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Working with Farmers in Cameroon and Rwanda

New Strategies to Improve Food Crops

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International Institute of Tropical Agriculture

Preface

Root and tuber crops are among the most important staple foods in tropical Africa. They play a vital part in the region's food security because they are very tolerant of environmental stresses and give reasonable yields under marginal soil conditions. Their importance grows as population pressure increases on land resources and causes farm productivity to decline sharply.

A decade ago, national agricultural research systems in the region were generally unable to carry out adequate research to improve root crops. During the 1980s a tripartite partnership of national research institutes, the International Institute of Tropical Agriculture (IITA), and donor organizations, primarily Canada's International Development Research Centre (IDRC), succeeded in helping several countries to develop improved technologies and deliver them to farmers. Among the programs in the region, the Cameroon National Root Crop Improvement Program (NCRCIP) and Rwandan National Root Crop Improvement Program (RNRCIP), although small, were able to demonstrate how to co-opt the help of "elite" farmers in generating, evaluating, and disseminating improved technologies of root crops, particularly cassava and sweetpotato, for the benefit of small-scale farmers. Although they are dissimilar in agroecological features and cultural institutions, Cameroon and Rwanda followed similar approaches in developing their root crop improvement programs. Four factors enabled them to succeed:

- strong government commitment to the crop improvement goals
- excellent scientific leadership in crop improvement programs
- long-term support of donors
- assistance from IITA in research and training, and in linking national agricultural research systems with donors.

The experience which Cameroon and Rwanda have gained in working with farmers can be a useful example to other national agricultural research systems, international research and development agencies, and donors, in formulating policies and strategies for strengthening research capabilities of other countries in the region. That hope has led IITA and IDRC to produce this booklet.

Credit for the success of the program efforts belongs, first of all, to those scientists and technicians, national and international, whose research and extension work produced the improved technologies and took them to the farmers. Others contributed in other vitally important ways: government officials in Cameroon and Rwanda, and representatives of the donor agencies of IDRC, Belgium's General Administration for Cooperation and Development (AGCD), and the United Kingdom's Gatsby Charitable Foundation, who together provided effective support in building up CNRCIP and RNRCIP. I would like to record my own great appreciation of the farmers who carried out the on-farm adaptive research crucial to the successful results. I would also like to acknowledge with gratitude the work of Ms. Lynn Simarski in collecting information and taking photographs in Cameroon and Rwanda, and in writing the draft of the text for this booklet. Finally, IITA's Publications Unit also deserves our grateful acknowledgement for their work in editing , designing, and producing this volume.

Sang Ki Hahn
Director Emeritus

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New Strategies

Better varieties of root and tuber crops, and improved methods of growing them, could help significantly to ease Africa's growing food shortage. Two contrasting countries, Cameroon and Rwanda, have begun to raise production of roots and tubers to feed their swelling populations. Through their innovative research strategies they have successfully sown the results of research in farmers' fields, furnishing valuable lessons for other African countries facing similar problems.

For many years, agricultural research neglected the root crops that are essential subsistence staples across tropical Africa. Scientific attention focused instead on increasing the production of cash and export crops, bypassing those grown for food. Even among food crops, cereals and legumes took research priority over roots and tubers. At last, however, root crops such as cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), yams (*Dioscorea* spp.), and cocoyams (*Colocasia* spp. and *Xanthosoma* spp.) have begun to benefit from scientific improvement.

Scientists seeking to develop superior root crops in Cameroon and Rwanda have faced very different technical and cultural challenges, yet their approaches to establishing their research programs share some key elements. Each country has sought to produce not only better-yielding crops but also to build an indigenous capacity for research, instead of merely executing projects that leave no legacy of trained national personnel behind. As the programs have grown, critical yet relatively modest outside funding from international donors has been balanced by increasing financial support from government. Perhaps most critically, the sustained character of the support has allowed the time required for both scientific expertise and new agricultural technologies to mature.

Both countries have also established close links with an international research center, the International Institute of Tropical Agriculture (IITA), based in Ibadan, Nigeria. IITA's technical expertise has helped the countries build their research programs through access to training courses, research networks, and collections of plant genetic resources used for varietal improvement.

Each country now has a nucleus of committed and confident researchers, produced by a combination of academic training at home and abroad, practical courses on root crops at IITA, and opportunities to work with IITA scientists posted in their countries. These dedicated national scientists, whose training has been focused on their country's agricultural needs, have steered root crops research in directions that have begun to change farmers' lives.

In both countries, the scientists have adopted an approach that ensures that new crop varieties and growing techniques are appropriate for local conditions, modifying them for areas of high or low elevation, for instance, and for different amounts of rainfall. The foundation for the research is a broad system of research stations located in different agroecological zones, and program staff drawn from a number of disciplines—including plant breeding, agronomy, entomology, plant pathology, food technology, and extension—helping to guarantee a comprehensive research approach.

Neither country's scientists consider their task complete when they have developed a promising new line of cassava or sweet potato that yields well on the research station.

Surmounting bureaucratic divisions, they have established close links with the agricultural extension services in their countries, which have become enthusiastic partners in the process of research and dissemination, relaying farmers' reactions to new varieties back to the researchers. The programs also work energetically through channels such as development projects and agricultural businesses, forging links with any institution or person willing to cooperate to multiply the new varieties and distribute them to farmers.

Perhaps the paramount ingredient in both countries' research successes, however, is the scientists' partnership with farmers and their families—from the beginning, when they survey farmers to determine their needs, to later stages when farmers test new crop lines under field conditions and let scientists know the results. New varieties must meet the demanding test of being grown under farmers' constraints, for only in this way can the scientist be sure of good performance. Not only must new varieties perform well in the field; they must also have acceptable storage and processing characteristics, and they must taste good once cooked. Thus the whole farm family must be consulted to ensure that all the criteria that make a new variety successful are met.

