution under natural conditions that year in the farmers' field were the trial was situated and reliable data on sources of resistance was not ascertained. The evaluation will be repeated in 2001.

6.2.3 Establish multilocational and regional trials of elite genotypes in various agroecologies (Forest margins and lowland savannas of West and Central Africa, Mid-altitudes of Eastern and Southern Africa and Lowlands of East Africa)

by A.D., J.A.W., W.K. - in collaboration with, S. Y. C. Ng and NARS

Considering the high level of interaction between cassava genotypes and their environments, multi-site testing and site specific selection is required to improve the effectiveness of the enhancement program. Also, a good understanding of the relative importance and pattern of response of cassava genotypes, environments and their interactions in target agroecologies is needed to enhance the development and adoption of improved cassava cultivars. Various multilocational and collaborative multi-national trials were established in 2000 to identify promising and stable cassava genotypes for various traits of interest. These trials are constituted to generate information on the performance of a range of elite cassava genotypes in the region. In this way the extent of genotype x environment interactions and possible pathogen variations could be estimated. They also served as a means of delivering germplasm to NARS for evaluation and possible identification of suitable cultivars.

In 2000, a new set of multilocational trials were constituted in Nigeria, Benin, Togo, Burkina Faso, Niger and Chad, and are yet to be harvested.

6.2.4 Introduction and distribution of improved germplasm to collaborators and network countries

by S.Y.N., A.D., J.A.W, W.K., M.G.

During 2000, a total of 6,500 cassava in vitro plantlets were distributed to NARS collaborators in the Democratic Republic of Congo, Ghana, Nigeria, Seychelles, and Uganda, Advanced Research Institute in Austria, and to CIAT, Colombia (Table 5). The biggest consignment was to the Democratic Republic of Congo where about 200 selected

CMD-resistant genotypes including some with yellow-fleshed roots were introduced to combat cassava mosaic disease pandemic that is ravaging cassava in the country.

To ensure a high success in establishment of in vitro plantlets a researcher from Democratic Republic of Congo was at IITA for a two-week training in post flask management of cassava prior to the delivery of these plantlets. In vitro plantlets of IITA and CIAT cassava mapping populations (derived from embryo culture, maintained and micropropagated in vitro) were introduced into Uganda for mutilocational evaluation for multiple resistance to various strains of CMD (ACMV, EACMV and EACMV-UG).

More than 1,000 certified cassava ministakes of 26 genotypes produced by growing virus-tested in vitro plantlets in protected screenhouse were delivered to NARS in Sierra Leone. At the same time, 127 local cassava cultivars collected from secured regions of Sierra Leone were introduced to IITA for conservation and utilization in the breeding program.

Ministakes of 75 certified cassava genotypes with culinary qualities, high root yield and dry matter percentage, and resistance to major pests and diseases were introduced to countries, Burkina Faso, Niger and Chad for clonal evaluation.

In addition, 219,733 seeds, covering 1,120 families of broad-based and special trait populations were distributed to national programs in six countries. IITA also received 2,923 seeds collected from local landraces constituting 61 families from Mozambique as part of an effort to exploit favorable traits in African landraces, including resistance to CMD and cassava green mite.

Table 5. IITA's distribution of cassava virus-tested plantlets in 2000

Country	Number of genotypes	Number of plantlets
Austria	2	20
Colombia (CIAT)	20	137
Democratic Republic of Congo	202	2,011
Ghana	2	40
Nigeria	27	893
Seychelles	5	25
Uganda*	867	3,382
Total		6,500

*Cassava mapping populations

6.2.6 Investigation of GE interaction, rationalization of selection, testing sites and distribution areas

by A.D., J.A.W., W. K. - in collaboration P. Ntawuruhunga

Cassava is known for its adaptation to different environmental conditions due to its ability to grow under conditions considered sub-optimal for the majority of other food crops. In spite of its broad adaptation, cassava cultivars find optimum physiological expression of their genetic potential within relatively narrow ranges of biophysical conditions. Potential production of a cultivar would thus be attained only when the environmental attributes of the ecology for which it is targeted meets its physiological requirements. The success of identifying stable genotypes for desirable traits or specific genotypes for target environments from field research where both main effects and interactions are important, depends on a good understanding of GE interactions and the effectiveness of the statistical tools used to explain the patterns in the data, estimate the traits of interest as accurately as possible and select truly superior genotypes.

GE analysis, stability and adaptability studies of yield and its components, pests and diseases of new improved cassava genotypes developed in various agroecologies is regularly assessed to identify those with high and stable performance for such traits as well as those with specific adaptation to target environments. The characterization of genotypes as well as environments enables the plant breeder to target cultivars to specific environments as well as rationalize testing and selection sites.

GE interaction in cassava was studied using 10 genotypes in a multilocational trial in Uganda at 3 different (low, mid and high) altitudes for 2 years. The study investigated the magnitude of GE interaction and diagnosed the underlying causal factors of the GE pattern. The analysis of variance indicated that the effects of environment, genotype, and GE interaction were significant for storage root number, storage root size, storage root girth, fresh storage root and dry yield, but not for dry-matter content. Additive main effects and multiplicative interaction (AMMI) model was then used to assists the selection and zonation of the environments into homogenous ecosystems.

The environment, genotype and GE interaction accounted for 52.5%, 28.7% and 18.8% respectively of the sum squares for storage root yield while it was 21.6%, 39.6% and 38.8% respectively for storage root number. Storage root yield was more sensitive to environmental changes than storage root number.

The AMMI analysis and bi-plot interpretation indicated Migyera as an unstable high yielding genotype. SS4 was not adapted to high altitude. TMS I 92/0067 had, on average, good yields and was stable across altitude (locations). TMS I 92/0057 was found to have high yield and broad adaptation. Although poor yielding, the genotype TMS I 92/0397 was found specifically adapted to the high altidude environment. The mid altitude location (Namulonge) was found to be more stable for selection than the low altitude (Bulisa) and high altitude (Kapchorwa).

GE interaction was found to be very important in cassava storage root yield. Temperature was observed to be one of the underlying causal factors of the GE interaction. Environments with low temperatures (high altitude first and second seasons) caused a large negative contribution to GE effects, while environments with high temperatures caused large positive contribution. It is deduced that the GE interaction caused production delay of genotypes sensitive to temperature and was severe when temperatures were low, because more days were required for completion of the vegetative development prior to the tuberous root filling process.

6.2.7 Disease (pathogen) elimination and micropropagation of selected germplasm

by S.Y.N. - in collaboration with A.D., J.d'A.H. and Nigerian Plant Quarantine Services.

During 2000, plantlets of 30 cassava genotypes derived from meristem culture were transplanted and established in pots in an isolation room for virus indexing and certification. The 30 genotypes tested negative for cassava mosaic virus both by inoculation to *Nicotiana benthamiana* and enzyme linked immunsorbent assay (ELISA) performed on both cassava and innoculated *N. benthamiana* leaf samples. They were all certified by the Nigerian Plant Quarantine Services. This gave a total of 438 cassava genotypes, which were certified free from virus infection and are available for distribution. The range of cassava germplasm available for distribution represents selections targeted for different agroecologies: humid forest, moist savanna, and dry savanna. A total of over 20,000 plantlets were produced, and used for distribution, production of ministakes, and as stock cultures for further propagation.

In 2000, 37 selected cassava genotypes were subjected to meristem culture for pathogen elimination. Plantlets were obtained from 18 genotypes. In addition, meristems of four genotypes had green growth and may develop into plantlets thereafter. The regenerated plantlets were subcultured for initial multiplication. Most of them were acclimatized and planted in isolation room for virus indexing. They will be certified in 2001.

6.3 Tools to increase the efficiency of breeding for appropriate agroecological adaptation

Background

A better understanding of the underlying mechanisms of physiological adaptation of cassava to a range of agro-ecosystems from the humid forest, forest transition, moist savanna, dry savanna, semiarid and mid-altitude agroecologies aims to strengthen the selection and adoption process of improved cassava clones. Physiological studies on cassava emphasize the adaptation of cassava clones to the different abiotic stresses experienced in each of these ecologies. The adaptation characteristics include tolerance to low solar radiation, soil acidity and low soil phosphorus (humid forest zone); tolerance to drought varying from mild to severe stress (forest transition to semiarid zone); early season wet, mid season drought or late season wet soil stresses (inland valleys); and tolerance to low temperature (mid-altitudes). The genetic variability and genetic control of these traits and biotic stresses enables the plant breeder to formulate an efficient breeding strategy. To optimize the use of genetic variability, heterotic and combining ability relationships should be determined. The bases for adaptation to biotic stresses and the elucidation of the interaction of biotic with abiotic stresses would also enhance the breeding process. Development and refinement of screening methods is a prerequisite to the efficient determination of genetic variation of source materials in breeding programs.

On-going and future activities

6.3.1 Investigation of interactions between drought tolerance and resistance to cassava green mite

by R.H., A. D.

6.3.2 Investigation of interactions of cassava cultivars, natural enemies and CGM

by R.H., M.T, A.D. - in collaboration with D. Ojo, G. Paraiso, M. Otema, B. Agboton, N. Famah

Investigations of exotic phytoseiids and cassava plant interactions have followed three tracks. In the first track, we relied on field surveys in conjunction with other *M. tanajoa* biocontrol implementation activities and on screening of the IITA cassava germplasm collections, in Ibadan, Nigeria, and in Serere, Uganda, to identify cassava cultivars with favorable apex characteristics (e.g., hairy, large and compact apices). In the second track, a subset of the identified cultivars were selected along with a set of unfavorable cultivars thus providing a wide range of characteristics affecting *T. aripo* abundance. These cultivars were then tested in common and replicated on-station and farmer field experiments, where regular observations were made on the abundance and severity of *M. tanajoa*, *T. aripo*, and several other biotic constraints, as well growth rates of the various cultivars. At 12 months, storage root yield and above ground biomass were estimated. In the third track, we conducted greenhouse and laboratory experiments to understand the mechanisms underlying the effect of cassava cultivars on *T. aripo* preference.

Preliminary analyses of the data from field experiments support previous observations that *T. aripo* prefers cultivars with large hairy apices. In addition, *T. aripo* abundance appears to be positively correlated with the number and size of the bracts (small vegetative tissue) at the base of the petioles of the immature leaves in the apex. Of the cultivars tested in Benin and Nigeria, the following classification has been developed: high preference - TMS 92/0326, Agric, Oko Iwayo; medium preference - TMS 91934, Somidoloro, Odongbo; low preference: Ideleru, Amala, and TMS 30572. In field surveys, and other evaluations in eastern and southern Africa with the cultivars 'Kabushi' (Zambia), Fernando Po (Mozambique) and I92/00067 (Uganda), it is found I92/00067 combines good CMD and *M. tanajoa* resistance with preferred traits for *T. aripo* and good cooking quality of fresh roots.

On-going laboratory experiments have shown that *T. aripo* stays and survives longer and produces more eggs on excised tips of the hairy cultivars Agric and TMS 92/0326 compared with the glabrous cultivars Odongbo and TMS 30572. Additional field, greenhouse and laboratory experiments on the effects of foliar exudates and cyanogenic potential on the development, survivorship and persistence of *T. aripo* on cassava cultivars are on-going.

6.3.3 Investigation of plant morphology and its relation to agronomic performance

by J.A.W., A. D. in collaboration with R. Rubaihayo, D.S.O. Osiru and P. Ntawuruhunga

Experiments were conducted to determine genotypic performance of cassava under different altitudes; and investigate the cause-effect relationship of yield performance. The first was a potted experiment which was conducted at Namulonge to determine the morphological and physiological determinants of yield performance using two genotypes from five sources of origin viz. East African lowland, mid-altitude and highland, and West African lowland and mid-altitude. The following genotypes were selected and used: East Africa lowland (Nyarukuhi, Nyarubekane), East Africa midaltitude (Migyera, SS4), East Africa highland (Eala 07, Kiryumukwe/Serere), West Africa lowland (TMS 81/01635, TMS I 92/0057) and West Africa midaltitude (TMS I 92/0067, TMS I 92/0397). In the second experiment, a field study using the same cultivars was conducted at three locations of different altitudes (Bulisa: 650m, Namulonge: 1250m and Kapchorwa: 1750m). This aimed at growth and development processes with conventionally known performance components for a period of 15 months during 1997/1998 growing season and 9 months during 1998/1999 growing season. For both experiments, a randomized complete block design was used with three replicates.

The potted experiment revealed variability among genotypes in all the agronomic characteristics evaluated. The results indicated significant differences ($P<0.001$) among sources of origin in sprouting ability, plant height, leaf area, storage root formation and differentiation. For the majority of plant traits (total root number, potential root number, root length, total leaf area), the genotypes within sources did not differ significantly. Plant height was expressed exponentially and was significantly ($P<0.001$) correlated with all plant characteristics. The high altitude East African cassava had a meristem length significantly ($P<0.01$) longer than other sources while the mid altitude (West African) cassava had the largest meristem width. The width of the apical meristem was significantly ($p<0.01$) correlated with all plant traits except dry matter content of storage roots, indicating that the apical meristem plays an important role in controlling plant development and storage root differentiation. The results also revealed starch accumulation in all genotypes by 10 weeks after planting (WAP) except for the genotypes from the low altitude (East African) source that showed poor root enlargement and a generally poor performance.

Principal component analysis did not reveal discontinuity among the genotypes. Early tuberization was detected in Migyera, SS4 and TMS 81/01635 and were considered early bulking genotypes, while Nyarukuhi and TMS I 92/0397 were characterized by late bulking genotypes.

In the field experiment, plant height growth behaved allometrically rather than exponentially, as observed in the potted experiment. Plant height growth curves indicated that the midaltitude site was the best followed by the low altitude and the least was the high altitude. Mid altitude (West African) source was the tallest at both low (Bulisa) and mid (Namulonge) altitude locations, while the high altitude (East African) source was the tallest at high (Kapchorwa) altitude. Crop growth rate (CGR) was lowest in the high altitude compared to low and mid altitude. The maximum CGR obtained at 12 months after planting (MAP) for the altitude was 41.2g/m^2/week compared to 53.1g/m^2/week for mid altitude and 75.1g/m^2/week for low altitude. Migyera, SS4, TMS I 92/0057 were the best for storage root number formation. At 12 MAP, TMS I 92/0057 had the highest fresh storage root yield, 38.1 t ha^{-1} at mid altitude and 47.4 t ha^{-1} at high altitude while TMS I 92/0067 (54.7 t ha^{-1}) was the best at low altitude. The low altitude site was most suitable for storage root yield. Prediction of storage root yield by these quantitative traits evaluated did not provide adequate information to explain its complexity.

Dry matter percentage in roots was not correlated with storage root yield. However, it was significantly and positively correlated with leaf area ($r = 0.56$, $P < 0.001$) and negatively correlated with storage root size ($r = -0.25$, $P < 0.001$). Storage root dry matter percentage increased with altitude. Sugar content (%) and cyanogenic potential were found to be higher in storage roots at high altitude than at low and mid altitude. Stomata open in larger numbers at mid and low altitude than at high altitude due mainly to the temperature factor. No significant difference among genotypes was observed for stomata number, photosynthesis rate, stomata conductance and transpiration.

Broad sense heritability (h^2) of storage root yield was relatively low. Storage root number, size and girth were found to be the most important yield components with high direct path coefficients of 0.530, 0.454 and 0.217 respectively.

The genetic variation in performance was observed among genotypes due to differential production efficiencies exhibited among genotypes at each location and across locations.

6.3.4 Assessment of genetic variation, diversity and establishment of heterotic relationships, and gene complementarity for desirable traits among African landraces and improved germplasm

by scientists named in each subsection

by A.D. - in collaboration with I. Fawole, A. Raji

Diversity analysis of a crop is fundamental to the optimal use of genetic resources in broadening the genetic base and subsequent systematic exploitation of heterosis. The genetic relationships among 500 cassava cultivars from different parts of Africa were analyzed with various multivariate techniques based on 35 agrobotanical traits. Differentiation of the cultivars into 12 cluster groups was obtained with cluster analysis. Further analyses with canonical discriminate analysis and principal component analysis showed that there is an appreciable amount of variation in the germplasm, but there was also considerable overlap among cluster groups. Genetic distances between clusters groups were mostly small, except for those between cluster group 5 and 11, 5 and 2, and 5 and 9. Agronomic, canopy and storage root quality traits were the principal discriminatory characters for grouping cultivars together, and this could have been attributed to adaptation to similar climatic conditions, farmer's selection for particular root quality traits over a long period or common ancestral population. It was evident that farmers' cultivars may not be unique to the particular place of collection, because there is a high degree of turnover of cultivars grown by farmers, who are continually introducing new genotypes with desired attributes from neighboring villages, regions and countries. The results also indicated that an expanded germplasm collection might be necessary to ensure a broader genetic representation of African cultivars. A molecular analysis of the germplasm is being conducted to provide complementary information that will increase the resolving power of diversity analyses.

Genetic diversity within a collection of African cassava cultivars resistant to the cassava mosaic disease using SSR Markers

by A.D. - in collaboration with M. Fregene and Y. Lokko

A study was conducted to determine the extent of genetic diversity within a collection of African cassava cultivars resistant and susceptible to cassava mosaic virus disease (CMD) and to determine different sources of resistance to CMD. A dendogram of genetic distances grouped the 78 cultivars into 5 group suggesting five sources of resistance with some similarity between two sources of resistance and the susceptible landraces. Close associations were detected for some of the resistant landraces suggesting the possibility of duplicates. The analysis of genetic diversity performed on the cultivars partitioned into the cluster groups, revealed high levels of variation. On the average, 3.12 alleles per locus were detected and the probability that any two randomly sampled alleles in a given cultivar were different, was 0.50. The FIS values for cultivars within cluster groups indicated an excess of heterozygosity. The estimate of heterozygosity within cultivars was 0.58. The amount of genetic differentiation (GST) was 0.07, and was lower than what is expected for outcrossing plants. The low levels of genetic differentiation suggest that the African cassava germplasm is not well structured genetically and that the SSR markers may be poor predictors of population differentiation of resistance to CMD in cassava.

Complementarity of genes for resistance to cassava mosaic disease

by A.D. - in collaboration with S. Ofei, and E Danquah, Y. Lokko

Cassava mosaic virus disease (CMD) is the most important disease of cassava in Africa, causing severe economic losses. The genetic stock, clone 58308, has been extensively used in breeding for resistance to the disease, but recently, several African landraces have been identified as new sources of resistance to the disease which could be used could be used to diversify resistance. Gene complementarity among 70 segregating F1 crosses between resistant by resistant, resistant by susceptible, susceptible by susceptible parents including clone 58308 was assessed for their potential uses in a breeding program. The genetic materials were evaluated on the field for their symptom severity to CMD in 3 CMD-occurring environments. Mean disease severity scores of the progenies suggested polygenic inheritance and both parents of a cross contributed effective factors to their progenies. Resistant phenotypes were detected in crosses between susceptible parents, which suggests that resistance in these sources may be due to recessive genes. The presence of transgressive segregants in the crosses of some of the parents may suggest evidence for the polygenic control of resistance to CMD. Different alleles in different parents may be involved and are cumulative for degree of resistance. Allelic differences were detected between 58308, the most extensively used source of resistance, and some of the resistant improved clones and landraces and between the landrace TME 1 and other resistant landraces.

Combining ability analysis of field resistance in cassava to the cassava anthracnose disease.

by A.D. - in collaboration with S.O. Osunlaja and O.F. Owolade

A North Carolina Design II mating scheme involving four improved clones as females and nine landraces as males was used to produce their 36 F1 hybrids. The parents and their hybrids were evaluated for their reactions to CAD at 12 MAP under natural infection at Ibadan (a high infection zone) in 1998 and 1999 cropping seasons. The objectives were to determine the relative importance of GCA and SCA, estimate heterosis, and compare line and topcross for resistance to CAD. Results showed that GCA of the female parents accounted for a greater proportion of the total genetic variation. All the improved lines except 30572 contributed significantly to GCA effect for resistance and showed higher negative GCA effects. TME 3, TME 6 and TME 11 were the best male general combiners for resistance. The female parent, 30572, and the male parent, TME 7, were poor general combiners. Significant negative SCA effects also existed among the crosses. Eleven crosses had significant negative heterotic effects. The per se performance of the parents was not significantly correlated with their topcross performance (r = 0.32) and the relative magnitude of the ratio (GCA/(GCA+SCA)) was 0.67, indicating that progeny performance cannot be predicted based on parents per se performance alone. For the enhancement of cassava resistance to CAD, careful selection must be placed on the female parents, and selection based upon many testers to identify specific combiners that would give higher levels of resistance.

