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Copies of this publication may be obtained from

Distribution Unit, IITA

ISBN 978 131 187 8

Printed in Nigeria by IITA and Modern Design & Associates Ltd.

The contribution of IITA-improved cassava to food security in sub-Saharan Africa: an impact study

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Abstract

Since its foundation in 1967, the International Institute of Tropical Agriculture (IITA) has worked, in partnership with national agricultural research systems in sub-Saharan Africa, on the improvement of cassava and dissemination of improved cassava germplasm. This paper describes the impact of this work, by looking at the spread of improved cassava varieties, their use in national breeding programs, and the ultimate benefits of this work on food security in sub-Saharan Africa. Twenty countries were surveyed, which together account for over 90% of cassava production in sub-Saharan Africa. A total of 206 cassava varieties were released between 1970 and 1998 by the national agricultural research systems of these countries. Genetic materials from IITA represented the major source of germplasm used in the development of released varieties. In 1998, improved cassava varieties were grown on about 22% of the 9 million hectares that were planted to cassava in the 20 countries. The use of improved varieties resulted in a yield increase of 49% over the average yield, and an additional production of 10 million tonnes of fresh storage roots per year, or 2200 kcal per person per day for 14 million people. Between 1970 and 1998 a total of 1381 scientists were trained at IITA, accounting for 38% of senior and 49% of intermediate level researchers currently working in cassava research in these countries.

Key words: cassava, impact, IITA, sub-Saharan Africa

Introduction

Cassava (*Manihot esculenta*) is a major food crop in sub-Saharan Africa. It is primarily a root crop, but the leaves and shoots, which are relatively high in protein, are also often eaten. The roots are an important calorie provider: more than 200 million people in sub-Saharan Africa—about one-third of the population—get more than half of their calories from foods made from cassava roots. Its value further lies in its ability to grow in suboptimal conditions, for example, drought and low soil fertility, conditions which are often encountered in parts of Africa. During times of social and political unrest, when people are forced to farm marginal lands, cassava has proved to be an invaluable food security crop. Cassava is also becoming a major source of income for smallholder farmers (Nweke 1996) and of raw materials for local industries (Onabolu and Bokanga 1998; Sanni et al. 1998).

In 1993, Africa produced about 88 million tonnes of cassava or about 55% of the world's cassava. This output is projected to more than double by 2020 (Scott et al. 2000). Trends in cassava production indicate a steady growth over time. For example, growth rates of 2.5% between 1961 and 1975 and 2.7% between 1976 and 1998 were recorded in all of Africa. In West Africa, the major cassava-growing area, a rate of 4.4% was recorded between 1976 and 1998 (FAO 2000). About two-thirds of that increase was due to the expansion of the area cultivated; the remaining third was the result of increased yields from new improved varieties. These improved varieties can have yields nearly 1.5 times higher than the local varieties.

IITA and its regional and national partners have clearly contributed to this increased cassava production in Africa. This paper describes the first systematic study of the impact of IITA's work in cassava improvement.

Cassava breeding at IITA

The challenges in the 1970s for the improvement of cassava in Africa were mostly related to finding ecologically sustainable ways of reducing or eliminating the effects of major diseases. The most widespread and economically damaging diseases, cassava mosaic disease (CMD) and cassava bacterial blight (CBB), received early attention.

CMD in Africa is caused by either of two geminiviruses (African cassava mosaic virus, ACMV, and East African cassava mosaic virus, EACMV). Both are transmitted by the ubiquitous whitefly, *Bemisia tabaci*, and together they caused a yield reduction estimated at US$2 billion per year. The disease can also be carried by plant cuttings and transmitted through grafts, adding to its persistence and spread.

CBB, caused by *Xanthomonas campestris* pv. *manihotis*, was first reported in Nigeria in 1972. It causes complete loss of leaves and death of plants. The best cassava varieties available at that time proved very susceptible. In 1973 it was estimated that CBB caused losses worth US$77 million in East Central State in Nigeria. CBB epidemics were also reported in a dozen other African countries and most local varieties were found to be susceptible.