Mainstays

Root crops play a key role in feeding not only the peoples of Rwanda and Cameroon but those of many African countries. Africans eat the most root crops per person of any region in the world. Only cereals surpass roots and tubers as a tropical staple. In tropical Africa, it is mainly small-scale subsistence farmers who grow root crops for their carbohydrate-rich, underground storage organs—swollen roots in the case of cassava and sweet potato, and modified stem structures such as the tubers of yams and the corms and cormels of cocoyams.

Africa produces more than 90% of the root crops produced in the tropics. From 1961 to 1985, the continent's average yield for root crops was only two-thirds of the world average yield, a proportion that underscores the untapped potential of Africa's traditional varieties, unimproved by science.

Many of the root crops grown today are relative newcomers to Africa. Cassava and sweet potato, for instance, came from Latin America. While some yams are indigenous to Africa, other species came from southeast Asia. Cassava spread from introductions during the sixteenth to nineteenth centuries, and in colonial times cultivation of both cassava and sweet potato was encouraged to safeguard against famine. The cocoyam *Xanthosoma* was brought to Africa from the West Indies as recently as early in the nineteenth century.

Root crops fit well into the region's traditional agricultural systems, in which several crops are typically grown in mixture in the same field at once. In environments where drought is a threat, crops such as cassava, sweet potato, and yam are a better risk than many others, and fewer pests and diseases attack roots and tubers as compared with cereals and legumes. Root crops also tolerate the low fertility of many African soils without requiring fertilizer inputs—a boon for the subsistence farmer who can rarely afford to purchase expensive chemicals from off the farm.

Hardy cassava—the foremost tropical root crop, grown in 31 African countries—has special advantages. It can yield adequately on leached tropical soils; at an early growth stage, it does not compete with intercropped plants for nutrients and other resources; and

it can be grown last in a crop rotation, when the soil is too exhausted to support other crops. Cassava is one of the few tropical crops that can survive the dry season, and it has the singular characteristic of keeping its tubers intact underground for up to 3 years after planting, as a cache against hunger.

Despite these many benefits, roots and tubers languished for decades as a low research priority, disdained as "the poor man's crops." Yet the unimproved varieties that farmers now grow suffer from a number of problems that science could alleviate. Pests and diseases suppress yields: a case in point is cassava, which has come under attack since the early 1970s by two new pests from Latin America—cassava mealybug and green spider mite. The high moisture content of root crops hampers transportation and marketing. Cassava tubers rot in 3 to 5 days after harvesting, while the bulk and awkward shapes of yam and sweet potato invite damage during handling, opening them to attack by storage diseases and pests.

Perhaps the major hurdle to increasing the production of roots and tubers, particularly yams, is their inherently low multiplication rate. Unlike cereals and legumes, which farmers grow from seed, roots and tubers are propagated vegetatively: a part of the parent plant is severed, regenerates roots and shoots, and grows into a new plant with the same genes and traits as the parent. Plant parts used in propagation are called planting material. Farmers thus propagate cassava from stem cuttings, sweet potato from vines, and yam from tubers. The slow rate of vegetative propagation often limits how much of a crop a farmer can plant and also curbs the spread of scientifically improved varieties to farmers. New rapid propagation techniques offer some promise in overcoming both bottlenecks.

Africa's national research programs, assisted by IITA, have recently begun to unlock the potential of roots and tubers. Particularly in Rwanda and Cameroon, improved varieties as well as better growing methods are already paying off in farmers' fields. A closer look at these programs could profit other African countries which have turned increasingly over the past 15 years to food imports and aid. For in the uncertain climates and vulnerable environments of the region, improved roots and tubers can enrich the crop diversity critical for food security and sustainable agriculture.

Cameroon: the Challenges of Diversity

Cameroon's dramatic landscape harbors examples of virtually all the environments of tropical Africa, presenting agricultural scientists with a considerable challenge in tailoring new varieties and better growing methods to a wide range of rainfall, topography and soil conditions. Between the humid coastal lowlands fringing the foot of Mount Cameroon and the arid northern plains bordering Lake Chad lies a spectrum of ecological zones characterized, from south to north, by decreasing rainfall and a longer dry season.