6.3.5 Improvement of cassava post-flask management system, and development of certified ministakes production system

by S.Y.N - in collaboration with M. Ayodele and Nigerian Plant Quarantine Services

Post flask management

There are two different options to establish the cassava plants after removal from the humidity chamber: cassava plants are directly transplanted to seedbeds after hardening in the humidity chamber (T1); and cassava plants, after removal from the humidity chamber, are transplanted to black polyethylene bags filled with top soil and kept under shade for further growth of 4 – 6 weeks before transplanting to seedbeds (T2). The second option is more laborious and involves extra cost. A study was conducted to compare these 2 options in relation to the percentage establishment and plant growth measurements after transplanted to seedbeds. Two genotypes were used, TME 596 and TME 594. There were 3 replicates for each of the treatments (T1 and T2). For TME 594, each replicate had 12 plants whereas for TME 596, each replicate had 15 plants. The results showed that there was no significant difference between the two treatments in plant establishment, plant height, and number of nodes and leaves per plant (Table 6).

This indicated that it might not be necessary to have the intermediate step of transplanting to polyethylene bags filled with topsoil as in T2. This will not only save cost but also avoid the risk of breaking the plants during the extra steps of handling. The results also showed that there was significant difference between the two genotypes in terms of number of nodes and leaves per plant (Table 7). TME594 had higher number of nodes and leaves per plant than TME596 and hence more vigor. It was observed that sufficient and regular watering was the most important factor contributing to the success in establishment in the field.

Table 6. Comparison of two post flask management process on percentage plant establishment and growth of cassava in vitro plantlets after transplanting to seedbeds

Treatment*	Establishment (%)	No. nodes	No. leaves	Plant height (cm)
T1	57.00±8.60	63.98±3.34	53.07±3.15	256.38±14.48
T2	70.83±4.96	68.30±3.84	57.90±4.17	260.70±16.00
CV (%)	26.91	12.63	15.33	12.05
	ns	ns	ns	ns

T1: Plantlets after hardening in humidity chamber were transplanted directly to seedbeds

T2: Plantlets after hardening in humidity chamber were transplanted to polyethylene bags with top soil before planting to seedbeds

NS Nonsignificant, and significant at 0.05 and 0.01 probability level, respectively

Table 7. Plant establishment and plant vigor between the two cassava genotypes after post flask management

Genotype	Establishment (%)	No. nodes	No. leaves	Plant height (cm)
TME596	72.17±4.75	60.94±2.08	50.75±2.37	244.70±11.90
TME594	55.67±8.24	71.83±3.48	60.22±3.88	272.40±15.80
CV (%)	25.49	8.85	12.43	25.49
	NS	**	*	NS

NS, *, **, Nonsignificant, and significant at 0.05 and 0.01 probability level, respectively.

Production of certified cassava ministakes

Selected *in vitro* plantlets of cassava after acclimatization in the humidity chamber were planted in protected screenhouse in pots filled with treated soil or directly to treated soil. They were regularly monitored visually for the presence of diseases (virus, fungus, and bacteria) and pests. During the growing period they were inspected by the Nigerian Plant Quarantine Officials. Before harvesting of the ministakes, samples were randomly taken from each genotype and tested for possible presence of pathogens. Ministakes were prepared from those that tested negative, and were treated with insecticides two days before packaging for delivery.

In 1999/2000, more than 500 cassava virus-tested plantlets (26 genotypes) were planted in pots under protected screenhouse after the hardening. Another batch of about 350 plantlets of 9 genotypes was planted after hardening in treated soil under protected screenhouse. The genotypes included selected germplasm from Sierra Leone (SL80/40, CARICCAS I and CARICCAS II). It was found that plants that were planted after the main rainy season (July/August) had less attack by fungal and bacterial diseases than those grown in the main planting season (April) did.

6.3.6 Development of near infrared equations for predicting feed value of cassava fodder

by A.L. - in collaboration with A.D.

This activity was not undertaken in 2000 because of lack of funding to develop the prediction equations at the University of Florida.

6.3.7 Development of regeneration and transformation system of cassava

by S.Y.C. Ng. - in collaboration with Y. Puonti-Kaerlas (ETH), I. Fawole, A.D. and B. Hankoua

Plant regeneration

Eighteen cassava genotypes selected among African cassava landraces and improved genotypes were tested for their ability to undergo primary somatic embryogenesis. Meristems and immature leaf lobes were tested on picloram-based embryo induction medium (P-CIM), and 2,4-dichlorophenoxyacetic acid based embryo induction medium (2,4-D-CIM). Results showed that there was no significant difference in the overall primary embryo induction between the two types of explants. Nevertheless immature leaf lobes gave significantly higher number of explants that produced higher number of embryos/cluster (5-10 per cluster and above 10 per cluster). The frequency of embryo induction was genotype dependent. P-CIM was superior to 2,4-D-CIM in the induction of somatic embryogenesis.

When the embryos induced on both media were transferred to the maturation medium, there were differences in the frequency of maturation among the genotypes tested (range: 38 – 100%).

Cyclic somatic embryogenesis was successfully established and maintained for 11 African cassava genotypes on P-CIM, and will provide source materials for transformation studies.

Plantlets were regenerated from 6 African landraces via organogenesis through direct shoot induction from cotyledon pieces of maturing somatic embryos. Although the percentage of explants that formed shoot buds was reasonably high (range:13-81%), the average number of plantlets formed per responding explant was low (ranged from 0.07 to 12). This indicated that in order for this system to be used for an efficient transformation system, there is a need to improve the conversion of induced shoot buds to plantlets.

Transformation system

The susceptibility of cotyledon explants of maturing somatic embryos was tested using four *Agrobacterium* strains, EHA105, GV3101, AGL1, and LBA4404 harboring the pCAMBIA1301. Cotyledon pieces of maturing somatic embryos of 3 cassava landraces (TME 8, TME 127, and TME 13) were used. Transient GUS assay was performed on the explants after inoculation and co-cultivation with *Agrobacterium*. Results obtained showed that compatibility between the genotype and *Agrobacterium* strains varied among the genotypes and the *Agrobacterium* strains. Although all the cassava genotypes were susceptible to most of the *Agrobacterium* strains, TME 8 was more amenable to infection than the other two genotypes. The percentage of GUS positive explants and number of blue spots per explants was higher in TME 8 than the other two genotypes. In most cases, the highest responses, in terms of the number of blue spots per explant, were recorded with *Agrobacterium* strain, GV3101, in all the cassava genotypes tested. In terms of the percentage GUS positive explants, EHA105 and GV3101 were higher than that of LBA4404, but there was no significant difference between EHA105 and GV3101. Transformation studies using the combination of TME 8 and GV3101 is underway.

6.3.7 Mapping of gene conferring resistance to CMD and other agronomic traits of cassava

by M.G. - in collaboration with M.Fregene (CIAT), A.D. and Y.Lokko

Collaborative work with the International Center for Tropical Agriculture (CIAT) has shown that a dominant gene (CMD 2), controlling a new source of resistance to CMD (TME 3) and different from the most extensively used gene for resistance to CMD derived from interspecific hybridization, is flanked by the SSR and a RFLP marker, rGY11 and rSSRY28, at 9 and 8cM, on linkage group R of the male-derived molecular genetic map of cassava. The groundwork to isolate CMD2 by positional cloning, using candidate genes and BAC contigs in Nigerian cassava land races is being undertaken.

Bulk segregant analysis made up of 10 most resistant and 10 most susceptible F1 progenies derived from the cross TMS 30555 (susceptible) x TME 7 (resistant) were screened with 140 RAPD, 150 SSR, and 104 AFLP primer combinations (64 combinations of EcoR1/Mse1 +3 primer pairs and 40 combinations of Apa 1/Taq 1 +3 primer pairs). Only 1 SSR primer consistently showed distinct differences between the resistant and susceptible plants, after screening the members of each bulk, the parents and the entire mapping population. Regression analysis indicated that this marker contributed 59% of the total variation in the population for resistance to CMD. The primer was then used to screen 23 cassava clones with varying levels of resistance to the disease, to confirm its usefulness as a marker associated with resistance to CMD. The results showed differences between some resistant clones and TME 7 with respect to that marker. The resistant clones 58308 and TMS 30572 (extensively used sources of resistance in the breeding program) and TME 8 did not have this marker suggesting that different genes may control resistance to CMD.

Other activities in 2000 was the genotyping of mapping population A (TMS 30572 x TME 117) with a set of 189 simple sequence repeat (SSR) markers. Repeated screening of the 189 primers yielded only about 30 % (65 loci for Joinmap; 43 in female, 53 in male map for Mapmaker) informative loci. Preliminary linkage analysis was successfully performed on the subset of the 65 loci of the present data using Joinmap version 2.0 and Mapmaker. To produce a reasonably dense framework map, more markers (SSR and AFLP) are being screened in t 2 mapping populations that are segregating for CMD resistance. In addition, previously mapped RFLP probes, kindly provided by CIAT, will be converted to amplification-based markers and placed on this map.

6.3.8 Purification of key protein and genes for cyanogenesis and identification of factors regulating cyanogenesis in cassava

by M. B, H.M. - in collaboration with J. Machuka and I. Dossou-Yovo

From a collaborator in Denmark, Dr. Birger Møller, we obtained two genes (CYP79D1 and CYP79D2) obtained from a Colombian cassava cultivar and coding for the enzyme catalyzing the first committed step of the biosynthesis of cyanogenic glucosides in cassava. These genes were found to be present in all 46 cassava genotypes that were tested. However, the degree of expression of the two genes varied in each genotype, but the results were not clear enough to distinguish between low-cyanide and high-cyanide cassava cultivars. We tried RAPD markers, and out of 60 primers tested, four gave good polymorphism and two of these were selected. Fig. 1 shows the polymorphic response obtained with the primer OPT-07850.

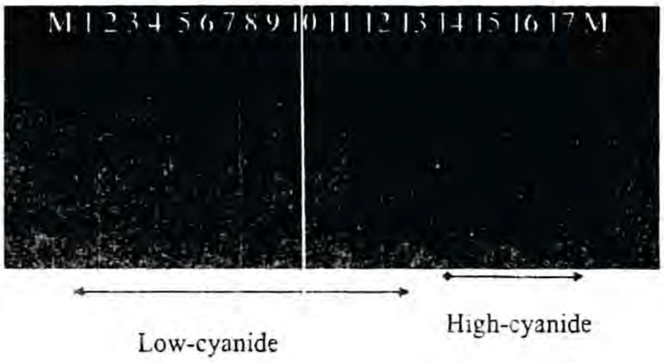

Fig. 1. RAPD electrophoretic profiles of 17 accessions of *Manihot esculenta* genomic DNA amplified with primer OPT-07850. Lanes 1 to 12 are for low-cyanide cultivars and lanes 13 to 17 are for high cyanide cultivars

6.4 Improved genotypes suited to intensive commercial production and utilization systems

Background

As cassava becomes a cash crop, identification and targeting of areas combining high production potential and market opportunities becomes necessary. The development of genotypes for intensive commercial production and utilization systems will then be needed. The development of robust seed-based production methods for large scale, and intensive commercial production and mechanization is desirable for the modernization of the crop. As cassava is also a highly heterozygous plant, sib mating or selfing for one or a few generations should unmask deleterious recessive genes during evaluation, and recombination after selection will capitalize on both additive gene action and heterosis.

Genetic male sterility has also been shown to facilitate efficient hybridization, and enhance hybrid production. Investigations of these options in cassava will in the long term produce information for the use of true cassava seeds or hybrid seeds as an alternate propagation technique.

On-going and future activities

6.4.1 Screening and selection for early and sustained bulking of cassava

by A.D., J.A.W., W.K.

Farmers' ability to respond to declining soil fertility/fallow periods by replacing more susceptible crops with cassava is constrained by its long cropping cycle. The currently available improved cultivars attain their maximum yield at 12 to 15 months as opposed to 22 to 24 months for local cultivars. According to COSCA, farmers require cultivars that can be harvested as early as six months. Selection for early bulking genotypes that can be harvested as early as six months after planting, and with sustained bulking up to 12 months after planting in the uplands is being emphasized. Several promising genotypes have been identified with potential for early and sustained bulking up to 12 months.

6.4.2 Selection for ease of peeling and uniform root conformation for mechanized processing

by A.D., J.A.W., W.K.

Uniform storage root conformation (thick rind, short neck, medium-sized compact, conical and short roots enhances both pre- and post- harvest handling of cassava, and will also facilitate mechanization of the crop. Emphasis was given to continuing selection for the above traits in all breeding trials. Most of the improved breeding lines obtained so far possesses many or all of these attributes. This activity will continue to be emphasized in breeding trials.

6. 4.3 Assessment of maturity time of advanced breeding lines of cassava

by A.D., M.A., J.A.W., W.K..

This experiment was put on hold in 2000 because of budget constraints.

6. 4.4 Evaluation of breeders lines for responsiveness to fertilizers)

by A.D., J.A.W., W.K.

This experiment was put on hold in 2000 because of budget constraints.

6. 4.4 Assessment of comparative yield, quality, and agronomic performance of 'seed' from open, controlled hybridization and cuttings

by A.D.

A trial with a new set of lines and their seed populations was planted in 2000 at Mokwa, Nigeria, but due to the long dry spell after planting, germination was poor and termite damage affected establishment, and the trial was terminated.

6. 4.5 Development of S-lines of genetically diverse parents and conversion of African adapted clones of cassava to male sterile lines

by A.D.

Selfed line selection in cassava unmasks deleterious recessive genes and fixes desirable recessive genes before recombination. additional S1-lines of selected and genetically diverse cassava parents were generated (Table 8). These will be evaluated in the seedling nursery in 2001. Several selfed lines were also advanced to the next generation for evaluation and selection of potential parents for testcrosses.

Preliminary analysis s of S7 lines obtained in 1999 using SSR marker indicated that these lines still had appreciable amount of heterozygousity.

To facilitate controlled hybridization, increase parental control and enhance hybrid production, genetic male sterile lines (GSMS 95/28 S1, GSMS 95/22 S1 (96/0826) and GSMS 96/66 S1 (96/0838-2), GSMS 95/38, GSMS 95/96 (96/0826-5), and GSMS 95/32 (96/0826-17)) earlier identified are being used in a systematic conversion scheme to convert elite African adapted clones to male sterile lines.

Table 8. Controlled hybridization of genetically diverse parents and male sterile lines

Crosses	No.of seeds	No. of families
Selfed lines		
Self Lines (Improved germplasm and African landraces)	661	26
Male-sterile lines		
Male sterile lines x IITA's earlier and newly improved germplasm (BC)	460	12
Male sterile lines x African landraces (BC)	801	18
Male sterile lines x IITA's earlier and newly improved germplasm (F1)	253	7
Male sterile lines x African landraces (F1)	449	17

6.5 Improved postharvest technologies for expanded utilization and increased commercialization in the food, feed and industrial sectors

Background

Agricultural development efforts in SSA are being aimed at increasing income and socio-economic growth through agro-processing, commercialization and development of more profitable agro-enterprises. An important aspect of ensuring that cassava is viewed as viable farming enterprises, rather than a crop of last resort, is the need for greater attention to the broad area of postharvest including primary processing, product development and marketing. A key requirement is to stimulate consumer demand for cassava products. In this way, in addition to satisfying their immediate domestic food needs, farmers will have confidence that there are assured outlets for their produce, and associated cash earning opportunities.

The wide range of technological pathways of traditional processing leads to an equally wide range of products that vary from one another in taste, appearance, texture, convenience of preparation into food, nutritive value, and other quality characteristics resulting from physical and microbial contamination. These processing technologies cannot assure consistent quality products, economies of scale and labor productivity. The extent to which the potential market for cassava may be expanded depends largely on the degree to which the quality of various processed products can be improved to make them attractive to middle and high income earners, and various markets, without significant increases in processing costs.

Technological, institutional, social and organizational interventions designed to strengthen and expand the marketability, quantity and quality of cassava products will contribute to increased food security and to the income generation capacity of cassava farmers and processors. Market/sub-sector analyses to identify opportunities, determine constraints, assess needs for transforming cassava from subsistence into broad-based commercial commodities will enable the commodity programs to propose areas of technological, institutional, organizational and policy options to effectively target its research development activities and disseminate end-user preferred technologies for equitable commodity sub-sectors. This will enable cassava products to be developed as a widely traded commodity that contributes to the economic growth.

The potential demand for starch and starch-derived products in a number of industries (food-based, textile, pharmacy, brewery, ply woods, packaging, battery making, glue and other adhesives etc.); root, foliage and other plant parts in different feed industry lines (poultry, dairy, pigs etc.); and details of cost savings by import substitution with cassava need to be analyzed. In addition, the functional (physical, chemical and sensory) varietal characteristics of importance to the various applications in high demand in the food and non-food product markets will contribute to the development of cassava cultivars that meet specific market opportunities.

Improved processing, storage and packaging technologies for smallholder farmers and processors will contribute to increasing cassava root availability, reliability and quality, and thus stabilizing prices and facilitating trade.

Linking small-scale cassava farmers and processors to existing, improved, or new growth markets will establish the capability and capacity to integrate research and development activities on cassava production, processing, and marketing to capture the market potential for the crop. The assessment of costs and returns of technologies (existing and new) with potential for increased trade through improved prioritization, monitoring and assessing impact accruing from increased production, value addition, commercialization and utilization needs to be addressed.

On-going and future activities

6.5.1 Characterization of the postharvest food system and markets to identify needs, constraints and opportunities for expansion of utilization in the food, feed and industrial sectors

by S.F., M.B,. V.M., J.A.W., W.K., J.T. - in collaboration with NRI

Two components of the cassava market survey (market chain and industrial uses) in Uganda were completed and the result are being used to devise the research agenda in Uganda based on market opportunities and potential to engage partners in new areas of research such as collective marketing with producers, development of trade associations and also public-private sector consortia.

EARRNET has initiated sub-sector analyses for cassava in six countries (Uganda, Kenya, Madagascar, Rwanda, Burundi and DR Congo).

FOODNET is also conducting a series of market surveys with the ASARECA networks and is developing a protocol for rapid market analysis to determine the demand and supply chains for a given commodity.

In addition, SARRNET has initiated its sub-sector analyses/ market studies for cassava and sweet potato in three target countries (Malawi, Zambia and Tanzania) in guiding its market led approach to commercializing cassava and sweetpotato. The secondary information has been compiled at a draft level and the next stage is to do the market chain analysis and industrial survey.

6.5.2 Characterization of the nutritional and food quality traits in cassava germplasm and in primary products targeting diverse markets

by scientists named in each subsection

Characterization of protein contents in roots and leaves of interspecific hybrids and normally cultivated cassava genotypes

by M.B. - in collaboration with A. Aduni

Cassava roots are well known for containing very low levels of proteins. Since they are consumed extensively as dietary energy source in the cassava growing belt of Africa, sometimes contributing more than 50% of the caloric intake, minor increases in their protein content would make a significant contribution to the dietary protein intake of cassava consumers. Since 1993, the cassava breeding program has initiated a program to cross cassava with *Manihot tristis*, a wild relative of cassava that is known to store large amounts of protein in the roots, with the objective of producing hybrids that would possess the food quality characteristics of cassava and the high protein content *of M. trisitis*. Back-crosses were made in 1994 and 1995 and have been evaluated yearly for their agronomic as well as food quality characteristics. We report here the levels of protein in the roots and leaves of the 84 cassava hybrids and we compare them to the protein content in roots and leaves of normal cassava genotypes (Table 9). The mean protein content in the roots of the hybrids was found to be 10.29% ± 2.99 (on dry weight basis) and in the leaves it was 30.83% ± 2.22, compared to values of 7.20% ± 1.75 and 32.77% ± 3.45 in the roots and leaves of 46 normal cassava genotypes. The protein content of the hybrids ranged from 5.97% to 18.08% while the range was 4.32% to 12.58% in normal cassava. The highest root protein (18.08% dwb) content was found in genotype 94/I0010 and correspond to about 6% protein in the fresh roots. Hybrid genotypes 94/I0019 and 95/I0014 had root protein content exceeding 15% on dry wet basis or about 5% on fresh weight basis. These levels are significantly high and are comparable to the protein content of cereals on dry matter basis. The retention of the protein during processing and the nutritional quality of these proteins remain to be evaluated.