Breeding for resistance to these diseases began at IITA in 1971. Scientists started work with an EACMV-resistant genotype obtained from interspecific hybridization in East Africa in the 1930s, which was found to also have resistance to CBB. Selected germplasm was also collected from Latin America, Asia, and East Africa along with local varieties from within Nigeria. This work resulted in several elite genotypes that had resistance to CMD and CBB as well as high, stable yields and good consumer acceptability.

This work, accomplished over a relatively short period of about 10 years, was the first major breakthrough in genetic improvement of cassava. The development of these resistant varieties, and their delivery to national programs for testing under specific local conditions during the late 1970s and 1980s, has led to the widespread and successful deployment of CMD- and CBB-resistant cassava in sub-Saharan Africa.

In the 1990s, IITA built on this success to develop more cassava varieties with improved characteristics for Africa's agroecologies. Seeds from Latin America with potentially useful traits were used to enhance local and improved varieties, allowing cassava production to expand into new areas. IITA amassed a large collection of cassava genetic resources which were routinely used in the breeding program. The Collaborative Study of Cassava in Africa (COSCA), a multi-institutional and multidisciplinary effort coordinated by IITA, collected extensive information from the perspective of farmers, marketing agents, and processors, which helped direct the breeding program.

The present germplasm collection at IITA has 2161 cassava accessions (plant samples), consisting mostly of hybrid clones (1193) derived from IITA's early breeding populations, local varieties from Africa, and about 300 samples of exotic materials and wild *Manihot* from Brazil and the International Center for Tropical Agriculture (CIAT) in Colombia. This collection is maintained in the field gene bank at IITA and partly in vitro. Over the past 20 years, IITA also encouraged and supported national scientists in Africa to collect and conserve their local cassava germplasm. A recent survey conducted by IITA revealed that about 4000 local varieties are currently being held in 17 major cassava-growing countries in Africa.

IITA's links with national systems are of great importance for the realization of common goals. IITA has been active in maintaining and further improving linkages between the cassava program and the national root crops programs in West and Central, East, and southern Africa. For the latter two regions, the main channels for linkage and collaborative research are two networks, the East African Root Crop

Research Network (EARRNET) and the Southern African Root Crop Research Network (SARRNET). For West and Central Africa, the main mechanism for interaction is through collaborators' meetings.

The impact study

The study aimed to measure the impact of IITA-improved germplasm on cassava production in sub-Saharan Africa. The objectives of the study were to:

- document the extent of use of IITA germplasm for cassava breeding and production in sub-Saharan Africa
- assess the spread of IITA-developed varieties
- document the impact of IITA's training program on human capital development
- assess the benefits of improved cassava on food security

The study included 20 countries, selected because together they account for over 90% of cassava production in sub-Saharan Africa (Table 1). Leaders of the national cassava breeding programs of these countries were asked to complete a questionnaire about use of IITA-improved materials in their breeding programs, release and extent of planting of improved varieties, and details of any training through IITA. Where respondents had difficulty providing data, literature data or expert opinion was used, or data available were averaged and applied to all countries.

Release of improved varieties

The research programs of the countries surveyed released a total of 206 improved cassava varieties between 1970 and 1998 (Table 1). The majority were released in West and Central Africa, the traditional cassava-growing regions; about 34% were released in Eastern and Southern Africa. No private seed companies released cassava planting material.

Most of these varieties were released after 1980 (Fig. 1). The releases appear to correlate with advances in IITA's breeding program: an average of 6.9 varieties have been released per year since IITA-improved varieties became available; prior to that the average was 1.7 per year.