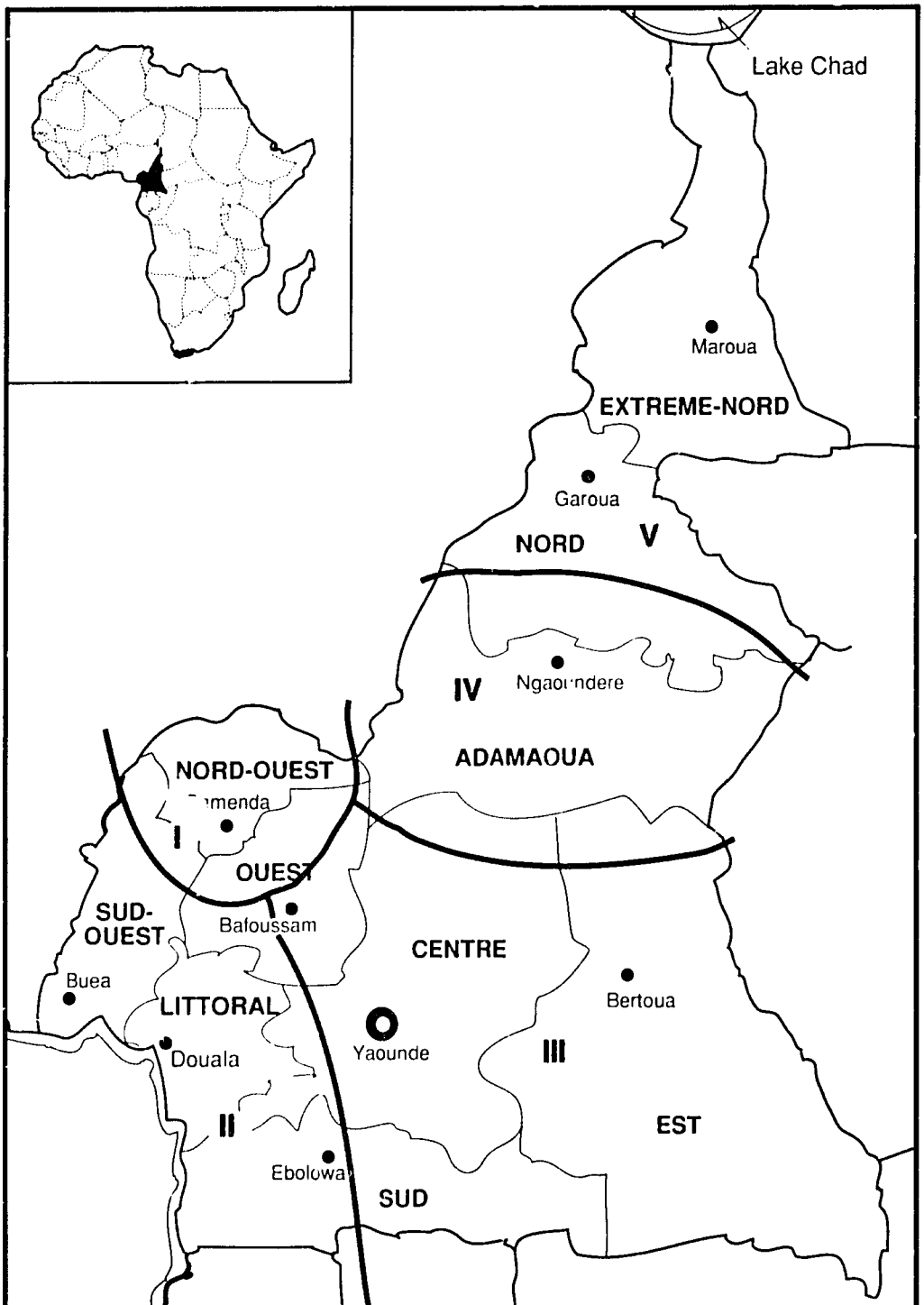
The continuum of natural vegetation mirrors this spectrum, as the south's dense evergreen forest grades into savanna and finally to steppe in the north, interspersed with areas of tropical montane forest and grassland. Soils range from sandy sedimentary to rich volcanic types.

Researchers have divided Cameroon into five broad agroecological zones (see Figure 1 and Table 1), a classification that helps to target the distinct research priorities of each

Table 1. Cameroon's agroecological zones and experimental sites

Zone	Characteristics	Experimental site (soil type)
I	*Western highland:* highland savanna, with highland monsoon-type of equatorial climate, high annual rainfall and short dry seasons. Average temperature: 21°C (range 15-30°C).	Babungo (andisol) Foumbot (andisol) Dschang (ultisol)
II	*Coastal lowland:* medium altitude/high rainfall lowland evergreen forest, with coastal monsoon-type of equatorial climate, high annual rainfall and short dry seasons. Average temperature: 20°C (range 20-30°C).	Ekona (andisol) Mujuka (ultisol) Njombe (andisol)
III	*Southern continental zone:* semi-deciduous forest and derived savanna, with Guinea-type of equatorial climate having four seasons, moderate annual rainfall and moderate dry season. Average temperature: 24°C(range 19-31°C).	Nkolbisson (alfisol/ultisol)
IV	*Adamaoua:* Sudan Guinea savanna, with Sudan highland-type tropical climate, moderate annual rainfall and severe dry season. Average temperature: 23°C (range 13-32°C).	Meiganga (alfisol/entisol) Mbang Birni (alfisol/entisol)
V	*North :* Sudan savanna with Sudan-type tropical climate, moderate to low annual rainfall and very severe dry season. Average temperature: 26°C (range 16-32°C). *Far North:* Steppe with Sudano-Sahelian climate.	Mbe (alfisol)

Source: Cameroon National Root Crops Improvement Program, Terminal Report, 1987.



I	Western Highland	Maize
II	Coastal Lowland	Root and tuber crops
III	Southern Continental Zone	Root and tuber crops
IV	Adamaoua	Root and tuber crops and maize
V	North Cameroon	Sorghum and millet

Figure 1. Major agroecological zones, provinces and towns of Cameroon

area. The zones are: western highlands with savanna vegetation, coastal lowlands with evergreen forest, the southern continental zone with forest and savanna, the Adamaoua zone with humid savanna, and the dry north and far north with savanna and steppe.

Diversity is the hallmark of Cameroon's human population as well as its agroecological zones. By one classification, the country embraces more than 100 ethnic groups, many different languages, and several distinctive dietary preferences. The population of about 10 million is distributed unevenly, with three-fourths of the people living on less than one-fifth of the land. The densely populated western highlands and coastal lowlands contrast strikingly with sweeping expanses of almost uninhabited land in other zones.

A Nation of Agriculturalists

Cameroonians of every region are oriented strongly toward agriculture, a sector that employs 75 to 85% of the population. The mainstay for food crop production is the small-scale family farm. Cash crops such as rubber, oil palm, and tea are cultivated mainly on commercial plantations, particularly in the south, but some are grown on family farms as well.

In the forest zone across south and central Cameroon, constituting about one-third of the country, farmers follow a bush fallow pattern, clearing the forest, cultivating crops for 1 to 3 years, and then leaving the plot fallow for a longer period to restore soil fertility. As the country's population rises, the fallow period is shortening. Mixed cropping—with as many as 10 crops planted together or sequentially in a single field—is the norm, especially in the south. This system supplies a nutritionally varied diet as different crops mature successively over the year.

Cameroon's drier north, with spacious savanna and steppe, presents a striking contrast to the forested south. Here the bulk of the country's livestock is reared and driven southward "on the hoof" to feed the cities, although tree, garden, and field crops are also cultivated.