Table 9. Protein content in root and leaves of interspecific hybrids and normal cassava

Interspecific hybrid cassava			Normal cassava		
	Protein content (%dwb)			Protein content (%dwb)	
Clone	Roots	Leaves	Clone	Roots	Leaves
94/I0010	18.08	33.08	TME 7	12.58	35.33
94/I0019	15.73	30.76	TME 14	11.90	25.63
95/I0014	15.64	32.41	I84563	9.82	34.09
94/013	14.32	28.76	89/02113	9.62	35.68
95/I0010	13.80	32.88	089/000774	9.45	30.47
95/I0007	13.55	32.00	I92/0397	9.42	37.53
94/I0100	13.45	35.11	O82/00762	9.17	26.70
94/I0074	12.15	26.93	O89/00034	8.76	33.44
95/I0024	12.15	26.76	I83672	8.23	31.10
4(2)1425	11.72	31.57	I89/00577	8.20	32.24
94/I0047	11.60	32.81	089/00042	8.17	28.81
94/I0127	11.34	33.03	089/00073	7.98	35.28
94/I0040	11.03	28.99	I88/02234	7.98	35.16
95/I0021	10.84	-	I89/00893	7.75	30.82
94/I0099	10.73	31.19	W4092	7.65	29.25
94/I0020	10.53	30.92	M81/0001	7.64	36.61
94/I0004	10.43	32.26	088/00695	7.62	32.50
95/I0026	10.21	29.93	TME3	7.60	34.00
95/I0017	9.32	33.69	42025	7.44	30.01
94/033	9.21	27.18	I89/00854	7.21	32.41
95/I0046	8.94	30.05	W820447	7.11	30.82
94/028	8.84	27.67	TME1	7.00	31.02
95/I0036	8.63	27.48	TME 5	6.99	36.91
94/I0083	8.57	30.19	TME 8	6.95	36.04
95/I0002	8.55	34.40	I89/01901	6.88	29.78
30572CHK	8.54	35.12	I89/02831	6.85	41.48
94/I0092	8.04	32.18	I81983	6.74	28.87
95/I0031	8.02	29.20	TME 11	6.69	36.46
95/I0003	7.97	31.13	82/00058	6.58	38.65
94/I0110	7.97	30.45	088/00675	6.52	32.07
95/I0009	7.77	27.60	W4080	6.46	31.02
94/I0022	7.21	32.02	TME 6	6.44	37.17
95/I0025	6.87	31.39	083/00109	6.39	28.30
91934CHK	6.72	33.09	30572	5.96	28.34
95/I0022	6.35	31.27	TME 1	5.88	33.32
94/I0036	6.04	31.46	TME 9	5.81	36.15
95/I0027	5.97	32.09	I88/02157	5.71	31.42
Mean	**10.29**	**30.83**	I86/00098	5.70	31.14
Std. Deviation	**2.99**	**2.22**	TME 4	5.64	34.33
			TME 38	5.61	35.81
			30572	5.37	36.59
			30572	5.22	35.14
			I88/02433	4.99	29.31
			TME 1	4.62	31.52
			M61033	4.60	28.30
			I30555P3-2	4.32	30.36
			Mean	**7.20**	**32.77**
			Std. Deviation	**1.75**	**3.45**

Biochemical and nutritional characterization of cassava leaf protein.

by M.B. - in collaboration with A. Aduni

Cassava roots are poor in protein but the leaves store considerable amounts of protein and are consumed as vegetable in many countries of Africa, Asia and Latin America. A rapid appraisal of the importance of cassava as food in various African countries was made using questionnaires administered to cassava researchers, nutritionists and development agents in agricultural meetings held in 1998 and 1999. The compilation of the data collected gives the picture indicated on **Fig. 2**. The heaviest rate of consumption seems to be concentrated in Central Africa with a pocket of high consumption in West Africa (Liberia and Sierra Leone). Consumption is moderate in eastern Africa and low elsewhere in West Africa.

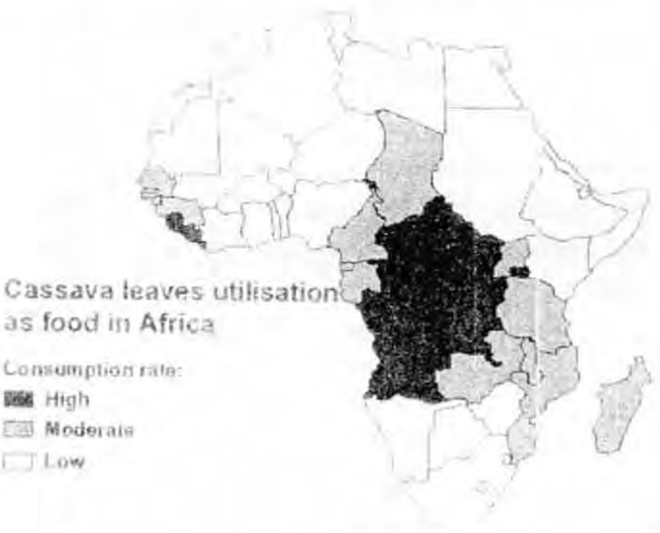

Fig. 2. Consumption rate of cassava leaves in Africa

A major concern related to the utilization of cassava leaf as food is the residual amount of cyanogenic compounds in cooked cassava leaves. It is well known that cassava leaf contains extremely high levels of cyanogenic glucosides linamarin and lotaustral in which upon lead to the formation of cyanohydrins which breaks down to hydrogen cyanide. Linamarase, the enzyme responsible for the breakdown of cyanogenic glucosides is present in cassava leaves in very high amounts. The removal of cyanogenic compounds from cassava leaves during two types of processing cassava leaves into traditional foods was investigated. The first method investigated is common in countries with high cassava leaves consumption such as Democratic Republic of Congo and Sierra Leone. In this method, cassava leaves are washed, blanched by pouring boiling water over them or passing them briefly over a hot metal plate, and then pounding the blanched leaves in a wooden mortar and cooking them in water. The second method investigated is found in some parts of Nigeria, particularly in the part of Edo State, the state of origin of the student involved in this research. It consists of scrubbing the leaves prior to grinding and cooking. Table 10 indicates the percentage reduction in cyanogen content at each processing step for the two methods and for leaves from two popular cassava cultivars. The data shows that both methods achieve the same high level of cyanogen reduction by over 99%, although the pounding stage reduces the cyanogen content by 90% compared to only 75% for the scrubbing method. These levels of cyanogen reduction are in agreement with earlier findings.

Table 10. Cumulative percentage reduction in cyanogen content at each step of two commonly used methods of cassava leaves preparation into food

Processing stage	Leaves from TMS 30572	Leaves from TME 1	Average
Method 1			
Fresh leaves	-	-	-
Blanching	55.1	59.8	57.5
Pounding	90.1	91.5	90.8
Cooking	99.6	99.1	99.4
Method 2			
Fresh Leaves	-	-	-
Scrubbing	53.5	51.7	52.6
Grinding	74.3	76.1	75.2
Cooking	99.6	99.4	99.5

Assessment of functional characteristics of EARRNET/ESARC cassava germplasm

by J.A.W, W.K. - in collaboration with T. T Kadere and A. O Makhokha

In collaboration with the Jomo Kenyatta University of Agricultural Science and Technology, Nairobi, Kenya ESARC/EARRNET is implementing functional quality analysis of 832 advanced genotypes from the regional germplasm program for potential end-uses and markets. Preliminary results reveal wide genotypic differences for storage root functional characteristics indicating suitability of cassava for a variety of end uses in the food, feed and industrial sectors.

6.5.3 Effect of cassava processing on the functional characteristics of cassava flour

by M.B. - in collaboration with Razafimahefa

The extent to which processing conditions affect the physico-chemical characteristics of cassava flour and its bread-making potential was investigated. A split-plot design was used with peeling and no-peeling of roots as the main plots; the treatments were fermentation in water, fermentation in a bag and no fermentation; sub-treatments were 4 levels of size reduction: a) roots longitudinally split in half, b) roots transversally cut in large chunks, c) shredded roots and d) grated roots. Physico-chemical analyses, including proximate composition, starch characteristics, rheological properties and pasting behavior of flour obtained from the 24 treatment combinations were conducted. The flour from these treatments were used as partial substitute (10%, 20%, and 30%) of wheat in the production of composite bread. Such bread were evaluated by a sensory panel made up of 5 men and 5 women.

The results indicate that the flour extraction rate is lowest when roots are peeled, grated and fermented in water (22%); fermented chips, chunks and slices have an extraction rate of 26%. Peeled cassava left to ferment in a bag have an extraction rate of 26-28%, while non-fermented peeled roots have an extraction rate of 31%. Extraction rates for cassava roots that are processed without peeling varies from 25 to 37%. They are highest when no fermentation is applied, and lowest when the roots are grated and fermented in water. The specific density of the flour obtained varies from 0.45-0.52 when the roots have been fermented with or without the peels; it varies from 0.53-0.64 when the roots are not fermented or are left to ferment in a bag.

The color of cassava flour is strongly influenced by whether they are processed with or without the peels. Cassava roots processed after peeling give flours with a bright white color. The pH of the flour is lower than 5 when the roots are fermented in water and higher when they are fermented in a bag or not fermented at all. However, grating the roots has a reducing effect of the pH of the flours for all treatment combinations.

The residual protein content in cassava flour is considerably reduced (0.65%) when the roots have been fermented in water after peeling while it varies from 0.94% to 1.88% in all other treatment combinations. The fermentation process has also a significant reducing effect on the ash content of the flours. On the other hand, the residual carbohydrate content was greater in flour obtained from roots that had undergone fermentation. Total reducing sugars were considerably reduced to 0.66%-0.91% in flours from roots that were fermented in water without peeling and to 0.61%-0.66% in flours from roots that were fermented in water after peeling compared to 4.51%-5.74% in flour from unpeeled non-fermented roots and 4.28%-5.09% in flour from peeled non-fermented roots.

The amylose/amylopectin ratio was higher in flour from roots fermented in water: roots fermented in water after peeling gave the highest amylose ratio (23%). The treatments did not affect the gelatinization temperature of the flour, which was about 76.5°C. The peak viscosity of the flours was highest in flours from roots fermented in water, probably because of these flours higher amylose ratios.

The flour were used to make composite bread and the quality of the breads were evaluated by a sensory panel. The data are being compiled and analyzed.

6.5.4 Cassava safety studies: tropical ataxic neuropathy (TAN) in Nigeria

by M.B. - in collaboration with A. Onabolu and S. Oluwole

The causation of tropical ataxic polyneuropathy (TAN), a neurologic syndrome of polyneuropathy, gait ataxia, optic atrophy and neurosensory deafness, has been associated with cyanide released from residual cyanogens in foods processed from cassava roots. Association of frequent consumption of cassava foods and high prevalence of TAN has been shown in epidemiological studies of several communities in Nigeria. Thiocyanate, the major metabolite of cyanide, has been shown to be elevated in the affected population providing strong indirect evidence of exposure of the population to dietary cyanide. However, the average amount of cyanide absorbed into systemic circulation from ingested cyanogens as well as the kinetics of cyanide and thiocyanate, the major metabolite of cyanide, are unknown. This study was conducted to determine the average amount of cyanide absorbed from ingested residual cyanogens in gari, its disposition, and elimination in a sample of healthy young adults.

Twelve healthy adults were given a meal of 150 g of gari containing cyanohydrin with 128 µmol maximum releasable cyanide ions. Concentrations of cyanide in erythrocytes and plasma, and concentrations of thiocyanate in plasma and saliva were determined at baseline, and following the meal every 15 mins for one hour, hourly for 4 four hours, and 2 hourly from 4 to 12 hours. Excretion of thiocyanate was determined in the urine 12 hours before the meal, at two 6 hourly periods after the meal and finally from 12 to 24 hours after the meal.

At baseline, geometrical mean concentration of cyanide was 1 µmol/L (0-1) in erythrocytes, and 5 µmol/L (2-17) in plasma, while thiocyanate was 37 µmol/L (22-61) in plasma, and 449 µmol/L (178-913) in saliva (Table 11). Cyanide peaked in plasma at 10 µmol/L (2-26) in 8.4 hrs (range 8-10), and returned to baseline in 11.8 hours (10-12), but concentrations remained unchanged in erythrocytes. Thiocyanate peaked in plasma at 46 µmol/L (32-88) in 7.3 hours (4-10), and returned to baseline in 12.5 hours (10-24), while it peaked in saliva at 744 µmol/L (266 –1839) in 7.1 hours (2-10) and returned to baseline in 12.7 hours (8-24). Excretion of thiocyanate in the urine increased from 1.6 µmol/L (0.7-3.0) at baseline to 2.0 µmol/L (0.9-3.4) during the first 6 hours after the meal and returned to 1.5 µmol/L (0.7-2.7) 12 hours after the meal. Twelve µmol (2-31), about 9% (2-24), of ingested cyanide was absorbed into systemic circulation.

Less than 10% of ingested cyanide was absorbed into systemic circulation, but the elimination from the plasma was slow suggesting that frequent consumption of foods with high residual cyanogens would lead to accumulation of cyanide. The kinetics of dietary cyanide may have implications for the causation of TAN.

Table 11. Kinetics of cyanide absorption and thiocyanate release in subjects fed with gari

Measured metabolites	Baseline status Conc. (µmol/L)	Peak status Conc. (µmol/L)	Peak status Time (h)	Time to return to baseline (h)
Cyanide in erythrocytes	1			
Cyanide in plasma	5	10	8.4	11.8
Thiocyanate in plasma	10	46	7.3	12.5
Thiocyanate in saliva	449	744	7.1	12.7
Thiocyanate in urine	1.6	2	6.0	12.0

6.5.5 Evaluation of methods for conserving cassava by-products for livestock

by A.L., A.D.

Various cassava plant parts were preserved for utilization as livestock feed as follows:

1. Cassava peels (sun dried and milled)
2. Cassava chips (sun dried and milled)
3. Cassava whole leaf (sun dried and milled)
4. Cassava seed cake (roasted and milled)
5. Cassava chips ensiled (pre-dried for 8 hours, ensiled under anaerobic conditions for 5 weeks, dried and milled)
6. Cassava leaf ensiled (pre-dried for 3 hours, ensiled under anaerobic conditions for 5 weeks, dried and milled)
7. Cassava feed composite of peel, chips, leaves, and seed cake (1-4 above) in equal proportions)

The proximate composition and cyanogenic potential were subsequently assessed. The various plant parts and their combinations varied in term of nutritive value (Table 12).

Whole leaf (sun dried and milled) and seed cake (roasted and milled) had the highest protein content of roughly 25%. Ensiled cassava leaf (dried and milled) had the highest fat content of 6.7% and was followed by whole leaf (sun dried and milled). Crude fiber and ash contents were highest in the cassava seed cake (roasted and milled). Cassava peels (sundried and milled) had the highest moisture content. For all cases, except for the cassava seed cake (roasted and milled) and cassava peels (sundried and milled) which were not assessed, the cyanogenic potential was less that 5 mg/100g of fresh weight, which is the recommended safe limit. The cyanogenic potential of the ensiled cassava leaf was not detectable.

Table 12. Proximate composition and Cyanogenic potential (CNP) of various cassava plant parts for livestock feed

Sample	Protein (%)	Fat (%)	Crude Fiber (%)	Ash (%)	Moisture (%)	CNP (mg/100 FW)
Cassava peels (sundried and milled)	5.50	1.62	16.62	9.25	7.98	.
Cassava chips (sun dried and milled)	3.00	1.55	2.20	2.68	2.46	1.38
Cassava whole leaf (sun dried and milled)	24.75	6.19	12.10	6.28	5.50	3.60
Cassava seed cake (roasted and milled)	24.88	5.03	32.88	14.74	4.70	.
Cassava chips ensiled (pre-dried for 8 hours, ensiled under anaerobic conditions for 5 weeks, dried and milled)	2.63	0.61	3.38	1.50	2.70	0.19
Cassava leaf ensiled (pre-dried for 3 hours, ensiled under anaerobic conditions for 5 weeks, dried and milled)	19.94	6.67	9.26	10.50	5.98	ND
Cassava feed composite (leaves, peel, chips and seed cake)	7.38	0.78	26.24	5.70	5.32	.

ND= Non-detectable

6.5.6 Development and dissemination of new processing technologies targeting increased income generation

by scientists named in each subsection

Cassava diets for poultry and pigs

by M.B.

The poultry industry absorbs over 90% of manufactured livestock feeds in Nigeria. The supply of maize, which is a major component of such feeds, has been drastically reduced due to high cost and competing needs for it from other industries. Cassava stands as a viable alternative to maize in the feed-milling industry because a combination of cassava roots and leaves could provide an optimal balance of energy and protein in the feed at a reduced cost. Pigs, which are commonly fed palm kernel cake (PKC) could greatly benefit from the addition of the cassava root-leaf mixture to improve the performance of pigs

The problem of cassava usage for livestock feeding has been related to its form of presentation. In the European Union where cassava is popularly used in livestock feeding, the cassava is palletized. Whereas in a few farms and feedmills where it is used in Nigeria, it is presented in a milled form thus creating problem of dustiness in feed mills and respiratory disorders in the animals consuming the feed.

The present study was designed to evaluate the performance of layers and growing pigs on maize, milled or palletized cassava based rations. The trial aims at comparing performance on conventional maize based ration and new cassava formulations in the rural livestock farm setting. This activity aims at obtaining cassava rations that can be packaged for promotion to farmers in Nigeria and other tropical countries.

A total of 48 laying birds of the Isa Brown strain were weighed and allotted to three treatment groups and paired in battery cages. There were 16 birds per treatment; with four replicates of four birds each. The birds were offered maize, milled cassava, or palletized cassava rations as in Table 13. Feed and water was offered ad libitum. Weekly feed consumption and daily egg production were determined. Body weights were also measured at four weekly intervals. Biochemical parameters measured include blood cholesterol and nutrient digestibility. Egg quality characteristics were also monitored. The trial lasted eight weeks.

Table 13. Gross composition of diets used for layers

	Control maize-Based diet	Cassava meal based diet	Cassava pellet based diet
Maize	45.00	-	-
Cassava mixture	-	47.00	47.00
Wheat Offal	12.00	4.25	4.25
Groundnut cake	13.00	20.00	20.00
Palm Kernel cake	16.75	12.00	12.00
Fish meal 65%	2.00	2.50	2.50
Palm Oil	-	3.00	3.00
Bone meal	2.50	2.50	2.50
Oyster shell	8.00	8.00	8.00
Premix	0.25	0.25	0.25
Salt	0.25	0.25	0.25
Lysine	0.15	0.15	0.15
Methionine	0.10	0.10	0.10
Calculated energy (kcal/kg Me)	2519	2513	2513
Calculated crude Protein (%)	16.70	16.80	16.80

For the pig feeding experiment, a total of twenty growing pigs were allotted to five treatment groups with two replicates of two pigs each. They were offered a commercial cereal based ration, threshed cassava ration, milled cassava based ration, pelleted cassava based ration and palm kernel cake (PKC) which is the rural farmer ration (Table 14). Pigs were offered the ration as supplement to a bulk of palm kernel cake (PKC) in a ratio of 4:1 PKC to supplement. Feed and water were provided and libitum. Weekly body weight and feed consumption were obtained. Serum cholesterol was also measured on termination of the study after eight weeks trial.

Whole cassava storage roots and leaves were harvested from IITA experimental plots. They were washed and separately threshed, sundried with occasional turning of the tubers for a period of between three and seven days. They were then left to dry in a glass house before being milled into powder using a hammer mill. The dried milled storage roots and leaves were then, thoroughly mixed in a ration of 4:1.

For the pelletized ration, a locally fabricated meat mincer was used to obtain the pelletized compound feed after treatment with hot water, which was added in a ration of 4 parts.