The released varieties had three main genetic sources: IITA and CIAT cassava breeding programs, and local varieties. IITA germplasm was the main genetic source (Table 2). IITA supplied germplasm in most cases as "ready-to-use" varieties with little selection for local adaptation required (Table 3). These IITA varieties (categories 3 and 4 in Table 3) represented 78% of cassava germplasm supplied from IITA. This was to respond to an urgent need for improved varieties in the study region, as

Table 1. Countries surveyed in the impact study, and number of cassava varieties released between 1970 and 1998

Country	Number of varieties released
West Africa	
Benin	8
Côte d'Ivoire	2
Ghana	4
Guinea	16
Nigeria	15
Sierra Leone	6
Togo	14
Central Africa	
Cameroon	13
Chad	30
D.R. of Congo	14
Gabon	14
Eastern Africa	
Kenya	3
Rwanda	8
Uganda	9
Southern Africa	
Angola	9
Malawi	4
Swaziland	2
Tanzania	24
Zambia	3
Zimbabwe	8
Total	206

many national cassava breeding programs are still weak and face declining trends in investment in agricultural research by many African governments.

The germplasm supplied combined one or more positive traits. The characteristics of the IITA germplasm included resistance to pests and diseases such as CMD, CBB, cassava green mite, and cassava mealybug. Other traits of importance were mealyness, storage root dry matter, harvest index, and low storage root cyanide content

The released varieties were also adapted to a wide range of African ecologies, and nearly half were adapted to two or more ecologies. They were mainly intermediate- and early-maturing (12–15 and 8–12 months to maturity, respectively), reflecting farmers' preferences (Nweke et al. 1996).

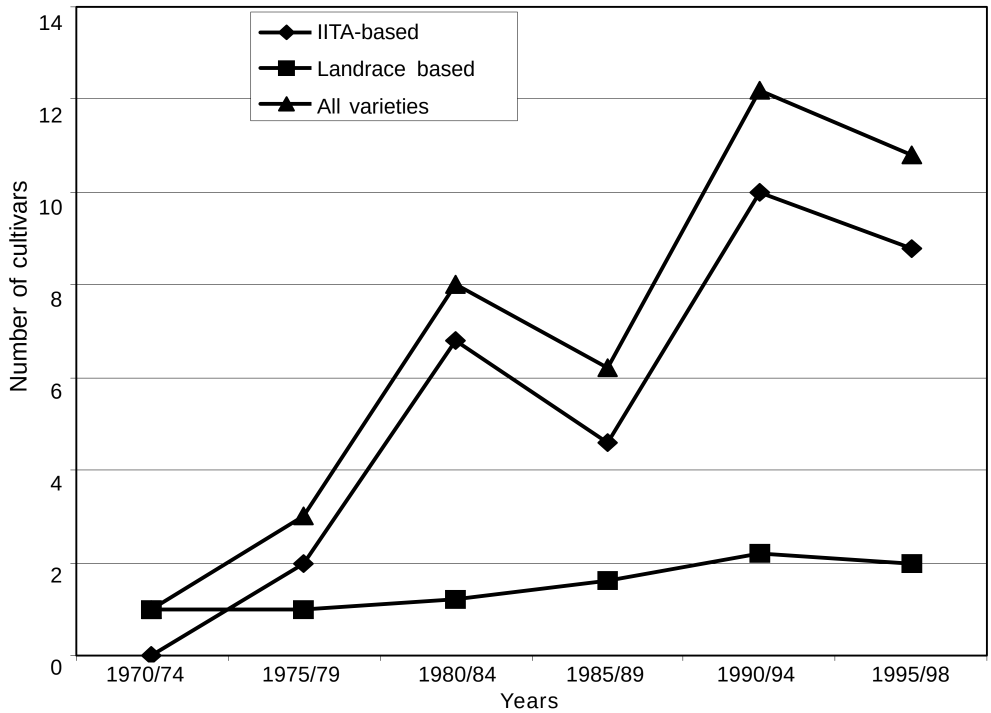

Figure 1. Average number per year of cassava cultivars released every 5 years by source of germplasm in sub-Saharan Africa, 1970–1998

Table 2. Source of germplasm incorporated in cassava varieties released in survey countries (%)

Source	1970–79	1980–89	1990–98
IITA	54.7	79.9	80.1
CIAT	0.0	0.0	1.8
Landrace	32.8	20.1	13.5
Others	12.5	0.0	4.6