Roots and tubers, accounting for half of Cameroon's 10 major food crop species, are the country's dietary staples, along with plantains and maize. Cassava, yam, cocoyam, and sweet potato are grown throughout the country. In the southern forest zone, root crops supply about 60 to 70% of dietary calories, with cassava alone accounting for about 44% of the total. In the savanna and highland areas, cereals such as maize, sorghum and millet dominate, with roots and tubers playing a backup role in case of crop failure.

Given the rapid increase of Cameroon's population over the past few decades, roots and tubers may well assume an even more vital role in the future. Their dependable yield in an uncertain climate, particularly in the face of drought, added to the many different forms in which they are eaten, underscore their potential to stabilize, increase, and diversify the nation's food supply.

Cassava

Cassava, which is the quintessential subsistence crop in tropical Africa as well as a commercial crop, is particularly prominent in Cameroon's forested south. Farmers grow

a number of different cassava varieties, from bitter and high in cyanide to sweet (also called non-bitter, and usually harvested earlier than the bitter types).

Generally grown in fields of 1 hectare or less, cassava is often intercropped with groundnut, melon and maize. In the forest zone, a common sight at planting time is women—cassava's chief cultivators—walking to the fields balancing bulky bundles of stem cuttings on their heads. A farmer in this zone usually plants three to five varieties in the same field, and grows the crop entirely with hand labor, using the cutlass and hoe as the major tools.

The principal diseases that attack Cameroon's traditional cassava varieties are mosaic virus (transmitted by the white fly *Bemisia tabaci*), bacterial blight (caused by *Xanthomonas campestris* pv. *manihotis*), and anthracnose (caused by the fungus *Colletotrichum gloeosporioides* f.sp. *manihotis*). In recent years, the crop has fallen under increasing onslaught by two pests inadvertently imported from South America: green spider mite (*Mononychellus progressivus* and *M. tanajoa*) and cassava mealybug (*Phenacoccus manihoti*). Poor planting practices, such as inappropriate intercropping or planting in waterlogged areas, as well as poor weeding and inefficient harvesting, can also limit cassava production.

Cassava is sometimes eaten fresh in Cameroon but, unlike other root crops, it is often laboriously processed into a range of more than 20 different products before consumption. Freshly harvested cassava keeps for only 5 days at most, so harvested roots must be marketed or processed into a longer-lasting product without delay. Processed products are lighter and easier to transport than the bulky tubers, and processing also reduces the cyanide content of cassava, rendering it safe to consume.

A popular cassava commodity is *fufu*, eaten in an array of different forms. (*Fufu* can refer both to flour used in making porridge and to a thick paste eaten with sauce; moreover, *fufu* can also be made from maize, sorghum, millet, yam, and other crops—alone or in mixtures.) Although each region of Cameroon has its local cassava *fufu* variant, most share the steps of peeling, washing, and fermenting the tubers in water for 3 to 4 days to reduce their cyanide content, then drying and pounding or milling the result into a fine flour.

Fermented *fufu* is most popular in the south. Northerners, who are not familiar with processing and dislike the strong smell of fermented cassava, primarily prepare unfermented *fufu*, drying the peeled and chopped tubers in the sun for 2 to 4 days, then milling them into a flour with a short storage life. An ingenious longer-lasting product is *fufu* balls (*kum-kum*); shaped from fermented wet pulp and dried on a wooden rack over a fire, the balls acquire a brown smoky coating that helps to preserve them for up to 2 years.

Fermented cassava, set out for sun-drying

Gari is another widespread cassava product, for which fresh, peeled tubers are grated, squeezed dry, left to ferment for 2 to 5 days, and then roasted. Fermented cassava is also ground and wrapped into rod-like shapes within leaves of plantain or other plants, then steamed to produce the rubbery, gelatinous *myondo* or *bobolo* sticks offered for sale in bound bundles along roadsides near the homestead. Still other cassava products include cake, starch, chips, doughnuts, an alcoholic drink called *arki*, and a homemade detergent from cassava starch. Even the plant's leaves, consumed like spinach, furnish protein, minerals, and vitamins for people in central and southern Cameroon.

Dried cassava pulp on sale, ready for flour milling

The country does not yet process cassava on a large industrial scale. Traders (called "buyam-sellam") purchase cassava products sold in local markets and transport them to cities, but marketing and pricing are rather unsystematic.

Cocoyam

Cameroon produces almost 1 million tonnes of cocoyam a year. Two kinds—macabo (*Xanthosoma sagittifolia*) and taro (*Colocasia esculenta*)—are grown throughout Cameroon, but the crop performs better in the higher rainfall areas, and production is greatest in the forest zone. Farmers grow only three traditional types of macabo (the more recently introduced kind of cocoyam) with characteristically white, yellow, and red-colored flesh, but plant a wider range of taro cultivars. Various cocoyam varieties mature over different periods ranging from 6 to 14 months.

The worst and most widely spread threat to macabo production is root rot blight complex (caused primarily by the fungus *Pythium myriotylum*), which can wipe out four-fifths of the crop in some areas. Found worldwide, root rot reached Cameroon about 15 years ago. The white macabo—the one most commonly grown—is also the most susceptible to root rot, while the yellow type—less productive and popular—can resist the disease. One reason root rot recurs in fields is that farmers plant infected material from the previous year's harvest to start the new crop. Chemicals to control root rot are costly and their distribution is impractical. On the scientific side, genetic incompatibility between the yellow and white types hampers efforts to breed a high-yielding, root rot-resistant macabo.

At maturity, cocoyam cannot be left underground like cassava. Wet soil, in particular, encourages sprouting and reduces yields, so farmers expose harvested cocoyam to the sun to induce suberization—the formation of corky tissue that retards spoilage. The suberized tubers are stored in cool, dry places such as holes covered with dry leaves, and

Cocoyam grows best in high-rainfall areas

sprinkled with wood ash to preserve them. In this way the crop can be stored for up to 4 months.