Table 14. Gross composition of diets used for pigs

	Control diet	Shredded cassava diet	Milled cassava diet	Pelletized cassava diet	Farmer's diet (PKC)
Wheat offal	40.00	-	-	-	-
Palm Kernel cake	39.25	-	-	-	100.00
Cassava Mixture	-	79.25	79.25	79.25	-
Soybean meal	3.00	3.00	3.00	3.00	-
Cotton seed meal	5.00	5.00	5.00	5.00	-
Blood meal	5.00	5.00	5.00	5.00	-
Fish meal	1.00	1.00	1.00	1.00	-
Brewers yeast	5.00	5.00	5.00	5.00	-
Oxytetra	0.20	0.20	0.20	0.20	-
Ferrous Sulphate	0.10	0.10	0.10	0.10	-
Micro mix (premix)	0.25	0.25	0.25	0.25	-
Salt	1.00	1.00	1.00	1.00	-
Methionine	0.10	0.10	0.10	0.10	-
Lysine	0.10	0.10	0.10	0.10	-

The performance records (Table 15) revealed that feed consumption was highest on the cassava pellet while those on the cassava mash were similar to the maize based diet. The hen day production was however poorest with cassava pellet diet. This trend is explainable by the higher feed consumption on cassava pellet based diet which resulted in higher body weight of 1.9 kg as well as a high level of serum cholesterol of 146.8mg/100ml which is an indicator of higher fat deposition. The cassava pellet diet therefore promotes higher body weight gain but lower egg production. Certainly, the egg production can be improved upon through incorporation of cheep fibrous ingredients into the pellet and feed thus giving a dual advantage of reduced feed cost and high egg production. The higher body weight gain on the cassava pellet diet also shows its potential for broiler production. Egg quality characteristics were similar on the diets. Remarkably, the yolk color was superior on the cassava pellet diet as compared to others. Feed cost per tonne was lower by about N1,000 on the cassava diets as compared to the maize (Control) diet.

Table 15. Performance of layers on the various diets

	Control maize-Based diet	Cassava meal based diet	Cassava pellet based diet
Feed intake (g/day)	105.0	108.0	122.0
Hen day production (%)	68.6	61.6	56.6
Final body weight (kg)	1.5	1.6	1.9
Feed cost/tonne (N)	19,965.0	18,957.0	18,957.0
Egg weight (g)	69.8	68.6	67.5
Yolk weight (g)	18.9	18.7	18.4
Shell weight (g)	7.3	7.0	6.4
Yolk color	1.7	1.7	2.0
Shell thickness (mm)	0.32	0.32	0.33
Serum cholesterol (mg/100ml)	125.3	105.4	146.8

The performance records as in Table 16 show the superiority of pelleted cassava diets to others in terms of the body weight gain. Feed consumption was similar with an average of 2.5 kg/day on all treatments. Cost of feed was increased by supplementation of farmers' Palm kernel cake based diet with cassava or cereal by products. However, considering the period of attainment of a finisher body weight of 100 kg, it will take only 195 days or 6.5 months to attain 100 kg weight on the pelleted cassava diet as compared to about 360 days or 12 months on the farmers' diet. A poorer response on the milled and threshed cassava diets further supports the need for adoption of pelletized feeds in pig production in Nigeria. While the cholesterol level was highest on the pelleted cassava diet, it should be noted that those values are within normal limit in grower finisher pig.

Table 16. Performance of pigs growing on conventional and cassava-based diets

Parameter measured	Control diet	Shredded cassava diet	Milled cassava diet	Pelletized cassava diet	Farmer's diet (PKC)
Body weight gain (g/day)	384	290	319	424	223
Cost of feed/ton (N)	6700	7340	7340	7340	5000
Period to attain 100kg body weight (days)	234	293	255	195	360
Serum cholesterol level (mg/100ml)	143.5	140.0	113.0	150.5	136.5

Cassava can replace maize in layers' with reduced feed cost and satisfactory performance even when presented in a milled form as the dustiness is controlled through oil supplementation. Pelletized cassava ration has high potentials for layers if such diets contain fibrous ingredients to reduce fattiness in layers. Improvements in feed consumption and body weight shows high potentials in its use for broiler production. Improved egg yolk color on pelletized cassava diet shows the advantage of cassava leaf incorporation in such diets. Supplementation of the local farmers' diet of PKC with cassava in the milled, threshed or pelletized form improves body weight gain. Pelletizing cassava for pigs confers the advantage of a higher feed conversion, faster growth rate and reduction in period of attainment of market weight of 100 kg from about 12 months to 6.5 months.

Pilot processing centers in Zimbabwe and Swaziland

by I.K.

Processing equipment (5) were purchased and delivered to Swaziland and Zimbabwe in the last quarter of year 2000. The installation of the equipment and operationalizing the pilot processing center is underway in these two countries. Cassava and sweetpotato multiplication and production plots have been established with the participation of farmers near the centers to provide raw materials for processing. Demonstration of processing techniques and exhibition of processed products and recipes have been carried out in selected communities and activities are expanding to other communities. Several field days have been conducted by local technicians and scientists in Swaziland and Zimbabwe with support from the project on cassava processing and utilization.

Pilot processing plant in Western Kenya

by S.F., J.A.W, W.K.

To expand the marketing opportunities available to smallholder farmers, reduce their dependence on traders, improve the quality of intermediate cassava products and encourage take-up of cassava as input by a variety of end-users, a pilot processing plant in western Kenya has been initiated with the installation and testing of five processing equipment (manual chipper, manual and motorized graters, screw press, hammer mill) and tested.

The cassava-based processing equipment developed at ESARC were technically reviewed in collaboration with FAO and a web-based catalogue on prices, fabricators, output, numbers of equipment sold and technical drawings of these equipment are being compiled.

6.6 Agronomic practices for sustained production of improved cultivars

Background

Current farm level yield increases from adoption of improved cultivars, while substantial, do not realize the full yield potential of the new and improved cultivars. To achieve the full benefits of these improved cultivars, it is necessary that smallholder farmers improve their crop management practices. To achieve this, participatory on-farm research to develop 'best practices' needs to be emphasized, but more critically, the capacity to translate, package and disseminate the results of this research to increasing numbers of smallholder farmers must be expanded throughout the region through partnerships.

Cassava cultivation is expanding into the savannas as well as into some non-traditional areas of East and Southern Africa. Few data exists on the cropping systems, and little is known about cassava cultivation and its interaction with the prevailing systems. Also agronomic practices tend to be area specific, depending on the local soil type and weather, and other biotic and abiotic factors as well as socioeconomic circumstances. A sustainable expansion of cassava in the savannas and other areas must lay emphasis on the dominant cropping systems to attract the interest of the farmers. An understanding of the interactions between improved cassava genotypes and prevailing cropping systems can help in developing better cultivars to be used in these agroecologies. Thus attention should be given to the crop agronomy and quality of planting material for the purpose of promoting systems of production that can sustain crop productivity in the longer term in these areas.

Although cassava as a crop performs relatively well under harsh conditions, research has demonstrated profitable responses to improvements in crop and soil management. Cassava requires relatively little nitrogen to achieve high yields, so that it responds to no more than 100kg/ha of nitrogen after which diminishing marginal returns set in. Phosphorous is the most important nutrient for obtaining yield increase in cassava. It has also been shown that cassava extracts more potassium from the soil than any other element. Potassium availability also affects tuber quality, since its deficiency leads to lower dry matter and starch content and consequently higher cyanide content. The relationships between the nutrient uptake and what the plants return to the soils by way of debris under continuos cultivation is not clearly understood.

With increasing population pressure and continual degradation of the physical environment, increasing proportion of cassava cultivation is being done under very marginal conditions: unstable climates, unreliable rainfall, fragile, degraded poor soil. To sustain productivity under such a declining resource base calls for an evaluation of existing production practices and development of improved management systems for both traditional and non-traditional cassava production areas.

On-going and future activities

6.6.1 Develop and test simple agronomic technologies capable of increasing yields, reducing the pressure of pests and diseases, and reducing production costs of cassava in various agroecologies

by scientists named in each subsection

Development of improved production technologies in SARRNET region

by NARS - in collaboration with J.T. and M.A.

No results to report in 2000.

Development of improved production technologies in EARRNET region

by T. Munga - in collaboration with J.W.A., W.K.

Dry matter partitioning of three local cassava cultivars in intercrops with maize and cowpea and in sole systems in the lowland elevation of coastal Kenya was evaluated for the second year and the resulta are yet to be compiled.

Development of improved production technologies in the semiarid zone of West and Central Africa

by NARS - in collaboration with A.D. and P. Ilona.

NARS were supported in the design and conduct of 'best bet' production technologies and practices in on-station with farmers' participation and some currently in on-farm trials to give farmers the opportunity to identify the best options under their local conditions. Cropping practices for increased cassava productivity, soil fertility maintenance and complementary crop management practices aimed at protecting cassava fields from animal damage during the dry season such as live fencing were evaluated.

6.6.2 Establishment of on-farm adaptive trials and farmer participatory research

by scientists named in each subsection

Establish on-farm adaptive trials and farmer participatory research in the semi arid zone of West and central Africa

by NARS - in collaboration with A.D. and P. Ilona.

Various collaborative breeding experiments (on-station and on-farm) continued to be planned and executed, and monitored jointly with NARS partners including farmers, women organizations and NGOs in Burkina Faso, Niger, Nigeria and Chad. The active participation of end-users (e.g. farmers and processors) in the research and development process ensures, among other things, the relevance of the outputs to the end-users and increased the potential for adoption and impact.

On-station participatory evaluation

Twenty-five new genotypes were selected from 6 trials harvested at 2 locations – Farakoba and Fada in Burkina Faso by 113 farmers and processors from 12 villages in Burkina Faso. Five of the genotypes, 91/02324, 92/0067, 92/0427, 91/02312 and 4(2)1425 are being tested in on farm trials.

Two hundred and fifty-five farmers from five villages (60% were women) evaluated and identified 36 new cassava cultivars from six on-station trials in Chad.

In Niger, 190 farmers comprising 82 men and 108 women from 10 villages evaluated and identified 35 new genotypes from 4 on–station trials.

Sixty-five farmers from Mallam Madori in Jigawa State, Nigeria evaluated and identified 25 new genotypes for the semiarid zone from 5 on-station trials.

On-farm trials

In Burkina Faso, 4 genotypes, 92/0057, Alice local (selected landrace from Nigeria), M94/0177 and 94/0270 produced 30.2, 25.0, 24.6 and 20.1 t/ha of fresh storage roots, respectively in 40 community-based on-farm trials involving 55 farmers' co-operatives across 15 villages. The 2 local checks had yields of 9.2 and 10 t/ha. Apart from the farmers retaining planting materials to grow on larger areas, these on-farm trials of improved clones also provided planting materials, which benefited over three thousand farmers.

The mean root yield of 12 improved genotypes evaluated by 700 farmers in 55 villages in Chad was 20.2 t/ha with a range of 7.3-35.7 t/ha. The root yield range of the 5 local checks used was between 7.3 to 12.4 t/ha. The best genotypes were 94/D01, 94/D23, 94/D30, 94/D66 and 94/D70 and produced root yields above 30 t/ha.

The best cultivar in community based on-farm trials involving 250 farmers in 10 villages in Niger was M85/01887, and produced mean root yield of 19.4 t/ha compared to the local check which produced root yield of 10.9 t/ha. Farmers at Barna and Tara have started replacing local cultivars with the improved genotype.

Establish on-farm adaptive trials and farmer participatory research in EARRNET member countries

by NARS - in collaboration with J.A.W, W.K. S.N

Five clusters of sites (Gulu, Mukono, Lira, Luero and Kumi) in Uganda with a total of 80 farmers, each receiving 5 clones were selected for on farm evaluation using an augmented design. It is anticipated that this arrangement will facilitate researcher-farmer collaboration, farmer participation in early identification of cultivars and improve technology uptake pathway.

Similar trials are being conducted in Western Kenya. Fourteen elite clones multiplied in 1999 are being tested on-farm using an augmented design. Preliminary results from these trials indicated that over 90% of the entries have consistently shown no symptoms of cassava mosaic disease.

Establish on-farm adaptive trials and farmer participatory research in Zimbabwe

by I.K. - in collaboration with World Vision International and farmers

Four cassava cultivars currently under multiplication were established in January, 2000 in a field trial in Mudzi District with the collaboration of World Vision International. The trial will be harvested in January 2001 and the farmer-preferred cultivars will be multiplied in the area for distribution. Preliminary results indicated that the local cultivar (SMART) and one improved cultivars (M7) performed well. It is expected that another trial with 10 IITA improved cultivars will be established in the District next season.

6.6.3 Long-term trial for assessing the sustainability of common cassava-based cropping systems in soils of Eastern Nigeria: cassava yield variations: cassava yield variations

by C.L. A. Asadu (Department of Soil Science, University of Nigeria, Nsukka, - in collaboration with A.D.

Three-year cassava yield data obtained from crop mixtures were analyzed in this study. The cassava mixtures were cassava + yam + maize + pigeon pea, cassava + maize + pigeon pea, cassava + pigeon pea, and sole cassava. All were grown in a randomized complete block design replicated trice in two locations of different land use history. The objective was to assess the performance of cassava in the selected crop mixtures over three years. The soil management technique involved returning the crop residue to the plots. The two locations were a virgin forest cleared in 1998 at the inception of the project and the UNN farm that had been under cultivation for more than 25 years earlier. Generally there were large reductions in root yield between the first and second crop year but there was a very slight increase in root yield between the second and the third year except in plots where all the crops were combined. At the forest location and between 1998 and 1999, the average root yield reduction across the crop mixtures was 42% with the highest reduction of 50% obtained from the sole cassava plots and the least 32% from plots where all crops were combined. At the UNN farm the mean root yield reduction was >70% with 81% obtained from cassava + maize + pigeon pea as the highest and 63% from plots that carried all the crops as the least. The mean reduction in harvest index (HI) over the same period and location was low. Between 1999 and 2000 there was <10% average increase in root yield across the crop mixtures and locations. Reduction in root yield, however, occurred in plots that carried all the crops. There were increases in harvest index especially at the forest location with a mean of >65%. On the other hand, there was an average reduction of HI at the UNN location. The overall trend from 1998 to 2000 showed that the mean reduction in root yield was about 35% at the forest location, 70% at the UNN location, increase in HI of about 60% at the forest location and a reduction of about 20% at the UNN location. The extent of yield reduction in both locations clearly showed the need for supplemental mineral fertilizer application for the sustainability of the system in both soils.

6.6.4 Management of speargrass (*imperata cylindrica*) with cover crops in cassava

by D.C.

No results to report in 2000.

6.6.5 Integration of herbaceous legumes with maize/cassava cropping

by G.T.

No results to report in 2000.

6.6.6 Response of cassava to N, P, and K on degraded terre de barre soils in southern Benin

by R.C., G. T. - in collaboration with M.A. Toukourou, INRAB-Niaouli

The 'terre de barre' soils of southern Benin and Togo have good physical properties but are known to be naturally low in exchangeable K, an important nutrient for cassava. A trial was initiated on 15 farmers fields (repetitions) on a relatively fertile 'terre de barre' site (Hayakpa 2°08'E; 6°33'N). The objectives include validation of critical K levels as well as estimation of recycling of K in cassava litter. Litter traps measuring 1 m^2 were located in unamended, K only, and NPK treatments of ten repetitions. Other treatments include NP, NK, and PK combinations. Our working hypothesis is that K is the limiting element for cassava root production. Index leaves for critical K levels are the youngest fully expanded leaves (YFEL) at 6 MAP. Cassava cultivar BEN 86052 is being used. The trials were established in May, 1999 and weeds were very well managed. Monthly litter collection began at 5 months after planting (MAP) and dry matter of four plants was estimated in each plot at 6, 9, and 12 MAP.

Leaf litterfall was an important fraction of the total dry matter. At 6 MAP mean cumulative leaf litter accounted for 14 to 18% of total dry matter and at 9 and 12 MAP cumulative leaf litter was 25 to 30% of total dry matter, amounting to more than 3 t/ha (Table 17). Nutrient concentration in the litter was estimated at 9 MAP. Assuming the same nutrient concentrations throughout the year, the nutrient recycled to the soil in litter was approximately 5 kg P, 40 kg K, and 80 kg N/ha (Table 18).

There was no significant response to N, P, or K fertilizer on the 15 fields on which the test was conducted. Fresh storage root yield by field averaged from 14.3 to 24.4 t/ha and storage root dry matter yield was 4.3 to 7.5 t/ha. Because cassava did not respond to N, P, or K it was not possible to estimate critical soil levels of these nutrients. The fields were relatively fertile. Organic carbon ranged from 8 to 12 g/kg and clay content was 100 to 180 g/kg. Mean Bray^{-1} P was 6.1 ppm (std dev. 1.6) and mean exchangeable K was 0.13 cmol(+)/kg (std dev. 0.04). Exchangeable Ca was 6 cmol(+)/kg (std dev. 1.2). Note that P was applied as TSP, which contains 12 to 16% Ca. Although the response to K was not significant, some evidence that K was limiting includes:

- K concentration in the youngest fully expanded leaves at 6 MAP responded significantly to K application, from 1.7% without K applied to 2.0% with K applied. But these levels are in the sufficient range as proposed previous authors.
- Storage root yield increase from K application averaged approximately 1 t/ha when exchangeable K was 0.13 cmol(+)/kg or below while on average mean storage root yield did not increase with K application if exchangeable K was above 0.13 cmol(+)/kg.

Table 17. Cumulative cassava litter dry matter (Mg/ha) and proportion (%) of total plant dry matter in 10 farmers' fields in southern Benin

	------ 6 months ------		------- 9 months ------		----- 12 months ------	
Treatment N-P-K	Cumulative Litterfall*	% of total	Cumulative Litterfall*	% of total	Cumulative Litterfall*	% of total
0-0-0	1.27	14.5	2.94	29.4	3.40	28.6
0-0-K	1.41	17.8	3.18	28.5	3.70	25.5
N-P-K	1.64	14.7	3.55	27.4	4.12	29.2
SE(diff)	----		0.220		0.249	
Prob.	n.s.		0.033		0.025	

Table 18. Nutrients (kg/ha) recycled in cassava litter 5^{th} to 12^{th} month on ten farmers' fields in southern Benin

Treatment N-P-K	N	P	K
0-0-0	74.6	5.1	38.5
0-0-K	81.1	5.5	41.9
N-P-K	90.4	6.2	46.7

6.6.7 *Mycorrhiza* association in cassava

by N.S.

This activity was put on hold for lack of a good Ph.D. student to undertake the studies.

6.6.8 Nutrient Management for High-Yielding Cassava in the Derived Savanna and Southern Guinea Savanna

by O.G., G.T

The agronomic performances of newly improved high yielding cultivars such as 91/02324 with multiple disease resistance in various agroecological zones have not been adequately studied with respect to nutrient management. A trial was initiated in 2000 to determine the "critical nutrient requirements" of N and K for such cultivar and thereby design economically optimal rates of fertilizer for the derived savanna (DS) and southern Guinea savanna (SGS). The trials involve factorial fertilization rates of N up to 150 kg ha^{-1} and K up to 300 kg ha^{-1}. The other aspect of this activity is to design a proper nutrient management package that involves the use of chemical fertilizer, animal farm yard manure, and nutrients recycled from cassava plant residues. A preliminary report on this activity will be available at the end of 2001.

6.7 Capability of NARS to undertake cassava research and development and training enhanced and partnership with NARS strengthened

Background

Recognizing the growing importance of cassava research in Africa over the years, a mutually beneficial collaboration through meetings, workshops, newsletter, exchange visits, training and technical backstopping are essential to build the institutional capacity of our NARS partners and contacts between personnel working with the crop. The effectiveness and efficiency in developing, adapting and disseminating improved agricultural technologies depends on the existence of a strong research base, comprising personnel, infrastructure, and financial resources. Strengthening national programs' capacity to conduct research and training is necessary for agricultural development and constitute the foundation of long-term sustainable agricultural research in Africa. Partnership in collaboration is indispensable for effective impact on a common objective. In addition, collaborative research schemes help to identify regional research priorities, catalyze information exchange, preclude duplicative research efforts and increase the transfer of technologies among partners. Making use of the comparative advantage of NARS to conduct different types of research benefits both NARS and IITA, and the ultimate beneficiaries, the farmers. Feedback on technologies in two directions is invaluable in the continuous refinement of research strategies for effective impact.