Table 3. Use of cassava germplasm from IITA in the varieties released by the survey countries (% of varieties)

Category	1970–79	1980–89	1990–98	All
1	11	3	18	10
2	56	8	5	12
3	11	59	45	48
4	22	30	33	30

1 = basic germplasm (substantial improvement and selection done after being received from IITA).
2 = IITA germplasm, with some improvement and selection for local adaptation.
3 = IITA germplasm, with some selection for local adaptation.
4 = direct use of IITA material, no additional improvement and selection done except planting material multiplication.

Capacity building

Capacity building through training has also been an important part of IITA's work. Between 1970 and 1998 a total of 1381 scientists were trained who now work in cassava research in sub-Saharan Africa (Table 4). These include 51 PhD and MSc students, 42 research associates (non-degree students), and 1278 group trainees. The number of PhD and MSc students increased over the time studied, while the number of group trainees increased from the 1970s to the 1980s, and then decreased in the 1990s, reflecting changes in IITA's training policy.

Assuming these former IITA students now work in their national systems, they represent about 38% of senior researchers and 49% of intermediate level researchers currently working in cassava research and planting material production, in the country programs surveyed (Table 5).

However, the number of national scientists remains very low compared to the area planted to cassava in the study area. The ratio of senior researchers and administrators to hectares planted to cassava is 1:84 280. These results highlight the need to further pursue individual long-term training schemes (PhD and MSc levels) for national systems in the study countries.

Food security

Increase in production was calculated from the area planted to improved varieties and the yield advantage. The area planted to improved varieties was found through farm surveys. The yield advantage was calculated as the difference between the average yields of improved and local varieties in farmers' fields (yield potential in research trials would be higher). The measurement of yield advantage did not take into consideration the number of years or cycles that were required to develop the improved varieties. Increase in production was then converted into energy, allowing for 25% waste (for fresh storage roots), using the energy content constant from FAO food composition tables.

On average, about 22% of the total area planted to cassava in the survey countries (about 9.0 million hectares) was planted with improved varieties in 1998 (Table 6). These improved varieties resulted in a yield advantage of about 49% over local varieties. The additional production of fresh storage roots was more than 10 million tonnes per year. This additional production supplied the required daily energy for 14 million people, or 4.2% of the total population of the study countries. This is above the 3% yearly growth of population in Africa. In money terms, improved cassava varieties gave gross returns of about US$204 per hectare of land.

The area planted to improved cassava varieties varied greatly, from 37% in Cameroon to only 0.4% in Zambia. Also, the yield advantage varied from 1% in

Table 4. Number of scientists trained at IITA to conduct cassava research in the survey countries

	1970–79	1980–89	1990–98	Total
PhD				
Men	3	6	13	22
Women	–	–	1	1
Total				23
MSc				
Men	5	18	4	27
Women	–	1	–	1
Total				28
Research training associates				
Men	17	21	2	40
Women	–	–	2	2
Total				42
Visiting research scholars				
Men	3	4		7
Women	–	1	2	3
Total				10
Group trainees				
Men	73	676	375	1,124
Women	4	66	84	154
Total				1,278
All				
Men	101	68	396	1,220
Women	4	725	89	161
Total	105	793	485	1,381

Table 5. Personnel working in cassava research in the survey countries in 1997–98

	Personnel
Senior researchers and administrators	107
Intermediate-level researchers and administrators	109
Technicians and other support personnel	294
Farm and casual laborers	527
Total	1,035

Figures for 19 countries (Ghana not included).

Kenya to 125% in Ghana; the gross economic benefit ranged from US$36 per hectare in Angola to US$643 per hectare in Rwanda for the areas planted to improved cassava; and the proportion of the population to gain food security varied from 0.05% in Zambia to 12% in Ghana.