Cameroon's subsistence farmers consume the bulk of the fresh crop—boiling, roasting, and baking the tubers for various sauces and soups. Taro, especially, is boiled, peeled and pounded into a paste, to which bananas are added in some areas. Another local dish, *achu*, is prepared by wrapping the paste in blanched plantain leaves and serving it with a distinctive yellow sauce made from a wood ash filtrate and other ingredients. Different variations of macabo *fufu* are also prepared, while leaves and, in some areas, even flowers are consumed.

Yam

Cameroon lies in West Africa's yam zone, which produces more than 90% of the world's crop. Yam is grown in all regions of the country, mainly as a subsistence staple, but also for market in the southwest. Of eight edible yam species identified in Cameroon, the four most widely grown are white yam (*Dioscorea rotundata*), yellow yam (*D. cayenensis*), water yam (*D. alata*), and sweet or traveller's yam (*D. dumetorum*).

The low multiplication rate that plagues root and tuber production in general afflicts yam the worst. Cassava is propagated from stems and sweet potato from vines, but next year's yam crop must come from the same harvest of tubers that provides the farmer with food. With as much as one-third of a yam needed for planting and one or two portions for eating, very little is left over for a smallholder to sell. Planting material can account for up to 45% of a yam crop's production costs.

Yam growing is also laborious, for the crop must be staked to minimize leaf disease and encourage leaves to spread and intercept sunlight—lest yields drop by up to 40%. Stakes are not always to be found, particularly in Cameroon's northern savanna, where firewood is scarce, and in other deforested areas. Yam's large, cumbersome tubers are easily damaged during harvest and transport, and wounded tubers, vulnerable to rotting and insect attack, are difficult to store.

Of the yams grown in Cameroon, the high-yielding *D. dumetorum* seems the best candidate for mechanized harvest, since it can be grown without stakes and produces short, easily harvested tubers. One of the main problems with this species is that the tubers begin to harden from 24 hours to 2 weeks after exposure to air, so farmers generally boil the tubers after harvest and sell them in this form.

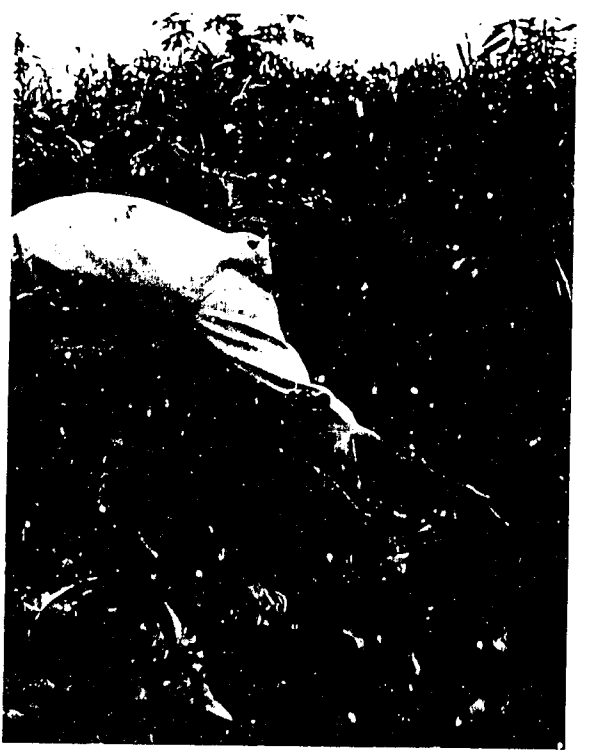
Other yam species are suberized and stored, covered with dry vegetation, in a cool dry spot in a house, under a tree, or in a pit. Most yam is peeled, boiled and eaten as a vegetable, although *fufu* and fried doughnuts and balls are also prepared.

Pastoralists have turned yam-growers through extension efforts

Sweet Potato

Of Cameroon's four major root crops, sweet potato is the least widely grown, although its range is expanding. It was once regarded as suitable only for livestock or children, but as knowledge of the crop's nutritional value has spread and improved varieties have been distributed, cultivation has increased. Sweet potato is a short-season crop harvested in 4 to 6 months, such that two crops can be grown a year in the forest zone, where sweet potato is sometimes planted in association with cassava, maize, yam, beans, and other crops. The plant is propagated vegetatively from vine slips, which must be conserved in a wet area such as a valley bottom during the dry season. When the rains come, the slips are planted in mounds or ridges, since the crop cannot tolerate excessive water and needs aeration. The farmers unimproved cultivars fall prey to a range of diseases and pests including sweet potato virus disease (SPVD) complex and weevils.

Sweet potato is harvested with a hoe, cutlass, or stick. Timing is critical, because mature tubers left in the ground are attacked by weevils, particularly in the dry season. Sound harvested tubers are suberized under shade for 2 or 3 days, stored in a dry location, typically a hole or a basket, sprinkled with wood ash, and covered with banana leaves or grass. Storage problems include rotting, greening (chlorophyll formation in the tuber skin, indicating quality deterioration), browning (development of brown spots on the tuber tissues), sprouting, and pest attack, especially by weevils.



Two sweet potato crops per year are possible in the forest zone

Sweet potato is steamed, boiled, fried, roasted, or baked and eaten as a vegetable. It is sometimes made into

dried chips (which can be stored up to a year as famine insurance), cake, a beverage called *dulo*, and flour. Traders buy sweet potato from farmers at roadsides and small markets to supply the cities.

The Dynamics of Successful Research

Cameroon's root crops research program, known as one of the best in Africa, rests on a comprehensive system of research sites located in the country's different agroecological zones (*see* Table I). Because its research is focused closely on local problems, the Cameroon National Root Crops Improvement Program (CNRCIP) has begun to make a significant contribution to the country's food self-sufficiency.