On-going and future activities

6.7.1 Develop manpower resources through regional and in-country, specialized and individual training and study visits to provide continuity and improved management of research in various national root crops programs and organizations

by scientists named in each subsection

The capability of NARS and NGOs to undertake cassava research and development was enhanced through three training workshops on cassava processing techniques; report and proposal writing; and cassava mosaic disease monitoring and diagnostics; as well as courses on rapid multiplication of cassava; commercialization and enterprise development for cassava and sweet potato planting materials production and distribution; cassava and sweet potato processing, products and market development; monitoring and impact assessment of root crop technologies; and virus elimination and detection for 123 technicians, extension workers and researchers in East and Southern Africa.

Training (EARRNET/ESARC)

by J.AW, W.K. S.F., V.A - in collaboration with M.T.A.

A total of 25 researchers from EARRNET member countries attended a one and a half-week training on report and proposal writing at the International Livestock Research Institute (ILRI), Nairobi Kenya June 26 to July 4 2000. The workshop aimed to assist NARS researchers in the region to develop skills in the preparation of research report and proposal writing with a view to promoting research management efficiency. It is envisaged that this workshop will strengthen participants' research planning and management skills through focused activities on report and proposal writing.

During the ASARECA Annual Consultative Forum for Work Plan Review and Programming held in Antananarivo, Madagascar, 7-14 July 2000, ECAPAPA and EARRNET were selected to plan for joint training for the networks and convene a workshop on impact assessment methodologies aiming at improving performance of the research networks and systems in east and central Africa. A total of 22 researchers from ASARECA countries attended a two-week workshop on monitoring and impact assessment of root crops technologies in Nairobi, Kenya. The course was designed to introduce NARS researchers to the concept of impact assessment and sensitize researchers to the needs of other stakeholders in the research process. The workshop will enable participants to integrate impact assessment into the research agenda and demonstrate competence in the use of appropriate analytical tools to assess project impact. Participants will develop a plan of action for further follow-up and evaluation.

Two scientists from KEPHIS attended a course in virus elimination and detection in the Republic of South Africa 28 July to 8 August 2000.

Eleven researchers from East and Central Africa participated in a cassava mosaic virus disease monitoring and diagnostics training workshop held at IITA/ESARC, Namulonge Uganda 8 – 19 May 2000.

The Agricultural Technology Development and Transfer Project in Rwanda organized a rapid multiplication course on cassava for 12 technicians. Program Leader of the Root Crops Program was sponsored to the report and proposal writing, and impact assessment courses at ILRI, Nairobi, Kenya. Two economists were also sponsored to the training course on market analysis, and impact assessment, respectively.

A website (www.cgiar.org/foodnet) established for the food network of East Africa (FOODNET) to avail regional partners with information about current events in the network and to provide a site for collating project and associated R&D information has been taken as the template for the recent construction of 14 regional network websites, which comprise the ASARECA portfolio.

Training in Zimbabwe and Swaziland

I.K. - in collaboration with SARRNET and NARS

A training workshop on cassava processing techniques was conducted and attended by 15 participants, mostly home economists from Lesotho and Swaziland. Several processing demonstrations were carried out in Swaziland and Zimbabwe with the aim of expanding the utilization of cassava.

On-ground training of farmers in rapid multiplication techniques and agronomic practices of both cassava and sweetpotato were also carried out in Swaziland and Zimbabwe.

Training and field days in the West and Central Africa

by NARS - in collaboration with A.D. and P. Ilona.

Farmers' field days were organized in Burkina Faso, Chad, Niger and Nigeria during the harvesting of trials. Farmers and farmers' groups, women organizations, other endusers and stakeholders e.g. NGOs were exposed to improved genotypes, 'best bet' production practices and expanded utilization of cassava.

In Burkina Faso, new production and processing technologies which included pre-sprouting stakes in polythene bags to reduce termite damage, early planting to reduce the period of stress on cassava, and use of organic manure to improve soil fertility were demonstrated to 113 farmers from 12 villages. In addition, women were taught to process cassava into couscous and to make confectioneries from unfermented cassava flour. In addition, 48 farmers at Santidougou and neighboring villages were trained in December 2000 to process cassava into gari, tapioca, starch and flour.

In Chad, 25 farmers, 4 extension agents from the National Extension Services and 2 technicians each from World Vision International and SECADEV participated in a village level training on rapid multiplication of cassava organized at Deli I, II and III.

Two major field days were organized by the Institute of Agricultural Research (IAR), Sierra Leone: one at Lungi in the Northern Province bordering the western Area and the other at Njala. The IAR also participated in a series of field days organized at various locations in the Southern and Eastern Provinces. Cassava flour production, composite bread and a number of improved cassava-based recipes were popularized during these field days. A total of 300 women farmers, of which about 50% are widows of war, participated at the Lungi field day while about 200 farmers of which 30% were women participated at the Njala field day.

A total of 25 agricultural technicians and 80 farmers (20 at each location) were also trained in rapid multiplication of cassava.

6.7.2 Establishment and enhancement of primary multiplication centers for production and distribution of clean planting materials

by scientists named in each subsection

Multiplication and distribution of planting materials in West and Central Africa

by NARS - in collaboration with A.D. and P. Ilona

Planting materials (160,000 stakes) of 5 improved cassava cultivars were produced in Farakoba and Fada to establish 4 ha of new multiplication fields at Farakoba, Banfora and Fada, and to distribute to farmers in 11 villages covering 7 provinces in the West, South West and Eastern parts of Burkina Faso. Planting materials were also distributed to local NGOs (Diocese de Bobo-Dioulasso and Diocese du Diebougou) for further multiplication and distribution to church members. Additional 100 farmers received an average of 500 stakes each for planting in their private farms.

In Chad, planting materials (350,000 stakes) of 10 improved cassava cultivars were produced on-station from 3 hectares of land at Deli and Bekao, and was given to the national extension agency (ONDR) for distribution to farmers. World Vision International and SECADEV (Secour Catholique pour le Developpement) also distributed over 100, 000 planting stakes to farmers in their target areas. Planting materials (150,000 stakes) were produced in community farms at Moundou, Deli, Bousso, Sarh, and Bekao. They were shared among members, and used to establish 15 ha of new multiplication fields.

In collaboration with the National extension service, in Guinea, planting materials for 1000 m^2 of three cassava cultivars was provided to each of 10 farmers (contact growers) from four regions (Coyah, Kindia, Mamon and Dalaba) to produce an estimated 150,000 planting stakes for distribution to farmers in 2001.

In Niger, planting materials (5000 stakes) of 4(2)1425 and M85/01887 were supplied to additional farmers in two villages (Barna and Tara). At Lossa and Bengou, 50,000 stakes of five improved cassava cultivars were produced. Fifteen thousand stakes were used to establish new multiplication fields on-station, and 20 000 stakes were multiplied in farmers fields. The rest was distributed to farmers through the extension service unit of INRAN and through NGOs (SIM International and World Vision International).

In Nigeria, 10 improved cultivars (TMS 30572, 92/0326, 92/0325, 4(2)1425, 91/02324, 93/0665, 95/0289, 96/0160, 96/0304 and 92B/00061) were multiplied at Mokwa, Zaria and Mallam Madori in Northern Nigeria to produce and estimated 465,000 stakes of improved cassava cultivars for distribution to farmers in 2001.

A total of 4.8 ha of cassava multiplication plots of two prominent cassava cultivars (86/1 and 83/15) were established by 5 Farmers' Associations in two regions (North-western and Western Area) in Sierra Leone between October and December, 2000. Smaller multiplication plots were also established with two promising individual farmers in the Northwestern Region and one in the Western Area.

Multiplication of and distribution of clean planting material in EARRNET countries

by NARS - in collaboration with, J.A.W. and W.K.

In collaboration with various stakeholders, all EARRNET member countries are implementing rapid multiplication and distribution of improved planting material to accelerate impact at the farm level. In Uganda, over 100,000 hectares have been planted to at least four improved CMD-resistant cassava cultivars throughout the country.

In Rwanda, planting material generated from five secondary sites (Kibungo, Kanzenze, Kibayi, Makingi and Rutobwe) have been made available to plant about 200ha. In addition, about 120,000 cuttings of five improved cultivars (NASE 3, TME 14, I91/0057, 95NA/0063 and MH95/0414) were introduced into Rwanda from NARO/IITA collaborative program via open quarantine facilities to be planted in Kibungo and Nyagatare for in country observation before multiplication and distribution to farmers.

In Western Kenya, cultivars SS4 and Migyera continued to be multiplied at primary (79ha.), secondary (31ha), and tertiary (339ha), respectively. Despite the serious drought experienced and damage due to termites, sprouting was reported satisfactory. So far, a total of 2395 bags (2,395,000 cuttings) expected to plant about 450 hectares have been distributed from the seven initial primary sites.

In Madagascar three locally developed H63, H43 and H59 are being multiplied in collaboration with CARE international.

Multiplication of and distribution of clean planting material in SARRNET countries

by NARS - in collaboration with, J.T. and M.A.

No result to report in 2000

Multiplication and distribution of cassava planting materials in Zimbabwe and Swaziland

by I.K. - in collaboration with NARS

Nine cassava cultivars (XM4, XM6, M7, TMS 82/30555, TMS 82/00075, and TMS 82/00061 and 3 local cultivars in Zimbabwe, and one local cultivar (Mnyasa) in Swaziland are being multiplied for distribution. In Zimbabwe, about 52 ha of multiplication have been established and 51,000 cuttings have been distributed to growers. Three primary and six secondary sites have been established. Multiplication activities will be expanded at the present sites and new sites will be established. Organizations (NGOs) such as World Vision and Africare have also established multiplication plots in their constituencies using materials from the primary sites established. These organizations have plans to expand their multiplication area and conduct on-farm trials during the next season.

In Swaziland more than 5 ha of the cassava cultivar, Mnyasa, are under multiplication in two primary sites. The materials produced will be used to expand the area under multiplication to 20 ha and the remaining materials will be distributed to the farmers.

6.7.3 Provide technical backstopping to formal and informal networks

by All scientists

EARRNET

The regional EARRNET Agronomist visited Karama station in Rwanda from 9-12 August, 2000 to provide technical backstopping to the Cassava program. Dr. Khizzah reviewed the germplasm at Karama and made a number of recommendations for new introductions and selections. He visited again the program in November to assess the farmers cassava fields identified for a possible source of cassava cuttings to fulfill a special request of 5,000,000 cuttings by the Ministry of Agriculture. The fields visited by him were found to have a high infestation of cassava mosaic virus, and he recommended that these fields should not be as a source for supplying the cuttings.

IITA-ESARC

As considerable concern has been expressed about the continued spread of the new and more virulent form of the cassava mosaic virus within the Great Lakes Region. Dr. James Legg, a virologist from IITA-Uganda, visited Rwanda to conduct a disease survey in collaboration with ISAR scientists, to ascertain the disease status in the country.

Results indicated that most of the cassava growing areas of Rwanda, have a low incidence of mild to moderate cassava mosaic disease (CMD). This form of the disease is largely propagated through planting diseased cuttings. In the Umutara prefecture, and also in Kibungu prefecture, there is a low incidence of moderate to severe CMD, which has been recently introduced through whitefly infection. This zone is considered to be an expansion of the CMD pandemic into north-eastern Rwanda from the bordering areas of southern Uganda and north-western Tanzania known already to be affected by the pandemic.

IITA-Headquarters

In addition, backstopping was also provided to the National Root Crop Research Institute (NRCRI) in Nigeria in the identification and nomination of genotypes for the statutory National Coordinated Research Project (NCRP) trials required for the release of cultivars to farmers and participation in the joint evaluation of performance of improved cassava clones.

The coordinator of this project attended the Annual Steering Committee Meeting of the Root Crop Networks and provides technical backstopping to the coordination office and member countries on cassava research and development. Project members also provide technical advice and assistance to the networks coordination office and member countries.

6.7.4 Meeting with collaborators to plan and review work and exchange information

by A.D., N.M., I.K., N.M. J.A.W. S.F, S.K.. J.L., R.H. M.T.

Recognizing the growing importance of root and tuber crops research in Africa, National and IITA scientists working on root crops have developed a mutually beneficial collaboration through meetings, workshops and symposia. The aim of these forums are to evaluate research results, and plan future research taking note of research successes and failures; exchange new knowledge; standardize procedures; assess research needs; and plan future collaborative research through steering committee meetings, root crop collaborators meeting, root crop workshops and symposia, scientist exchange visits, technical backstopping and monitoring tours, and newsletters.

Collaboration with CIAT continues to be strengthened through exchange visits and joint activities/proposal writing, and germplasm exchange for the enhancement of cassava research and development in SSA.

In 2000, a meeting was organized to explore the possibilities for establishing closer links between IITA and CIAT in relation to research and development activities on market analysis and agribusiness development for cassava in Eastern and Southern Africa. The request for assistance from the CIAT's Rural Agro-enterprise Development project was made by the SARRNET project following the events that occurred after the steering committee meeting in Malawi, March, 2000. At this preliminary meeting, the CIAT team made three visits to (i) Ibadan, Nigeria (IITA headquarters), (ii) Kampala, Uganda

(IITA regional Center for Eastern and Southern Africa) and to (iii) Lilongwe, Malawi, headquarters of the SARRNET project. The objectives of these meetings were to (i) introduce the CIAT team to the IITA cassava research and development team, (ii) provide the CIAT team with a clear understanding of the new R&D strategies being developed at IITA (West and Eastern Africa) and in particular to (iii) review the strategy and activities of the second phase of the SARRNET project and seek ways to shift the SARRNET research agenda towards a more market driven approach. It was also the desire of the IITA management that although the input from the CIAT group would focus on the activities in Southern Africa, the effects of the interaction with the IITA scientists would also percolate into the thinking and research implementation plans of cassava R&D in all zones of IITA operations.

Reports by FAO and others in 1999 and 2000 on the western and eastern parts of the country indicated that there had been a dramatic decline in the health status of cassava and that annual production was significantly decreasing. It was a matter of concern as it was likely to worsen the existing food deficit given that cassava is a staple food for 70% of the population. Several cases of famine and serious food insecurity had been reported in some regions. Moreover, it was also reported that in addition to traditional diseases and pests, other strains of cassava mosaic virus as well as other unidentified pests were constraints to cassava production and that this situation required urgent and concrete measures. In recent years, CMD has also caused devastation to cassava production in East Africa following the rapid spread of a new and abnormally virulent form of the disease-causing virus.

In the light of this, a Consultative Group composed of representatives of FAO, the Ministry of Agriculture, donors, INERA scientists, the private sector, and other partners in the DRC invited a team of scientists from IITA (2 cassava breeders, a virologist, and 2 entomologists) to visit the DRC. The purpose was to assist in the assessment of the phytosanitary status of cassava in the country, and participate in the development of an action plan to reinvigorate cassava cultivation. The IITA team, INERA scientists, and FAO staff collectively undertook field visits in December 2000 to Kinshasa and Bas Congo provinces. Cassava fields were assessed in the Plateau de Batéké (150 km from Kinshasa on the road to Kikwit), Kinshasa, and between Kinshasa and Boma in the Bas-Fleuve District, Bas-Congo. In all the fields visited, CMD-infected leaf samples were systematically collected and DNA extracted for appropriate analysis at IITA after the visit.

The field visits and findings of the IITA team confirmed the alarming phytosanitary situation of cassava in the country. As opposed to other African countries, all the diseases and pests reported in Africa were found in the fields visited. CMD was the most widespread and damaging constraint. Symptoms of CMD observed in the cassava cultivar 'Sedi' in the Plateau de Batéké were identical to those associated with the CMD pandemic in East Africa. The occurrence of both severe and mild CMD symptoms in different plants of the same cultivar suggested that more than one cassava mosaic virus and/or virus mixtures occur in the DRC. Laboratory analysis was also carried out at IITA after the visit on virus samples collected from 30 plants throughout the areas assessed in the western DRC. The results showed that there is a fairly strong indication that the Ugandan variant of East African cassava mosaic virus (EACMV-Ug) occurred virtually throughout the areas sampled. Overall, it was unanimously recognized that farmers in the DRC were suffering from major losses in cassava production caused by diseases and pests. In addition to the prevailing insecurity situation and the resulting disturbance of trading activities, the phytosanitary situation of cassava has compounded the general food insecurity in the country.

In the light of the findings, the following recommendation were made:

Short-term

- Establish decentralized and primary, secondary and tertiary rapid multiplication sites and distribution system of CMD-resistant cultivars in strategic locations in all the most recently affected areas in 11 provinces in the DRC
- Develop a multilateral-funded program to address present constraints in cassava production as the basis of sustainable production
- Establish a multi-institutional collaboration framework for the implementation of the multilateral-funded program. Institutional partners will be FAO, SECID, IITA, INERA, the relevant Technical Services Departments of the Ministry of Agriculture, NGOs, and the private sector
- Assess the status of cassava diseases and pests in all the accessible areas in the DRC and plant quarantine needs for cassava germplasm.

Medium-term

- Capitalize on the multilateral funded program and institutional collaboration in order to develop a foundation seed program and distribute new high yielding germplasm for specific uses. The program should also include the rehabilitation of the tissue culture facilities at M'Vuazi, the development of new technologies for a management system of various diseases and pests, the adoption of sustainable production and new cassava marketing approaches in the DRC, and capacity building in cassava research and development

The IITA team had the opportunity to report the findings of the visit and present their recommendations to the Government of the DRC, and to the international community during a planned feedback session with local representatives of donors in the country, and international and local NGOs. The representatives of the international community, already aware of the precarious food situation of the populations in DRC, notably in major cities such as Kinshasa, welcomed the recommendations presented by the IITA team. It was unanimously acknowledged that cassava is a key food crop for the great majority of the population and that there is an urgent requirement to adopt a coherent strategy in the face of the situation. The team was requested to submit in collaboration with the other partners, FAO and SECID, a proposal for a multilateral funded program.

Collaborators' workshop of the Multiplication Project for Zimbabwe, Swaziland and Lesotho was held in Marondera, Zimbabwe from 25-26 April 2000 to enable collaborators present progress made the multiplication and distribution of planting materials. The Steering Committee Meeting of the project followed this workshop on 27 April 2000.

6.6.5 Coordination of Network activities (EARRNET and SARRNET)

by J.A.W., J.T., I.K.

To effectively utilize the limited root crops resources in the East and Southern Africa region, EARRNET and SARRNET bring together root crop researchers in the respective regions, and link them to IITA and other relevant organizations for technical assistance. The coordination offices of the two networks collaborate with institutions that contribute to strengthen capacities of national programs to effectively and efficiently address their cassava research objectives.

The coordination of the Multiplication Project for Zimbabwe, Swaziland and Lesotho was fully implemented in all aspects ranging from administration, scientific matters, and public relations. Three quarterly reports were submitted to IITA, Donor and distributed to NARS. The financial reports were also regularly submitted. New collaborators were identified for multiplication and distribution of planting materials and plans to establish nurseries discussed. The project in collaboration with NGOs in Zimbabwe (World Vision International, Africare, SALRED TRUST and ORAP) has established multiplication plots and distributed planting materials to farmers in areas affected by droughts and floods in Mudzi, Mutoko, Manicaland, Tsholotsho, Shurugwe, and Beitbridge

Completed studies

Journal articles and book chapters

Asadu, C.L.A. and A.G.O. Dixon. 2001. Comparative effects of continuous cultivation of seven crop combinations on soil physicochemical properties in two soils of different land use history in eastern Nigeria. Agriculture, Ecosystem & Environment. (In review)

Changes in 29 soil physicochemical properties resulting from crop cultivation in newly cleared virgin forest were compared with those from previously cultivated land (UNN site). The aim was to assess the effects of the selected common crop combinations on the soil properties so as to obtain the best option for soil fertility enrichment in each location. The crops selected were those commonly grown by the local farmers. They included sole crops of cassava, yam, maize and pigeon pea, as well as a combination of all the four crops. Others were cassava + maize + pigeon pea and cassava + pigeon pea. Both the sole and crop combinations were grown in a randomized complete block design in three replicates in the two locations for two years. Changes in soil properties at 0-20 cm and 20-40 cm depths were monitored for the period. The pedogenic properties obtained from the diagnostic horizons were used to classify both soils as Rhodic Kindiustalfs (Haplic Lixisols). However, the differences in 19 of the properties at 0-40 cm depth were significant ($p \leq 0.05$) between the two locations ab initio. Sixteen of these properties were considered to be better in the forestland agronomically. Depth variations did not influence many of the properties significantly, especially between 1999 and 2000. The effects of crop combination were significant ($P \leq 0.05$) on physical properties such as the silt content, the total porosity at the forest location; clay content, bulk density, macroporosity, and hydraulic conductivity at the UNN site. The chemical properties significantly ($P \leq 0.05$) affected by crop combination were exchangeable Ca and total exchangeable bases at the forest; organic matter, exchangeable K, total exchangeable acidity, and available P at the UNN site. Within the short period there appeared to have been substantial improvements in some properties, especially at 0-20 cm depth, relative to their 1998 values. The changes were generally more in the UNN site than at the forest. The changes were adduced to be facilitated by tillage, as the soils were just brought under cultivation from the forest and fallow conditions. This is because the crop effects were less between 1999 and 2000. However, the improvements in some of the properties suggest that some of the crop combinations were capable of reducing soil fertility loss in the area.