Table 6. Estimated economic benefits from the use of improved cassava varieties, 1998

	Area planted		Average yield		Increased production (10^3 t)	GEB*/ha of improved varieties ($US)	No. of beneficiaries	
	Total (10^3 ha)	Improved varieties (%)	Local varieties (t/ha)	Advantage (%)			Total	% 1996 popn
Benin	158	10	7	71	79	83	109,941	1.98
Côte d'Ivoire	270	20	7.5	20	81	90	112,724	0.8
Nigeria	2,950	23	13	45	4,091	142	5,693,760	4.95
Sierra Leone	48	23	7	71	55	333	75,915	1.77
Togo	112	14	9	44	64	447	88,509	2.11
Malawi	76	10	8	63	38	434	52,883	0.54
Swaziland	15	42	8	50	24	329	33,734	3.83
Tanzania	580	38	3	78	536	189	745,588	2.42
Zimbabwe	38	10	8	80	24	421	33,845	0.3
Rwanda	40	3	10	40	5	643	6,680	0.12
Uganda	450	36	7	20	228	90	317,771	1.57
Cameroon	80	38	17	27	141	392	196,224	1.45
Gabon	43	20	5	60	26	313	35,905	3.25
D.R. of Congo	2,455	30	8	50	2,895	373	4,028,288	8.61
Chad	45	19	5.5	82	38	105	53,403	0.82
Zambia	165	0.4	5	90	3	90	4,110	0.05
Guinea	140	21	6	18	32	165	43,944	0.58
Angola	576	17	6	20	118	36	163,525	1.46
Kenya	98	20	9	1	20	38	27,276	0.98
Ghana	630	30	6.5	125	1,536	41	2,137,060	11.98
Total/Mean	9,018	22	8	49	10,032	205	13,961,085	4.15

*GEB = gross economic benefit.

Conclusions

On average, about seven improved cassava varieties were released per year by the public sectors of the main cassava-producing countries in Africa between 1970 and 1998. IITA and CIAT have played a significant role in increasing the number of varieties released by these countries' national programs since the late 1970s. Materials from IITA and other CG centers are an important factor in the ecological shift of cassava beyond traditional growing areas to the semiarid areas of western and southern Africa and the midaltitudes in eastern Africa. The increased production in 1998 resulting from improved varieties was about 10 million tonnes of fresh storage roots, which could feed about 14 million people. New traits are needed, and IITA is playing a key role in supplying new germplasm. CG centers such as IITA still have a role in increasing the rates of adoption of improved cassava varieties in sub-Saharan Africa.

IITA has contributed greatly to capacity building in sub-Saharan Africa. However, the ratio of senior researchers to the area planted with improved varieties is still very low. This highlights the need to pursue the individual training schemes in order to increase research capacity in sub-Saharan Africa.

Acknowledgements

The leaders of the cassava research programs from the national agricultural research systems contributed to this study through data collection in their respective countries: Angola (P.A. Muondo), Benin Republic (N.G. Maroya), Cameroon (J.M. Ngeve), Chad (L.K. Mbailao), Côte d'Ivoire (N. Boni), Democratic Republic of Congo (M. Bidiaka), Gabon (D. Nzoghe), Ghana (J.J. Afuaka), Guinea (E.B. Sanoussi), Kenya (Y.N. Migwa), Malawi (C. Moyo), Nigeria (T.N.C. Echendu), Rwanda (R.L. Mayala), Sierra Leone (A. Jalloh), Swaziland (M. Nxumalo), Tanzania (R. Kapinga), Togo (K.A. Somana), Uganda (G.N. Ssemakula), Zambia (M.S.C. Simwambawa), and Zimbabwe (Rukoye). The authors gratefully acknowledge their contribution to this study. Many thanks to the IITA scientists (Dr. I. Kasele and Professor Teri) posted in southern Africa for their help during data collection. This study was funded by IITA and the CGIAR Impact Assessment and Evaluation Group (IAEG). The authors appreciate advice and recommendations from Professor R. Evenson (Yale University), the principal investigator nominated by the CGIAR IAEG to coordinate study on the impact of crop germplasm from the CG centers.

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