Prior to setting research priorities—before a single experiment was designed—CNRCIP scientists surveyed root crop production all over the country in 1976/77 to gauge the crops' relative standing in the agriculture of different zones, identify key biological constraints to production, particularly pests and diseases, and study local agronomic practices.

The scientists then formulated the program's basic aim: to increase root and tuber yields by developing production systems for small-scale farmers with few resources. This required identifying genetic sources of disease and pest resistance, and incorporating them into new varieties with high yield, good nutritional quality, consumer appeal, and adaptability to different ecological zones. The scientists also sought to improve agronomic practices—to reduce inputs to a minimum—and ways of processing and preserving root crops. Now that new varieties and practices have been developed, the scientists are placing great emphasis on multiplying and distributing planting material to farmers.

From the beginning, the country concentrated on building an indigenous capacity for root crops research—training a cadre of expertise at all levels, from technicians to scientists (*see* Table 2). IITA scientists posted in Cameroon helped to train their national counterparts in root and tuber research, multiplication, and distribution, aiming at a longer-term impact than if they had concentrated solely on individual research. As an IITA scientist put it, "If the international funding stops, the national scientists will still be able to carry on."

Farmers' field days bring out the best in everything

Stable leadership, with more experienced scientists nurturing their younger colleagues, also accounts for the program's progress. National scientists benefit from financial incentives to produce results, and the program supports scientific and managerial training abroad. An atmosphere of energetic give-and-take prevails among the CNRCIP scientists and the international

Table 2. Numbers of CNRCIP staff trained at various levels during period of donor support (1978-1985)

PhD	MSc	Specialized training*	IITA production course
5	3	6	24

Source: Cameroon National Root Crop Improvement Program, Terminal Report, 1987.
Note: * Tissue culture and biological control.

experts and donors who support their work.

Instead of remaining sequestered on the research station, Cameroon's scientists have ventured out to the ultimate testing ground, farmers' fields—first to survey farmers' problems, and then to evaluate new technologies on the farm. As a veteran CNRCIP scientist explains, "The policy for government researchers many years ago was 'Don't interfere with farmers.' We were struggling to solve farmers' problems without involving them"—an attitude that Cameroon's Green Revolution, a government campaign to increase food production launched in 1973, helped to change.

Part of the reason Cameroon's farmers adopt new varieties so enthusiastically is that the scientists take into account not only technical constraints such as rainfall, climate, and soils, but also local settlement patterns, authority structures, and eating habits—all of which affect the spread of new technologies. A promising cultivar may be high yielding, for instance, but have an unacceptable taste or smell. A productive cassava variety that requires processing before consumption might not be welcome in central Cameroon, where 70% of the cassava crop is simply boiled, and only 30% transformed into other products. With a thorough understanding of the region in which they work, and a grasp of farmers' needs, scientists have bred new varieties that are clearly superior to local unimproved ones—a difference that farmers can both see and taste.

On-farm research is more demanding than on-station research—all the more so in the context of modest financial resources and poor transport and communications infrastructures. Even though forced to travel over rugged, unpaved roads that can become impassable after a sudden rainstorm and faced with few or no telephone links to rural areas, Cameroon's root crops scientists have managed to reach the country's farmers. CNRCIP scientists regard their connections with other institutions and individuals as invaluable in this task; these include cooperation with the Ministry of Agriculture's extension agents, influential and progressive farmers, village chiefs, local farmers' associations, missionaries, and parastatal organizations—all of which assist in distributing planting material to a much wider range of farmers than would otherwise be possible.

Building the Program

Cameroon's earliest root and tuber research was confined to yam and cocoyam in the western highlands, expanding to the coastal lowlands early in the 197 s. Cameroon's Green Revolution, launched in 1973, set the stage for greater research interest in basic dietary staples. In 1977, CNRCIP—the country's first national food crop program—was formally created within the National Institute of Agricultural and Forestry Research, with financial assistance from Canada's International Development Research Centre (IDRC) and Belgium's General Administration for Cooperation in Development (AGCD), along

with scientific backing from IITA. The program moved to the Institute of Agronomic Research (IRA) when this new institute was created in 1980.

Initially, Cameroon attracted IDRC and AGCD funding because it was a stable country solidly committed to agricultural development, yet one which had not yet received a great deal of donor assistance. Another attraction was Cameroon's wide range of different environments, presenting an opportunity to conduct research under a variety of conditions, with spin-offs in research methods as well as in new technologies for other African countries.

Donor support supplemented Cameroon Government funds, which gradually increased through 1986 as the research program matured (*see* Figure 2). Generally, IDRC supported research activities based at Njombe Research Station and aimed at parts of the western highlands and coastal lowlands, while AGCD funded research in other parts of the coastal lowlands and in the southern continental and Adamaoua zones. Both donors funded two IITA scientists to work in Cameroon's root crops program, in addition to underwriting some recurrent costs, essential equipment, and the training of national scientists and technicians.