Asadu, C.L.A., A.G.O. Dixon and R. Okechukwu. 2001. Comparative evaluation of the contributions of soil physicochemical properties to variations in the yields of four major staple food crops in eastern Nigeria. Agriculture, Ecosystem & Environment. (In review)

The contributions of soil variables to the variations in the yields of cassava (*Manihot esculenta*), yam (*Dioscorea rotundata*), maize (*Zea mays*) and pigeon pea (*Cajanus cajan*) were evaluated for two years in this study. The data were from three replicates of a randomized complete design experiment sited in a newly cleared forest and a previously cultivated land both in Nsukka, eastern Nigeria. The 28 soil physicochemical properties and six crop yield parameters were partitioned into location and year before applying a stepwise regression procedure to analyze them. The study showed that soil variables accounted for >70% variation in cassava root yields and harvest index. Both soil physical and chemical properties contributed but the former (particularly macroporosity, microporosity, total porosity and bulk density) contributed more. Selected soil variables also accounted for >70% variation in yam tuber yield and shape index of tubers especially in 1998. In both crop years chemical properties appeared to dominate over the physical ones. Soil variables accounted for between 51 and 97% of variations in maize grain and stover yields. The only exception was the 44% obtained at the forest location in 1998. Soil pH, total exchangeable acidity and microporosity were particularly important contributors to the variations in both maize yield parameters. The contributions of soil variables to pigeon pea yield parameters were particularly low (< 50%) except in 1999 at the forest location where seven soil variables accounted for over 85% variation in seed yield. Generally from the study it was obvious that soil variables were important determinants of yield variations in the four crops. It was also shown that physical properties should always be included in this kind of analysis. Again the number of soil variables selected generally increased when the level of soil properties was low as was the case with the cultivated site Vs forest site, and 1999 Vs 1998 analysis. Thus increasing the number of soil variables used and partitioning them into more homogeneous units helped to improve the results obtained using the procedure.

Abdullahi, I., G.I. Atiri, A.G.O. Dixon, S. Winter and G. Thottappilly. 2001. Effects of cassava genotype, climate and *bemisia tabaci* vector population on the development of African cassava mosaic virus (ACMV) Journal of Plant Pathology (In review).

In Africa, the whitefly transmitted African cassava mosaic geminivirus (ACMV) constitutes a major threat to the live of millions of people that depend on cassava as a major component of their carbohydrate diet. A survey was carried out between 1996 and 1997 on a field planted in three replicates with five clones of cassava at the International Institute of Tropical Agriculture, Ibadan, located in a transition forest, to determine the effects of cassava genotype and climate on the development of ACMV, and changes in B. tabaci population. Cassava genotype and climate, and their interactions have significant ($P<0.01$) effects on the population of B. tabaci and the development of ACMV. Incidence of ACMV was significantly ($P<0.01$) higher in clones 81/01635 and 92/0520 than in TMS/30572 and 94/0239, while 91/02327 showed the highest resistance. Positive correlation between incidence and severity of African cassava mosaic virus was observed, but they did not however correlate with whitefly population density.

Dixon, A.G.O. and C.L.A. Asadu. 2001. Performance of seven crop combinations in two soils of different land use history in eastern Nigeria. Agriculture, Ecosystem & Environment. (In review)

Crop yields obtained from crop mixtures grown in a newly cleared virgin forestland were compared with those from a previously cultivated farmland (UNN farm). The aim was to assess how the performance of the crops and their mixtures varies between the two sites without additional soil amendments. The study was on the commonest staples in the area, cassava, yam, maize and pigeon pea as pure stands and all four combined, as well as cassava + maize + pigeon pea and cassava + pigeon pea intercrops. Both the sole and crop combinations were grown in a randomized complete block design in three replicates in the two locations for 2 years. Various yield parameters and soil properties were measured for the period. Generally a greater number of soil physicochemical properties were considered agronomically better in the forest than in the previously cultivated land. These soil properties may constitute the driving force for significantly ($p \leq 0.05$) higher crop yields in the forestland and include: macroporosity, bulk density, saturated hydraulic conductivity, coarse sand content, pH, soil organic matter, total N, exchangeable acidity and Fe as well as base saturation. In both years, the highest cassava root yields were obtained from either cassava + maize + pigeon pea or cassava + maize intercrops (not from sole cassava plots) even though the only significant ($p \leq 0.05$) difference obtained was between cassava + maize + pigeon pea and all four crops combined, and at the UNN farm only. This suggests that it is even disadvantageous to grow cassava as a sole crop in the area. Cassava root yield reduction in 1999 relative to 1998 was higher (70%) in the UNN farm than in the forestland (40%). There was no significant difference due to crop combination on yam tuber yield in both locations in 1998. However, in 1999 sole yam plots gave significantly higher yields than cassava + yam + maize +pigeon pea plots. Increase in tuber yields was obtained in 1999 over 1998 in both locations but it was smaller (<3%) in the forest than in the UNN farm (27%). There was no significant difference due to crop combination on maize grain yield. The pigeon pea yields obtained from sole pigeon pea plots in the forest locations in both years were significantly ($p \leq 0.05$) higher than those obtained from the other plots except in the case of cassava + maize + pigeon pea in 1999 where the difference was not significant. With the land equivalent ratio (LER) obtained ranging from about 1.16 to 3.66, the study shows clearly that it was much better to grow the test crops in mixtures than in pure stands. The number of crops in the mixture should, however, not exceed three as an additional crop led to depressed LER. The recommended intercrop mixture was, therefore, cassava + maize + pigeon pea.

Ogbe, F.O., G.I. Atiri, A.G.O. Dixon and G. Thottappilly. 2001. Molecular and biological variations of African cassava mosaic virus in Nigeria. Annals of Applied Biology (In review).

To determine the occurrence of variants of African cassava mosaic virus 316 cassava leaf samples were collected from mosaic affected cassava plants in 254 farmers' fields in 1997 and 1998, covering the humid forest, coastal/derived, southern Guinea and northern Guinea savannas and semiarid and arid agroecologies of Nigeria. The samples were tested in triple antibody sandwich enzyme-linked immunosorbent assay using a panel of monoclonal antibodies against the virus; 29 reaction patterns were observed which, in cluster analysis, gave nine serogroups at 0.80 Jaccard similarity coefficient index. Isolates of serogroups one, two, four, and eight were widely distributed while those of the other serogroups were restricted to certain agroecologies. Four representative isolates of serogroups one, two, and eight produced distinct symptoms in biological assays. Polymerase chain reaction test indicated that the four isolates belong to two strains with members that can produce mild and severe symptoms in *Nicotiana benthamiana* Domin. The random distribution of these variants in the agroecologies, especially in the humid forest, derived/coastal, and southern Guinea savannas makes such agroecologies suitable for the selection of resistant cassava clones against ACMV.

Ogbe, F.O., A.G.O. Dixon, G.I. Atiri, and G. Thottappilly. 2001. Restriction of virus movement into axillary buds is an important aspect of resistance in cassava to African cassava mosaic virus. Journal of Plant Pathology (in review).

Axillary buds and bark samples of resistant, moderately resistant, and susceptible (control) cassava genotypes naturally infected under field conditions and artificially inoculated by grafting in the greenhouse were indexed for African cassava mosaic virus using enzyme-linked immunosorbent assay and polymerase chain reaction. This was to determine the distribution of the virus within the plant, thereby elucidating the response of the genotypes to virus movement. Significantly more bud and bark samples tested positive to the virus on the susceptible genotype TME 117 than on the resistant TMS 3000I and TMS 91/02319 and the moderately resistant TMS 30572. Virus titre was significantly lower in buds of the two categories of resistant genotypes than in those of the susceptible control. Buds of the main stem were significantly more infected than those of primary and secondary branches under field conditions but such a gradient was not obvious with bark samples. Shoots that recovered from symptoms on the field and in the greenhouse had no virus in their buds but some of their bark samples tested positive. There was significant interaction between cropping season and stem types in the detection of virus in the bud and bark samples. Also significant was interaction among cropping season, genotypes, and stem types in virus detection in bark samples of TMS 30572 and TME 117. Resistance to virus movement was established in the resistant and moderately resistant genotypes, and seemed to be directed towards keeping the axillary buds virus-free. This probably explains reversion in the crop, in which infected stems of resistant genotypes could sprout into healthy plants in the subsequent generation.

Ogbe, F.O., G. I. Atiri, A.G. O. Dixon, and G. Thottappilly. 2001. The nature of disease severity, virus concentration, and yield loss among resistant, moderately resistant, and susceptible cassava genotypes infected by African cassava mosaic virus. Plant Pathology (in review).

To determine the relationships between symptom severity and virus concentration, and tolerance to disease, cassava genotypes with different levels of resistance to African cassava mosaic virus were assessed under natural infection by the virus in 1997/98 and 1998/99 cropping seasons. The disease severity was lowest significantly ($P < 0.05$) on the resistant (R) genotypes than on the moderately resistant (MR) and susceptible (S) genotypes. However, genotype NR 8083 (R) was as diseased as TMS 30572 (MR). The moderately resistant genotypes were significantly ($P < 0.01$) less diseased than the susceptible genotypes. Nevertheless, similar virus concentrations were observed in TMS 30572 (MR), NR 8082 (MR), TMS 91934 (S), and TME 117 (S) as determined by enzyme-linked immunosorbent assay. Also similar virus concentrations were found in NR 8083 (R) and TMS 91934 (S). TME 8 (R) recorded the lowest virus concentration, which was significantly ($P < 0.05$) different from those of the other genotypes. There was significant interaction ($P < 0.05$) between cropping season and virus concentration in all the genotypes except TMS 30572. Yield losses by the genotypes were proportional to their disease severity scores. Tolerance to the disease was, therefore, not established among the genotypes. The severity of symptoms expressed was not necessarily a reflection of the virus concentration in the genotypes, which suggests a resistance response to symptom development.

Ogbe, F.O., A.G.O. Dixon, G.I. Atiri and G. Thottappilly. 2001. Responses in cassava to African cassava mosaic virus show resistance to virus multiplication rather than to infection. Euphytica (In review).

To shed light on the nature of resistance (resistance to virus infection and multiplication), nine resistant cassava genotypes which had remained either symptomless or shown inconspicuous symptoms of African cassava mosaic virus in field plots at the International Institute of Tropical Agriculture, Nigeria, were graft-inoculated with the virus. Most plants of these genotypes expressed symptoms, ranging from mild to severe, when artificially inoculated. However, only a few plants of TMS M94/0583 had mild symptoms while the remaining plants showed inconspicuous symptoms a situation similar to that in the field. Apart from TMS 92/0398, TMS 92B/00068, and TMS M94/0121, other genotypes significantly recorded ($P < 0.05$) lower virus concentration than the susceptible control, TME 117, as determined by enzyme-linked immunosorbent assay. TMS M94/0583 significantly ($P = 0.05$) had the lowest virus concentration. Whitefly vectors, collected on young leaves of the genotypes in the field, tested positive to the virus in polymerase chain reaction. The lack of symptoms on the plants in the field or inconspicuous symptoms despite viruliferous vectors on them, the copious symptoms on most plants when artificially inoculated, and the low virus concentration in most of the genotypes all suggest that the dosage level of inoculum and resistance to virus multiplication rather than resistance to infection determine the responses of the genotypes to the virus.

Ogbe, F.O., G. Thottappilly, G.I. Atiri, A.G.O. Dixon and H.D. Mignouna. 2001. Occurrence of variants of East African cassava mosaic virus and their distribution in double infections with African cassava mosaic virus in Nigeria. Plant Disease (In review).

In a diagnostic survey in 1997 and 1998 to determine the status of cassava mosaic begomoviruses in Nigeria, East African cassava mosaic virus (EACMV) was detected by polymerase chain reaction (PCR) technique in double infections with African cassava mosaic virus (ACMV) in 27 out of 290 cassava leaf samples of infected plants from 254 farmers' fields in five agroecological zones. One plant had EACMV alone. This and the doubly infected plants occurred in the humid forest, coastal/derived and southern Guinea savannas but not in the northern guinea savanna and arid and semiarid zones. Doubly infected plants were more severely diseased than those with single infection. Three EACMV variants were observed based on cluster analysis of the reactions of the 28 isolates with five primers specific for the detection of Cameroonian and East African isolates of EACMV. Type 1 variant occurred in the three agroecological regions where the virus was detected, while type 2 was limited to the coastal/derived savanna and type 3 to the humid forest region. The presence of doubly infected plants and variants of EACMV in the three agroecologies make these regions suitable for the selection of resistant cassava genotypes.

Conference papers, workshop proceedings, abstracts, newsletters

Hankoua, B.B., J. Pounti-kaerlas, S.Y.C. Ng, I. Fawole, and A.G.O. Dixon, 2000. Plant regeneration of African cassava (*Manihot esculenta* Crantz) germplasm via somatic embryogenesis. In Book of Abstracts Third International Symposium on Tropical Root and Tuber Crops, 19-22 January 2000. P. 137. Indian Society for Root Crops, Central Tuber Crops Research Institute, Indian Council of Agricultural Research.

Five African cassava genotypes underwent primary and secondary embryogenesis on embryo induction media using meristem and immature leaf lobe explants. Preliminary results showed that picloram based embryo induction medium gave a higher frequency of embryogenesis than a 2,4-D based medium. In general, apical meristems are more responsive to the embryo induction. There is genotypic difference in their response to culture media. Plantlets were successfully regenerated via organogenesis through direct shoot induction from cotyledon explants of maturing somatic embryos. The regenerated shoots rooted with great efficiency on the elongation medium. Regenerated plants were successfully established in the field and evaluation is underway.

Atehnkeng, J. 2000. Somatic embryogenesis in cassava (*Manihot esculenta* Crantz). M.Sc. Thesis, University of Ibadan, Nigeria.

Somatic embryogenic competence of eleven cassava genotypes was determined in induction media containing 8 and 12 mg/l of picloram, using both meristems and immature leaf lobes as explants. Seven of the eleven genotypes developed proembryos within 27 to 35 days. Genotypic differences for somatic embryo formation were apparent with the highest value of 34.5% for TME596 and the lowest values of 1.54 and 0% for I60142 and SL80/40. Pro-embryos formed by two of the eleven genotypes, I96/1439 and I95/0528 did not survive beyond globular developmental stage. The results indicated higher success with leaf lobes (21.7%) as compared to meristems (13.8%). There was no significant difference in somatic embryo induction with the two picloram concentration treatments. TME596 developed mature embryos from both types of explants and at two picloram concentration. Interaction of genotypes with culture media and genotypes with explants were apparent. While TME594 developed mature embryos from leaf lobes cultured in medium containing 12mg/l picloram, Z95/0826 formed mature embryos from leaf lobes cultured in both induction media and on meristems cultured in medium containing 8mg/l picloram. Four genotypes, I96/0016, I96/0860, I96/0035 and TME8, developed mature embryos from leaf lobes cultured in medium with 12mg/l picloram.>

Staff

	Project research time allocation (%)
1. V. Aggarwal (VA), PhD, Breeder	C*
2. M. Andrade (MA), PhD, agronomist	80
3. M.T. Ajayi (MTA), MS, training specialist	C*
4. M. Bokanga (MB), PhD, biochemist and food technologist	25
5. R. Carsky (RC), PhD , agronomist	10
6. D. Chikoye (DC), Ph.D, weed scientist	15
7. K. Dashiell (KD), PhD, breeder/geneticist CID Director	10
8. A. Dixon (AD), PhD, breeder/geneticist, project coordinator	65
9. A. Ebert (AE), PhD, planting material specialist	C*
10. S. Ferris (SF), PhD, postharvest technologist	15
11. M. Gedil, PhD, molecular geneticist (MG)	85
12. O. Ghebreyesus (OG), Ir. Agronomist	100
13. R. Hanna (RH), PhD, acarologist/entomologist	10
14. J. d'A Hughes (JH), PhD, virologist	C*
15. I. Kasele (IK), PhD, agronomist/breeder	75
16. S. Kolijn, (SK), Ir.Postharvest specialist	C*
17. D. Keatinge (DK), PhD, agronomist, RCMD Director	5
18. W. Khizzah (WK), PhD, breeder	80
19. A. Larbi (A.L),PhD, forage agronomist (ILRI)	C*
20. J. Legg (JL), PhD, virologist	10
21. V. Manyong (VM), PhD, agricultural economist	5
22. B. Maziya-Dixon (BM), PhD, food technologist	10
23. H. D. Mignouna (HM), PhD, molecular biologist	5
24. S. Y. Ng (SYN), MSc, tissue culture specialist	27
25. S. Nokoe (SN), PhD, biometrician	10
26. N. Saginga (NS), PhD, soil microbiologist	5
27. J. Teri (JT), PhD, plant pathologist, coordinator (SARRNET)	50
28. G. Tian (GT), PhD, soil fertility specialist	20
29. M. Toko (M.T), PhD, Entomologist	C*
30. J. Wendt (JWT), PhD, soil chemist	C*
31. J. Whyte (JAW), PhD, breeder, coordinator (EARRNET)	80

Total scientist time: 7.97 scientist years
C*: Complimentary

Postgraduate training

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Atehnkeng, J.	MSc	Cameroon	99/00	Self	Ng, S. Y. C.
Hankoua, B.	PhD	Cameroon	98/01	ZIL	Ng, S. Y. C.
Lokko, Y	PhD	Ghana	97/01	Rockefeller	Dixon
Ntawuruhunga, P.	PhD	Rwanda	96/00	IITA/RF	Whyte
Ogbe, F.	PhD	Nigeria	97/01	IITA	Thottappilly,Dixon
Okai, E.	MSc	Ghana	99/01	IITA	Mignouna, Dixon
Onyeka, J.	PhD	Nigeria	97/01	IITA/Self	Dixon, Gedil
Olufemi, A.	PhD	Nigeria	99/02	IITA/Self	Dixon
Owolade, T.	PhD	Nigeria	99/02	IITA/Self	Dixon
Raji, A	PhD	Nigeria	97/01	IITA	Dixon, Mignouna
Ida Dossou-Yovo	PhD	France	98-00	-	Bokanga
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4. Rockefeller Foundation, USA
5. Gatsby Charitable Foundation, U.K.

Publications 2000

Journal Articles and Book Chapters

Dixon, A. G. O and E.N. Nukenine. 2000. Genotype x environment interaction and optimum resource allocation in cassava yield trials. African Crop Science Journal 8:1-10.

Eke-Okoro and A.G.O. Dixon. 2000. Influence of genotype x environment interaction on the productivity and stability of improved cassava genotypes in humid ecozones of Nigeria. Niger Agric. J. 31:125-133.

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Fokunang, C.N., T. Ikotun, A.G.O. Dixon, C.N. Akem, E. A. Tembe, and E. N. Nukenine. 2000. Efficacy of antimicrobial plant crude extracts on the growth in Colletotrichum gloeosporiodes f. sp. manihotis. Pakistan Journal of Biological Science 3:928-932.

Fokunang, C.N., T. Ikotun, A.G.O. Dixon and C.N. Akem. 2000. Field reaction of cassava genotypes to anthracnose, bacterial blight, cassava mosaic diseases and their effects on yield. African Crop Science Journal 8:1-8

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Scott, G.J., R. Best, M. Rosegrant and M. Bokanga. 2000. Roots and Tubers in the Global Food System: A vision statement to the year 2020 (including Annex). Centro Internacional de la Papa (CIP), Lima, Perú - Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia - International Food Policy Research Institute (IFPRI), Washington DC - International Institute of Tropical Agriculture, (IITA) and International Plant Genetic Resources Institute (IPGRI), Rome, Italy.