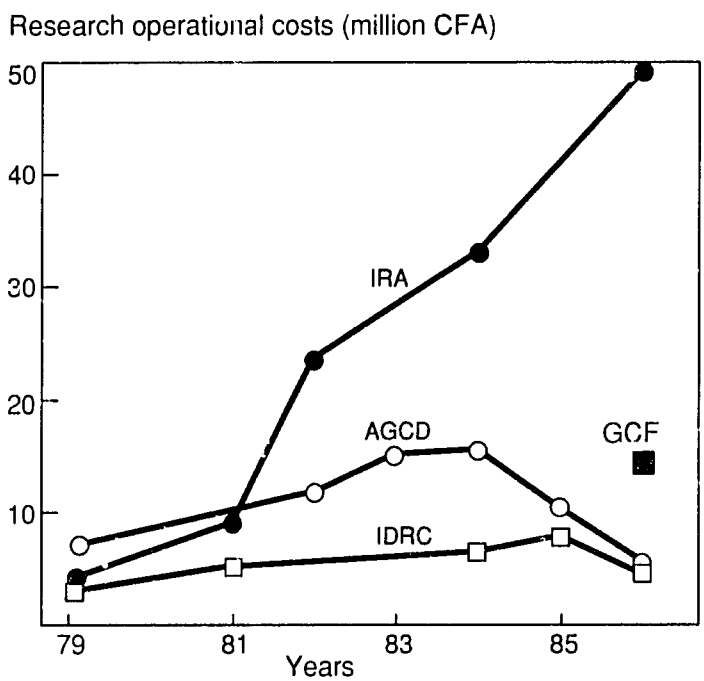


Figure 2. Financial contribution to running research costs of Cameroon National Root Crops Improvement Program by donor agencies

IDRC and AGCD assistance ended in 1986 as the program solidified. Another donor, Gatsby Charitable Foundation (GCF; United Kingdom), has since financed CNRCIP's multiplication and distribution activities.

Program Structure

The root crops program is the second largest of 17 programs in IRA, which is itself one of five research institutes under the Ministry of Higher Education, Computer Services and Scientific Research (MESIRES). The Ministry of Agriculture, a separate institution, is charged with extending new technologies to farmers through its extension agents around the country.

CNRCIP was able to use the country's network of research stations and substations established at key locations within the major agroecological zones (*see* Table 1). Al-

though the program generally follows an interdisciplinary approach, intensive breeding work takes place at Njombe Research Station, where laboratory facilities and staff are concentrated. Research activities that require rigorous control—such as genetic improvement, early selection of varieties from a large population of plants, and experimentation with chemicals—as well as tests of production techniques carrying a high risk of failure, are carried out on the research stations.

A relatively new link between researchers and farmers is provided by IRA's Testing and Liaison Units (TLUs), located at four research stations. The units are responsible for *prévulgarisation*—testing new technologies under farmers' conditions. Interdisciplinary TLU teams, consisting of an extension agronomist and an agricultural economist or a socio-economist, were originally created as part of the National Cereals Research and Extension Project (NCRE), funded by the United States Agency for International Development (USAID) and assisted by IITA. The units were envisioned as a bridge between cereals researchers, extension agents and farmers, and were later expanded to encompass root crops—reflecting the reality of intercropping in farmers' fields.

The Significance of Sustained Support

Long-term donor support was vital to molding a qualified, committed team of national researchers. The program began with a nucleus of four researchers—two national scientists and two from IITA—that has now grown to 11 researchers and over 20 technicians. The program's strategy is to employ a new staff member for an initial period, both for orientation and evaluation, before sending him or her for additional training at IITA or abroad. (Indeed, national researchers comment that technicians are often in short supply because they are continually advancing through training to higher levels in the program.) After a practical grounding in the country's root crops program, the new researcher is able to grasp the application of training such as IITA's short, intensive courses in root and tuber research and technology transfer. As one scientist has aptly observed, "Practical training produces scientists who can make stakes out of sticks."

Like capable researchers, better varieties also require time and sustained support to develop. Breeding a new root crop variety can take 6 years or longer, after which multiplication and distribution must follow.

The breeder winnows out plants with undesirable characteristics, retaining those with favorable genes and interbreeding them to produce, eventually, a variety superior to the one the farmer is using.

Seeking to collect the widest possible range of plant genetic variants—both cultivated and wild—the breeder may well begin with 30,000 distinct seeds, each with its own complement of genes. The seeds are planted (seedling nursery stage) and perhaps 2000 of the best plants are selected. Through vegetative reproduction, genetic copies called clones are made of these plants. The clones are grown the following year (clonal evaluation stage), and the breeder selects the best 300 to 500 clones; the next year, about 100 are chosen (preliminary yield trial); and the following year, 25 or 30 (advanced yield trial); finally, the remaining 12 are tested for stability of performance over different locations and years (uniform yield trial).

Rising through the ranks

Two individual scientists' advancement in the root crops program exemplifies CNRCIP's commitment to professional development, as well as the benefits of sustained donor support.

One scientist, who now heads root crops research in central Cameroon, originally joined the program as a technician with a degree from a national agricultural college. Eighteen months later, he attended IITA's root crops production course, staying on to do some additional research on root crops pathology, and then returned to Cameroon in 1978 to work as a technician for a Belgian researcher assisting the program. Both the Belgian aid agency AGCD and IDRC provided funds, through IITA, for the scientist to pursue his bachelor's and master's degrees at the University of Georgia in the United States. He returned in 1982 to work once more with the AGCD scientist—this time as a colleague.

From 1984 onwards, after the AGCD researcher moved to northern Cameroon to initiate root crops research there, the Cameroonian scientist became head of root crops research in the central region. He then returned to the US—continuing as a staff member in the root crops program even while abroad—to pursue an IDRC-funded doctorate at the University of Maryland, under the stipulation that his dissertation field research would be carried out in Cameroon. The thesis addressed a practical problem of the research program: how to reduce the number of experimental sites needed to establish the yield stability of sweet potato, thereby saving the program time and money.

Another Cameroonian scientist, with a master's degree in agronomy, joined IRA in 1980 as an agronomist in root crops. After 2 years, the program nominated him for an IDRC-supported doctorate, which he began to pursue part-time in 1982 at the University of Ibadan in Nigeria. His dissertation research, carried out in Cameroon, addressed the agronomy of cassava growing in the southwest of the country. The head of IITA's Root and Tuber Improvement Program and the scientist's thesis advisor visited him twice a year to guide his research. The scientist was subsequently named head of food and fruit crops research at Ekona Research Station.