Conference Papers, Workshop Proceedings, Newsletters, and Training Materials

M. Bokanga. 2000. The ethanol industry in Nigeria: Growing on a New Crop. Proceedings of the International Fuel Ethanol Workshop, Windsor, Ontario, Canada, 20-24 June 2000.

James, B., J. Yaninek, A. Tumanteh, N. Maroya, A. Dixon, R. Salawu and J. Kwarteng. 2000. Starting a caasava: IPM field guide for extension agents. International Institute of Tropical Agriculture. Ibadan, Nigeria. 20 pp.

Manyong, V. M., A.G.O. Dixon, K. O. Makinde, M. Bokanga, and J. Whyte. 2000. Contribution of IITA-improved cassava varieties to food security in sub-Saharan Africa: an impact study. International Institute of Tropical Agriculture. Ibadan, Nigeria. 7 pp.

Nweke, F.I., D. Lutete, A.G.O. Dixon, B.O. Ugwu, O. Ojobo, N. Kalombo and B. Bukaka. 2000. Cassava production and processing in the Democratic Republic of Congo. COSCA Working Paper No. 22. Collaborative Study of Cassava in Africa (COSCA), IITA, Ibadan, Nigeria. 206 pp.

Nweke, F. K. Ngoram, A. G. O. Dixon, B. O. Ugwu, O. Ojobo. 2000. Cassava production and processing in Côte d'Ivoire. COSCA Working Paper No. 23. Collaborative Study of Cassava in Africa (COSCA), IITA, Ibadan, Nigeria. 174 pp.

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 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. Development of integrated annual and perennial cropping systems
14. Impact, policy, and systems analysis

CGIAR Systemwide and Ecoregional Projects

Ecoregional program for the humid and subhumid tropics of sub-Saharan Africa

Systemwide program for integrated pest management

Annex 2

PROJECT LOGFRAME

PROJECT PLANNING MATRIX (PPM)	Project Ref. No: 6	Project Title: Improving Cassava-based Systems	Estimated Project Duration: 10 years	PPM prepared: December 1, 1995 Revised : 1/3/00

Summary of Objectives	Objectively Verifiable Indicators	Means/Sources of Verification	Important Assumptions
Goal: Cassava production and utilization increased and sustained in SSA	• Cassava production and utilization increased at an annual rate of 2 %	• National & international statistics on cassava	• Political situation does not get worse • Economic conditions and agricultural policies remain favorable for cassava production and utilization
Purpose: Improved and adapted cassava germplasm, production practices and postharvest technologies developed, evaluated and promoted in collaboration with NARES for sustainable production systems, expanded utilization and increased commercialization	• At least 20 improved genotypes with superior yield and stable performance and acceptable quality recommended for release in at least 10 countries in SSA by 2003. • Potentially adoptable technologies for improved and sustained production demonstrated in long term on-station trials and in benchmark sites by 2001 and at least two in use by farmers by 2005 • Improved nutritional quality, increased demand and commercialization of an expanded range of cassava products for food, feed and agroindustries by 2003. • Knowledge-base on cassava of NARES in at least 20 countries significantly strengthened for effective prioritization, planning, implementation and monitoring of cassava R&D activities by 2005	• IITA, NARS, NGO reports and publications • Ministry of trade statistics and reports	• Current strength and links with NARS maintained • Links with NGOs developed • Commercial sector interest in utilization of cassava

Outputs:			
R1. Cassava source populations for traits of major importance in SSA available	• Special trait populations targeting multiple pest resistance (CGM, CMD, CBB, CBSV, CAD), low CNP, and the preferred root quality including yellow roots maintained and available to collaborators annually as from 1997. • At least 10,000 botanic seeds representing at least 40 families from various special populations and at least 10 breeding lines are introduced to at least 15 collaborating countries annually as from 1997.	• Field plot visits at IITA main stations (e.g. Ibadan, ESARC) • Project and NARES reports. • Records on germplasm distribution.	• Materials meet quarantine regulations
R2. Genetic base of cassava in Africa broadened	• Broad-based populations available targeting major agroecologies: – forest margins of West & Central Africa (WCA) – lowland savannas of WCA – mid-altitudes of East & Southern Africa (ESA) – lowlands of ESA. • At least 10 additional genotypes will be certified for international distribution in each project year • At least six NARES per region (WC, E, S) requesting for germplasm in each project year. • At least 300 breeder's lines in the form of in vitro plantlets and 1,000,000 botanic seeds targeting the various agroecologies will be distributed to at least 15 collaborating countries by the end of the project year • Regional trials of a standard set of at least 10 elite genotypes established in various collaborating countries especially EARRNET and SARRNET Countries by end of 1999. • At least 10-15 improved genotypes (potential cultivars) at the Uniform Yield Trial stage (multilocational and available for on-farm trials) in at least 15 collaborating countries by the year 2000. • At least two countries per region conducting on-farm testing of improved cassava genotypes annually by end of 1997. • NARES productivity data for improved cassava (yield/unit area/unit time) demonstrate stable and at least 20% improvement over local checks in on-farm trials by end of 2000. • At least 15 genotypes would have been recommended for release in at least six countries by 2003, and at least, an additional five genotypes would have been recommended for release in at least four additional countries by 2005. • Sources of resistance to cassava root scale insect, a pest of regional importance, identified and incorporated into breeding populations by 2002.	• Database of improved germplasm • NARS and Project reports • Journal and Symposia publications • Regional trial reports.	• Materials meet quarantine regulations • Links with Project 1 and 10.
R3. Tools for increasing breeding efficiency for agroecological adaptation available	• Genepool structure and relationship for exploitation of heterosis elucidated by the end of 2001. • Molecular markers for genes conferring resistance to at least cassava mosaic disease and other traits identified by 2003 and used in marker assisted selection. • Phenotypic characteristics, which are most appropriate for various production and utilization system elucidated by 2005. • Aspects of the bases for adaptation to abiotic and biotic stresses elucidated by the end of 2005.	• Project and NARES reports • Journal and other publications	

R4. Genotypes available for intensive commercial production and utilization systems	• Superior performance of germplasm on pilot commercial scale demonstrated by year 2001 for: - early bulking (6 months) – good response to fertilizer – suitability for mechanized processing – suitability for livestock feed and industrial use – use as leafy vegetable. • Seed-based production methods evaluated on-station on large blocks of land (at least 4ha) by year 2001.	• NARS, NGO and project reports • Journal and other publications • Private sector correspondence and reports	• Scope of postharvest utilization widens
R5. Improved postharvest technologies for expanded util	• At least five breeding programs within NARS using food quality traits routinely by 2002. • Quality trait descriptors included in germplasm database by 2002. • Cassava lines with improved nutritional quality and specific functional characteristics identified by 2002. • Links between cassava consumption and tropical ataxic neuropathy (TAN) elucidated by 2001. • New cassava-based value-added food products and income generating processing techniques disseminated through NARS by 2003. • Cassava sub-sector and market characteristics described and the approaches to strengthen links between producers and endusers developed by 2002. • At least 5 pilot rural micro-enterprises operated by farmers/women groups functioning by 2003.	• Database of improved germplasm • NARS and Project reports • Baseline survey report	• Socioeconomic environment conducive to small business development Links with project 14 (impact, policy and system analysis)
	• On-farm adaptive trials in benchmark sites by the year 1999. • Nutritional requirements for sustained production in relation to specific soil types and nutrient use efficiency in cassava elucidated by 2001. • Prototype production practices under evaluation by 2001. • Solutions/options for long term sustainability for small/large scale production tested in benchmark sites by 2002. • Crop management practices for sustainable production recommended for at least three target agroecologies and at least two in use by farmers by 2005.	• Network reports • Pilot site visits • Extension and NGO feedback	• Linkages to IITA projects on natural resource management (projects 11, 12 and 13)

R7. Capability of NARES to undertake cassava research and development, and training enhanced, and partnership for realization of common objectives strengthened	• Regional exchange of germplasm increased and facilitated among at least 15 collaborating countries by the year 2002. • Expanded genetic base for selection programs and improved capacity of NARES to increasingly undertake collaborative cassava research and development by 2002 and onwards. • Regional collaborators meetings at least once every three years. • At least 100 NARES personnel trained in cassava research production and utilization techniques every two years. • Trained staff assume increasing leadership role in cassava research, development and training • Increased participation in annual Steering Committee Meetings: Networks, ESARC, Special projects, ASARECA, CORAF, SACCAR meetings • At least two publications from joint research with NARES published annually. • Increased NARES consultancy assignments by the end of project year. • At least one backstopping visit to at least 10 collaborating countries annually. • Strategically placed multiplication sites and increased availability of healthy planting materials of improved genotypes to end-users in at least 15 collaborating countries in year 2000 and onwards. • Increased involvement of stakeholders in the multiplication and distribution system in at least 15 collaborating countries by year 2000 and onwards.	• Project, NARES, consultants and meeting reports • Journal and other publications • Training schedules and materials • Report of IITA impact study of training	

Annex 3

Research highlights

IITA's work is structured as 14 multidisciplinary research projects. Some projects focus on production systems for specific crops or crop combinations; others are thematically oriented and can involve many crops. Most of the projects cut across the agroecological zones for which IITA's work is targeted. IITA also serves as the convening institute for the Systemwide Program for Integrated Pest Management and for the Ecoregional Program for the Humid and Subhumid Tropics of sub-Saharan Africa.

This section presents the highlights of each project for 2000. These summaries are not a complete account of the work begun or completed during the year; rather, they describe some key scientific results and are intended to give the reader an insight into the breadth of the research themes and problems being investigated by IITA scientists.

Project 1

Conservation and use of biodiversity

- Ten accessions of *Dioscorea alata*, one accession each of *D. batatas* and *D. purpurea* from Taiwan, and 38 accessions of *D. alata* from South East Asia were added to IITA's yam germplasm collection.
- The feasibility of the 2n gamete breeding approach to produce triploid plantain and banana hybrids from diploid × diploid crosses was confirmed with the selection of hybrid 25287 (14.0 kg) derived from selfing TMP2x 1448-1(3.6 kg).
- Somaclonal variation in micro-propagated triploid *Musa* landraces was ascribed to preexisting genetic differences among tissues (chimerism) rather than de novo mutations induced by meristem culture.
- Amplified fragment length polymorphism (AFLP) analysis of *Musa acuminata* accessions showed 3 major clusters representing 3 major subspecies in the *M. acuminata* complex: the Malaccensis group (Madang, Mal. Holotype, Zebrina, and Pisang lilin); the Microcarpa group (Truncata, Selangor, sf247, Tjaulagada, and Borneo); and the Calcutta 4 group (Calcutta 4 and Long Tavoy). Other subspecies listed by other workers may have resulted from natural hybridization between members of the 3 basic subspecies. Selangor, previously classified as a Malaccensis, clustered with the subspecies microcarpa (Borneo). Zebria and Truncata accessions clustered with the subspecies malaccensis and microcarpa, respectively. Two genetic forms were identified among the *M. balbisiana* (BB) accessions: the Singapuri form and the 1-63 form.
- Six pubescent *Vigna rhomboidea* accessions and 3 nonpubescent cultivated cowpea lines were crossed in a partial diallel mating design to determine the inheritance of pubescence. Results of diallel analysis showed that an additive gene effect was more important than a dominance effect in the inheritance of pod pubescence. Generation mean analysis supported the preponderance of an additive gene effect but also indicated that dominance and epistatic gene interactions made significant contributions.
- Genetic inheritance of resistance to cowpea mottle virus disease in *Vigna vexillata* was elucidated.
- A course on biodiversity, biotechnology, and law for scientists, lawyers, and policymakers from sub-Saharan African was conducted.

Project 2

Improving plantain- and banana-based systems

- The virus causing banana die-back was detected with primers designed against nepoviruses using RT-PCR, and its field spread as well as that of banana streak virus (BSV), genus Badnavirus, was confirmed using monoclonal antibodies. Cucumber mosaic virus (CMV), genus Cucumovirus (subgroups A and B) and associated symptoms in hybrids and landraces and several weed hosts are more prevalent than previously recorded and may account for some of the BSV-like symptoms.
- Unidentified hymenopteran egg parasitoids and dipteran larval parasitoids of banana weevil were detected in Sumatra (Indonesia), the area of origin of the pest, opening prospects for classical biological control.
- An improved procedure to observe meiotic chromosomes was developed and random amplified polymorphic DNA (RAPD) fragments specific for the A and B genomes were cloned and sequenced to make more specific primers. An AFLP fragment associated with fruit parthenocarpy was identified by bulk segregant analysis of a diploid population.
- Breeding triploid plantain from diploid parents through unilateral sexual polyploidization (2n gamete) was achieved, and resistance to *Radopholus similis* was identified in 12 diploid hybrids that had been selected for resistance to black Sigatoka and good plant and bunch characteristics. A BSV-tolerant secondary triploid plantain hybrid (TM3x 26636-2) with high yield, excellent fruit characteristics, and resistance to black Sigatoka was derived from a BSV-susceptible primary tetraploid hybrid.
- An efficient genotype-independent in vitro regeneration protocol from apical shoot meristems was developed and standardized; transient expression of GUS (uidA) gene was achieved by *Agrobacterium*-mediated transformation.
- Eight scientists in Cameroon were trained on virus diagnostics, two scientists in Rwanda on nematode identification, and one technician from Benin on cultivar evaluation. A workshop was organized to set up a strategy for delivery of improved hybrids to farmers in Nigeria. Adoption of technologies to reverse the decline in banana plantations was achieved through farmer participatory evaluation of soil fertility conservation techniques and weevil control through residue management

Project 3

Improving cowpea–cereal systems in the dry savannas

- Over 500 new cowpea breeding lines were developed and tested at selected locations and promising lines were selected. Of these, IT97K-499-39, IT97K-608-14, IT97K-366-1, IT97K-560-1, IT97K-568-18, IT97K-568-19, IT97K-556-4, IT98K-277-1, IT98K-423-13, and IT98K-131-1 were outstanding. Major differences were observed between varieties for grain and fodder yields under poor fertility.
- IITA/ILRI/ICRISAT/Kano Agricultural Development Project participatory trials revealed 100–300% gross economic superiority of the improved 2 rows cereal : 4 rows cowpea strip cropping system compared to the 1 row : 1 row traditional intercropping system. This was found ideal for crop–livestock integration, and feeding of residues from the improved system resulted in higher weight gain in sheep.

- Farmers showed great appreciation for improved cowpea variety IT93KZ-4-5-6-1-6 for its resistance to *Striga* in Abomey plateau of southern Benin where the local varieties are highly susceptible.
- Major differences were observed among cowpea varieties for protein content, cooking time, and seed hardness.
- A total of 139 sets of cowpea international trials and 225 sets of special nurseries were sent to international collaborators.
- Extra-early maize varieties 97TZEE-Y2Cc1 and 97TZEE-Y STR and early-maturing soybean varieties TGX1871-12E and TGX1830-20E were found most promising for the dry savannas.
- Farmer-to-farmer diffusion of improved cowpea seed became extremely popular. From just a few farmers in 1997, over 10 000 farmers adopted new cowpea varieties in 2000 in Kano State.
- Economic analysis revealed that cultivation of improved cowpea varieties with two sprays of insecticide results in a gain of 11 naira for each naira invested.
- Eight national agricultural research system (NARS) scientists are conducting PhD thesis research under this project. A workshop on drought tolerance screening was organized, and the World Cowpea Research Conference III was held in September; many NARS scientists participate.

Project 4

Improving maize–grain legume systems in West and Central Africa

- An experiment was conducted over 2 years (1999–2000) to compare the performance of 29 maize hybrids and 30 improved open-pollinated varieties with local farmers' varieties under controlled drought stress and sufficient moisture supply. As a group, hybrids and improved open-pollinated varieties out-yielded the local varieties by 71% in the nonstress environment and by 56% in the drought stress environment. The increase in yield was accompanied by an increase in the number of ears per plant, shortening of anthesis to silking interval, and a delay in leaf senescence.
- Some maize varieties were compared at 0, 30, and 90 kg N/ha at 2 sites in the Guinea savanna in Nigeria. The latest cycle of selection from the low N-tolerant pool (C3) produced consistently higher yields than a widely grown open-pollinated variety, TZB-SR, at all levels of nutrient supply. This variety also yielded as high as an N-efficient commercial hybrid, Oba Super II, at all N levels and had good agronomic features.
- A study was conducted to quantify the effect of phosphorus fertilizer and a soybean variety that stimulates the germination of *Striga hermonthica* on the emergence of this parasitic plant in subsequent maize crop in 3 farmers' fields. The results showed that this soybean cultivar reduced *Striga* parasitism on a succeeding maize crop and its effect on emergence of the parasitic plant increased with P application to the preceding soybean crop.
- A study was conducted to estimate the contribution of early-season cowpea to a late-season early-maturing maize in a double cropping system. Maize grain yield from a plot preceded by early-season cowpea was higher than the maize grain yield from a plot that received 30 kg N/ha. Thus, planting cowpea in the early season with adequate P supply appears to supply a small amount of N for the succeeding cereal crop in a double cropping system.

- To improve the capacity and efficiency of NARS scientists to generate and transfer appropriate technologies in West and Central Africa, an impact assessment workshop, an advanced statistical computing course, and a monitoring tour to Nigeria and Cameroon were organized in 2000. In addition consultation visits were made to Ghana, Togo, Benin, and Chad by the WECAMAN Coordinator and selected Steering Committee members.
- To strengthen the capacity of NARS scientists to generate and transfer appropriate technologies to farmers, a total of $197 300 was allocated to the collaborative research projects in member countries through the African Maize Stress and USAID projects. Through the funds, stress tolerance screening sites in Senegal, Burkina Faso, Nigeria, Ghana, Cameroon, and Benin have been improved and made operational. Also, quantities of seed of early and extra-early varieties were produced in member countries through the community seed production scheme.

Project 5

Improving yam-based systems

- A stakeholder analysis in Benin Republic showed that only experienced male yam growers are involved in the domestication of wild yams. The main reason for domestication is to select more productive varieties and to rejuvenate the pool of genetic material. The principal criterion for the selection of wild yams for domestication is the similarity of their leaves to those of cultivated varieties (58% of respondents).
- *Dioscorea* mottle virus from *D. alata* was fully characterized and confirmed to be a member of the genus Comovirus using serological, biological, and molecular techniques; the two strains of the virus (causing mottling, mild chlorosis, and necrosis) can be detected using IITA's monoclonal antibodies.
- It was demonstrated that *D. alata* plants that flower behave as quantitative short-day plants and that duration from the end of dormancy to flowering can be predicted.
- Short-day treatment applied at the early stage of plant growth promoted rapid enlargement of tubers in *D. rotundata*, *D. alata*, and *D. cayenensis*. Differential responses of species and varieties were observed, suggesting the potential of the treatment in distinguishing between early- and late-maturing varieties.
- About 60% success was achieved in the grafting of vines from different yam varieties using the approach method. This sets the stage for further studies on yam flowering.
- One RAPD marker linked to a locus with a major effect on resistance to yam mosaic virus genus Potyvirus in *D. rotundata* was identified.
- Three varieties of *D. cayenensis* were certified for export following meristem culture and virus indexing. Over 19 000 minitubers of *D. rotundata*, out of 21 000 produced from virus-tested tissue culture plantlets, were delivered to NARS partners.
- The techniques for production of dry yam "chips" and the preparation of dishes based on yam flour were introduced from western Nigeria and Benin Republic to Burkina Faso, north Cameroon, and Côte d'Ivoire in order to add value to yams in urban markets.

Project 6

Improving cassava-based systems

- Thirty selected genotypes of cassava for various agroecologies with multiple resistance to cassava mosaic disease (CMD), bacterial blight, anthracnose, and green mite as well as acceptable agronomic and end-user characteristics were pathogen-tested and certified for distribution.
- More than 20 000 cassava in vitro plantlets were produced for distribution, ministake production, and use as stock cultures. The plantlets were distributed to NARS collaborators in 5 countries and to the International Center for Tropical Agriculture (CIAT) in Colombia, and more than 1000 certified ministakes were delivered to Sierra Leone. In addition, 219 733 seeds of 1120 families were distributed to national programs in 6 countries. IITA received 2923 seeds constituting 61 families from Mozambique.
- IITA's Eastern and Southern Africa Regional Center (ESARC) continues to identify clones with high dry matter (> 40%) and low cyanogenic potential at its major regional evaluation sites of the midaltitude agroecology. At Mtwapa, Kenya (lowland ecology), 2401 clones with multiple resistance to the major diseases and pests and good quality characteristics were selected for further evaluation.
- The Government of Uganda officially released 3 additional CMD-resistant varieties of IITA origin. NASE 12, a selection under high CMD and the Ugandan variant of CMD (UgV) infection pressure at midaltitudes, has consistently shown no symptoms of the diseases indicating near immunity, and it has excellent cooking quality, low cyanogenic potential, and good agronomic characteristics as well as multiple pest resistance.
- In collaboration with the Institute of Plant Sciences (ETH), Switzerland, cyclic somatic embryogenesis, organogenesis, and plant regeneration were achieved in more than 10 selected African cassava genotypes. The regenerated plantlets have been established in the field with survival ranging from 60% to 100%, and no abnormalities were observed in these plants. Transformation studies are under way.
- Collaborative work with CIAT has shown that a dominant gene controlling a new source of resistance to CMD is flanked by the SSR and an RFLP marker, rGY11 and rSSRY28, at 9 and 8 cM, on linkage group R of the male-derived molecular genetic map of cassava.
- A pilot cassava processing plant was set up in western Kenya.
- A website (www.cgiar.org/foodnet) was established for the food network of East Africa (FOODNET), and was used as a template for 14 regional network websites.
- A total of 123 technicians, extension workers, and researchers attended training workshops on cassava processing, CMD monitoring, rapid multiplication, proposal writing, and other subjects.

Project 7

Biological control and functional biodiversity

- The first field applications of *Metarhizium* for termite control produced significant population reduction.
- Commercial production of Green Muscle®, a microbial control agent for grasshopper and locusts developed by the collaborative LUBILOSA project, began in South Africa.

- A press release on LUBILOSA was launched during International Centers Week in Washington creating a large amount of international publicity.
- Elevated levels of fungal infection among populations of accidentally introduced cassava green mite have been measured in two experimental release sites of exotic isolates of the pathogenic fungus *Neozygites floridana* in the Republic of Benin.
- The importance of IITA's insect collection was reflected by an increasing number of working visits by both regional and internationally recognized taxonomists.
- Thorough faunistic surveys conducted in Ghana, Togo, Benin, Nigeria, and Cameroon resulted in an increase of the reference collection by 20 000 new specimens.
- WAFRINET, the West African loop of the global taxonomic network BioNET INTERNATIONAL, was established to support biodiversity conservation and agricultural development programs.
- In Niger and Mali, seminars were carried out to train and inform plant protection agents, NGO members, and distributors in the use of Green Muscle®. NARS scientists were trained in insect taxonomy and biocontrol survey techniques.

Project 8

Integrated management of legume pests and diseases

- A number of cowpea breeding lines gave higher yields than local lines under no spray conditions at 3 sites in Nigeria. However, none of the lines was best at all locations, indicating possible G × E interactions.
- An Achishuru-type local landrace cowpea line was found to exhibit resistance to flower thrips. Plant damage was low and similar to another landrace (Sanzi) from Ghana. Crosses were made to accumulate the resistance.
- Two plants, *Tephrosia candida* and *Dioclea guianensis*, have demonstrated their potential for in-field mass production of the exotic thrips parasitoid *Ceranisus femoratus* at the IITA-Benin station.
- Follow-up surveys of experimental releases of *C. femoratus* in southern Ghana indicated that *C. femoratus* could still be recovered 10 months after the release in spite of the very low thrips population level.
- Synthetic sex pheromones of the pod borer *Maruca vitrata* were used for the first time with success to monitor field populations. The highest catches were made with cheap, locally available 5 liter plastic jerricans suspended 120 cm above the ground.
- Plant-based insecticides such as aqueous extracts from neem and papaya leaves were actively promoted to farmers through NGOs and national agricultural research and extension systems (NARES) in Benin, Ghana, Niger, Nigeria, and Senegal.
- PEDUNE and RENACO merged to form a new project called PRONAF (Projet niébé pour l'Afrique), which was launched in May 2000 with joint funding from the International Fund for Agricultural Development (IFAD) and the Swiss Agency for Development and Cooperation (SDC).
- Baseline household surveys were completed in 8 PRONAF countries where the benchmark sites had already been delineated the previous year (Benin, Cameroon, Burkina Faso, Niger, Mali, Ghana, Nigeria, and Senegal). At the same time, to capture the demand characteristics for the different cowpea technologies, trader perception surveys were carried out in the same countries.

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- Improved cowpea storage techniques which enable storage for more than 6 months without tangible losses were widely disseminated to about 3500 farmers through NGOs and NARES in 7 PRONAF countries.
- Eighty-five participants from NGOs, farmers organizations, and government institutions in 5 countries were trained in cowpea integrated pest management (IPM) and, in turn, established training for 185 farmers.

Project 9

Integrated management of maize pests and diseases

- Leaving maize on the ground due to lodging, harvest operation, or before storage considerably increases the risk of development of *Aspergillus flavus* fungi and aflatoxin contamination. Management strategies are being developed with farmer participation to help them to produce better quality maize.
- Isolates of *Trichoderma harzianum* have been found to significantly reduce endophytic stem infection of maize by *Fusarium verticillioides* (syn. *F. moniliforme*).
- *Fusarium verticillioides* in maize stems and grain has been conclusively shown to attract female *Eldana saccharina*, *Mussidia nigrivenella*, and the beetles *Carpophilus dimidiatus* and *Sitophilus zeamais* and causes higher survival and fecundity but shorter generation time of offspring.
- A cross-sectional study of 480 one- to five-year-old children across Benin and Togo found that 98% had aflatoxin in their blood, with levels increasing in months after weaning. Blood aflatoxin was significantly related to the use of white maize as a weaning food.
- The success rate of a simplified scouting program to detect damaging infestations of *Prostephanus truncatus* in grain stores, when applied to field data from 1997–98 and 1999–2000, was more than 97% when *P. truncatus* was present in the store. Farmers are being trained to use the program to: (a) avoid treating uninfested stores, and (b) make economically sound decisions about store management, such as treating or selling, when stores are infested.
- Development of a stem borer-resistant maize population was strengthened with the formation of a pair of reciprocal maize populations (TZBR Comp 1 and TZBR Comp 2) with combined resistance to *Sesamia* and *Eldana* and the development of a new *Eldana*-resistant maize population (TZBR Eld 4 C0).
- In association with Green River Project of Agip Oil, Shell Petroleum Development Company, and the National Rice/Maize Centre of the Federal Department of Agriculture in Nigeria, two stem borer-resistant populations (TZBR Eld3 C2 and Ama TZBR-WC1) were successfully deployed in more than 100 on-farm trials in southeast Nigeria.
- Advanced generation inbred lines with resistance to *Sesamia* and/or *Eldana* were identified.
- The methodology for improving on levels of resistance to downy mildew (DM) attack was standardized. A maximum of 3 to 4 cycles of S1 selection will upgrade DM resistance to 95% in DM converted populations.

Project 10

Integrated management of cassava pests and diseases

- Africa-wide implementation of cassava green mite (CGM) biological control continued in 2000. The exotic phytoseiid predator *Typhlodromalus aripo* is now established and persisting in 20 countries in sub-Saharan Africa. Surveys showed that *T. aripo* has covered much of the cassava-growing areas of West Africa, Kenya, Tanzania, and Malawi, with limited distribution in the Central African Republic, Democratic Republic of Congo, and northern Mozambique and Zambia.
- In the first apparent establishment of a mite-pathogenic fungus in Africa, Brazilian isolates of *Neozygites floridana*, released in southeastern Benin in January 1999, continued to produce an average of 35% CGM infection levels nearly 2 years after the initial introductions, while CGM infection levels in southwestern, south-central, and central Benin have remained generally at the preintroduction background level of < 1%.
- Diagnostic surveys of the African root and tuber scale *Stictococcus vayssierei* in Cameroon identified several host crops including, with decreasing order of infestation levels, cassava, yam, cocoyam, taro, and groundnut. Scale infestations were most severe in degraded forest and on the more acidic soils, particularly when cassava followed *Chromolaena odorata* fallow. *Anoplolepis tenella* is the ant species most consistently associated with *S. vayssierei* and is considered essential for the scale's survival.
- Expansion of the cassava mosaic disease (CMD) pandemic, associated with the novel virus variant EACMV-Ug (Ugandan variant of East African cassava mosaic virus), was reported for the first time from northeastern Rwanda. Severe CMD reported from both the shores of Lake Tanganyika in Tanzania and Bukavu in eastern Democratic Republic of Congo was shown to be the result of mixed ACMV/EACMV infections, and not the occurrence of EACMV-Ug.
- In a major CMD management program for the Lake Zone of East Africa, IITA in partnership with NARES and NGOs deployed CMD-resistant germplasm in more than 500 ha of recently affected zones of Uganda, Kenya, and Tanzania; identified 10 elite clones from more than 500 East Africa Root Crops Research Network-derived materials introduced to open quarantine in northwestern Tanzania; and established 19 technology transfer centers, combining resistant variety multiplication, participatory evaluation of new germplasm, and training.
- Over 2000 farmers and 200 agricultural officers were trained in cassava pest and disease management in Kenya, Malawi, Mozambique, Tanzania, and Uganda; 11 scientists from 6 countries of East and Central Africa were trained in virus diagnostic techniques; and 5 technicians were trained in advanced techniques of molecular markers, virus indexing, and tissue culture.

Project 11

Protection and enhancement of vulnerable cropping systems

- A survey of users of LEXSYS, a decision support tool on the use of green manure cover crops, found that the program was valued for its references to completed trials and information on legume species and their pests and diseases. Respondents recommended that the program should be made Windows-compatible, available over the Web or on CD, and should include photographs and more information about actual farmer usage.
- In the Forest Margins Benchmark, groundnut variety JL-24 out-yielded local groundnut varieties by an average of 60% in the first season. During second season production,

when groundnut yields are usually poor, soybean and cowpea out-yielded groundnut by an average of 63% and 132%, respectively, in 12 farmer fields in 4 benchmark villages. Yields of best soybean, cowpea, and groundnut varieties correlated with soil exchangeable aluminum.

- A minimum estimate of 345 kg of herbaceous legume seed consisting of 271 seedlots was distributed to international agricultural research centers (IARCs), NARS, and NGOs during 2000, mainly for experimental evaluation. An additional 410 kg of seed was supplied to NGOs for multiplication and distribution. Private companies and NGOs are willing to pay for the seed, indicating active investment in cover crops.
- In the preliminary demonstration trials of cover crops for soil improvement, pest/weed control, and livestock feed, 7 or more cover crops were tested in 4 pilot sites in collaboration with NGOs/NARS. At one site in Nigeria where extensive tracts of land have been abandoned by farmers because of *Imperata* invasion, *Mucuna* suppressed this weed better than the other legumes. This confirms that *Mucuna* has the potential to reclaim stretches of impoverished land.
- In a long-term fallow experiment at Ibadan, 1 year of *Pueraria* fallow was better than natural and *Leucaena* fallow in maintaining the maize grain yield. *Leucaena* fallow was best in maintaining soil organic matter. While 1 year of fallow increased grain yield, 2 and 3 years of fallow resulted in a smaller increase, with no difference between 2 and 3 years of fallow.
- At the end of the 1999–2000 dry season a total of 433 kg of herbaceous legume seed was harvested and stored from seed multiplication plots at Ibadan, and 118 kg from plots at the Institute of Agricultural Research, Zaria. The seed constitutes a resource for researchers, and development and extension agents who wish to further evaluate and multiply seed.
- Almost every activity under this project is carried out jointly with NARS partners including NGOs. Many students from national universities are conducting research under the project.

Project 12

Improvement of high intensity food and forage crop systems

- With phosphorus (P) and potassium (K) applied, cowpea yields at Adingnigon on "terre de barre" plateau (dominant soil Nitosols) in the southern Benin benchmark were still low in spite of a good variety and adequate protection from insects. Organic matter addition gave a dramatic increase in grain yield from 131 kg/ha in 1999 to 539 kg/ha in 2000.
- The cowpea cultivar IT-90K-59 was tolerant to low-P soil and was able to deplete the stable P fraction (non-Olsen-P) in the rhizosphere in P-deficient soils in the derived savanna in Nigeria.
- The response to P addition was related to the Olsen-P content for most soils in the derived savanna and in the northern Guinea savanna villages, showing an inflection point near 12 ppm Olsen-P.
- Evidence from trials with ^{15}N-labelled fertilizer indicated that although direct interactions between nitrogen (N) fertilizer and particularly low quality organic matter were substantial, this was not consistently reflected in improved synchrony between N fertilizer supply and uptake by a maize crop. The impact of direct interactions between N fertilizer and high quality organic material, whether incorporated or surface applied, was shown to be minimal.

- Medium- and late-maturing soybean resulted in an addition to the soil of 4.2 kg N/ha, whereas the early-maturing varieties resulted in depletion of the soil N reserve by 5.6 kg N/ha in a cereal–legume rotation.
- An efficacious cultivar of soybean reduced *Striga hermonthica* parasitism on a succeeding maize crop and the effect was increased by P application to the soybean in 3 farmers' fields in northern Nigeria.

Project 13

Development of integrated annual and perennial cropping systems

- In May 2000 the official launching of the Sustainable Tree Crops Program (STCP) took place in Accra, Ghana. STCP is a joint public–private partnership between European and American chocolate manufacturers, bilateral donors, NARES, and IARCs in West and Central Africa convened by IITA. Activities falling under the 4 program components (research and technology transfer, grower and business support services, market and information systems, and policy) were endorsed by a broad coalition of stakeholders including farmer organizations, marketing agents, industry concerns, and research and extension. STCP is using a systems approach focused principally on the sustainable supply of cocoa, coffee, and cashew nuts through diversified multiproduct agroforestry systems.
- At the launching, Project 13 research activities on the reforestation of degraded lands through the creation of tree-based livelihood assets by small farmers were presented and endorsed by the stakeholders. Project activities addressing the rehabilitation of degraded lands under the umbrella and funding of STCP are slated to begin in Côte d'Ivoire, Nigeria, and Cameroon in 2001.
- In Cameroon and Nigeria, the project is implementing reforestation establishment trials with 70 households. In Cameroon hybrid oil palm and multistrata cocoa systems establishment is being targeted to deforested *Chromolaena odorata* bush and *Imperata cylindrica* grasslands.
- Based on interactive needs analysis by the 30 farmers participating in the cocoa agroforestry trial, a consensus was reached to include the indigenous fruit trees *Dacryodes edulis*, *Ricinodendron heudelotti*, and avocado trees, and the timber species *Terminalia ivorensis* as upper canopy permanent shade component. Temporary shade treatments include a plantain and cooking banana species of *Musa* and the fast-growing legume *Inga edulis*. In 2000, cocoa was planted under this shade canopy and soil nutrient trials were implemented to address the issue of fertility constraints on degraded lands. In addition to the agronomic data, labor and input costs are being gathered in order to calculate establishment costs and returns.

Project 14

Impact, policy, and systems analysis

- Results from food demand surveys in major cities of northern Nigeria indicated that each household consumes an average of 5 kg/week of cowpea. This and other results were used to make projections on the future demand and supply of cowpea in Nigeria. The projections indicate a deficit of about 2.5 million tonnes for 2005 and 2010 and about 2.4 million tonnes for 2015. A minimum average yield of 1200 kg/ha versus the current 530 kg/ha is required in 2015 for production to meet the growing demand for cowpea in Nigeria.

- Patterns of household food expenditures in the dry savanna indicated that food expenditure constitutes about 56% of total expenditure. Rural households experienced food stress for 7 (high expenditure group) to 9 (low expenditure group) months in 1 year.
- A survey in the western highlands of Cameroon targeted about 100 cowpea traders from both rural and urban markets. Wholesalers and semi-wholesalers were more inclined to treat their stored product compared to retailers. Some traders (42%) used synthetic chemical products. Actellic was the chemical most widely used (57% of traders). Traditional methods include the use of wood ash, pepper, and tobacco leaves. Four variables were significant in explaining the decision to adopt or not adopt chemical pesticides: education level and age of the trader, proximity to urban centers, and infrastructure for storage.
- A comparative economic analysis of the management of speargrass in the derived savanna of Benin using cover crops integrated with hand weeding and chemical control indicated that the net returns were 2.5 to 7.4 times higher in maize plots that received glyphosate than in weeded plots. Weeding consumed 62–74% of the total budget invested in crop production.
- Agricultural transformation in the northern Guinea savanna has occurred in the past 30 years. Changes were noticed in the land use systems (with maize and soybean becoming increasingly important), productivity of major crops (maize, sorghum, soybean, and cowpea), and rural capital assets (roads, rural markets, and population). However, changes in total population did not modify the social structure of the household. Increase in fertilizer use was closely associated with the changes in land use systems and capital assets.
- Participatory poverty mapping involving 462 heads of households and 298 housewives in the cowpea growing area of northern Nigeria resulted in the definition of 3 wealth classes: rich (13% of farmers), middle class (60%), and poor (27%).
- A total of 109 scientists from 16 sub-Saharan African countries received specialized training on methodologies for the measurement of impact and the evaluation of agricultural technologies. This training covered multivariate techniques for data analysis, methods for market analysis, and quality control in manufacturing and servicing of improved agro-processing equipment.

CGIAR Systemwide and Ecoregional Projects

Systemwide program for integrated pest management

- Pilot sites for testing by farmers of "best bet" IPM options, based on the research of 5 participating IARCs and numerous partner organizations, have been established at 6 sites in contrasting agroecological zones across Africa (in Burkina Faso, Cameroon, Egypt, Kenya, Morocco, and Nigeria). As well as serving as focal points for integrating the products of IPM research, the pilot sites are helping to raise public awareness of the key role of IPM in sustainable agriculture.
- The Systemwide Program on Participatory Research and Gender Analysis and the Global FAO Facility have joined the SP-IPM and Swiss Agency for Development and Cooperation in launching a comparative study of participatory research and training methods in IPM, based on an analysis of IPM projects in Bolivia, the Philippines, Honduras, Vietnam, Indonesia, Kenya, Zimbabwe, and Bangladesh.

- The SP-IPM has been strengthened by the addition of CABI Bioscience as a full member. CABI researchers are already active participants in the SP-IPM's Task Force on farmer participatory methods and, with the International Centre of Insect Physiology and Ecology, in our Kenya pilot site. The program's steering committee has been further diversified by the inclusion of representatives of the Global Crop Protection Federation (a private sector group) and the Pesticide Action Network (an NGO).

Ecoregional program for the humid and subhumid tropics of sub-Saharan Africa

- The EPHTA Benchmark Area concept has been accepted by both IITA and the NARS. The benchmark areas have become the key areas for IITA's on-farm research and testing.
- Because of limited resources, the research plans of EPHTA have largely been implemented through IITA core activities. EPHTA faces the challenge of finding supplemental funding in order to increase activities with the NARS.
- In the Degraded Forest Benchmark Area in southeast Nigeria, stakeholder interest and involvement have resulted in participatory development, evaluation, and dissemination of improved crop production technologies. Technologies such as hybrid yams and improved cassava, sweetpotato, rice, and maize varieties have been evaluated and farmers' selections made based on their food preferences and cash returns.
- A workshop on multivariate analysis was held in Cameroon in May 2000 to introduce EPHTA NARS member researchers to the concept of domain delineation in resource management research and upgrade their skills in the use of multivariate techniques for the analysis of data from the resource management surveys conducted in EPHTA benchmark areas. All of the 6 EPHTA benchmark areas were represented by a least 2 researchers per benchmark area.
- An example of successful introduction of a new technology through collaborative research with farmer involvement is the use of leguminous cover crops in short fallow systems to control weeds and restore soil fertility in the derived savanna benchmark area in the Republic of Benin.
- The adoption and rapid expansion of soybean in Kaya village in resource domain 3 of the Northern Guinea Savanna Benchmark Area in central northwest Nigeria is another success story during the year.

Annex 4

Map of agroecological zones