At every stage, clones are chosen on the basis of superior disease resistance, yield, stability of performance, and other characteristics. The clones are then evaluated on farms—first by scientists and then by farmers, who compare somewhere between three and eight of the best. The numbers at each stage can vary, but by the end of the process three or four improved varieties are identified as ready for multiplication and distribution. If the breeder's financial resources are cut off at any stage, the new variety cannot reach the farm, so continuous commitment is critical if research is to have an impact.

Forging Effective Links

The program's development has been marked by cooperation—within the program between researchers and farmers, and between the program and other governmental agencies, international donors, IITA, and research networks.

To disseminate new technologies, IRA collaborates with an array of organizations—such as rural development projects, agricultural production companies, cooperative and regional development authorities—which are all established or sustained by the government (and therefore called "parastatals" in Cameroon). The parastatal Food Development

Authority (MIDEVIV) is a special example: its task is to multiply the planting material of new varieties produced by IRA.

CNRCIP's link with the parastatal Cameroon Rubber Corporation (HEVECAM), based in La Niete, has another aim: to evaluate cassava material in advanced stages of breeding. This work assumed new urgency when mealybug entered the country. As a breeder explains, "We're using La Niete in a system of 'frontline attack' against mealybug—instead of waiting for the mealybug to get to our own cassava selection site, we're going to see how our selections do where mealybug has already appeared. We've now moved all our cassava material in different stages of the breeding pipeline to the La Niete site."

CNRCIP also cooperates with commercial enterprises such as a commercial farm near Njombe, which is cultivating several hectares of an IRA-improved sweet potato variety for export to France.

Cameroon's cooperation with IITA has been particularly productive. One in a network of international centers supported by the Consultative Group on International Agricultural Research (CGIAR), IITA seeks to improve food production and cropping systems in tropical Africa. As part of this work, the center maintains a germplasm collection of roots and tubers, safeguarding the genes of more than 2000 cassava accessions, 2000 yam accessions, 1500 accessions of sweet potato in tissue culture form and about 1000 in the field, and 150 cocoyam accessions in tissue culture.

The major responsibility for maintaining most of the world's cassava germplasm is held by the Centro Internacional de Agricultura Tropical (CIAT), a sister center of IITA in Colombia, while IITA has primary responsibility for African material. IITA holds over 2,000 accessions of cassava clones of African material and wild species introduced from South America which are maintained in the field and in vitro. IITA's Root and Tuber Improvement Program uses this germplasm to breed improved materials that are sent to national programs for further refinement.

IITA's tissue culture facilities are vital in helping different countries to benefit from the Institute's collection of root and tuber germplasm. Since root and tuber crops are vegetatively propagated, planting material usually carries undesirable diseases and pests. National programs need disease-free material. This can be produced either through tissue culture techniques (followed by virus indexing), or in the form of true seed. In the tissue culture laboratory, parts of plants or tissues taken from a plant's shoot tip or nodes can be used to regenerate healthy plantlets for further testing under local conditions. A single copy of a virus-free plant, for instance, can be multiplied at an exponential rate—producing many plantlets genetically identical to the original plant.

Plantlets grown at IITA are certified as disease-free, and sent in test tubes across international boundaries for national breeders to test under local conditions. The seedlings can be transplanted and multiplied quickly for evaluation in many locations, shortening the time needed to test a promising variety and make it available to farmers.

Cameroon values scientific interchange with its neighbors, and is considered to be at the forefront of research in West and Central Africa. The country is a member of the Conference of African Directors of Agricultural Research (CORAF), formed to advance food crop research through joint activities such as collaborative research and seminars. CNRCIP researchers attend the triennial symposium of the International Society for

Tropical Root Crops (Africa Branch), whose member countries keep in touch through the quarterly *Tropical Root and Tuber Crops Bulletin* produced by IITA's Root and Tuber Improvement Program.

Research Highlights

Cameroon's scientists have made significant strides in improving local root crops. Using cassava germplasm from IITA and Cameroon, the researchers have bred new varieties that yield better than local cultivars and resist prevailing pests and diseases. Improved material tested at the most advanced stages of breeding can yield from 50% to over 100% more than the best local varieties in each agroecological zone (*see* Table 3). The new varieties are now being multiplied at IRA research stations and distributed to farmers—the culmination of many years of research.

Disease-free cassava plantlet from IITA ready for transplanting

Researchers have made major progress on sweet potato (*see* Table 4), a short-cycle crop amenable to more rapid breeding, multiplication, and dissemination to farmers than slower maturing cassava and other root crops. Different varieties have been selected that are adapted to various ecologies, but the most popular with Cameroon's farmers is IITA's TIb 1, a high-yielding variety tolerant of pests and diseases with a very stable performance in a range of different environments. Researchers have also formulated recommendations on better growing techniques for sweet potato, including specifications on the best planting time, ridge-building, and the best length and part of the vine to be planted for propagation.

The crop presenting the greatest selection challenge is cocoyam, for which Cameroon has one of the world's most significant breeding programs. Root rot disease is the major threat to this crop, with dasheen mosaic virus a serious but lesser problem. To expand the narrow genetic range of local macabo cocoyams, and thus allow breeding to combine such traits as good yield and root rot resistance in one plant, the program has collected 72 accessions from Ecuador, Puerto Rico, the Dominican Republic, Nigeria, and other countries through IITA. It is now making good progress in incorporating disease resistance identified in the exotic germplasm into locally cultivated types.

The mechanics of cocoyam breeding present special problems, especially for breeders with modest resources. Seeds must be evaluated to produce new varieties, yet cocoyam rarely sets seed under natural conditions. Imported agar, the laboratory medium that gives the best germination rate, is too expensive, so the program has come up with a soil and sawdust mixture that gives lower but adequate germination.

The program currently has five promising macabo varieties to test for three different altitude ranges. In the meantime, to help farmers obtain acceptable yields until a root rot-

Table 3. Performance of selected cassava clones in three agroecological zones of Cameroon

Zone	Clone	Yield (t/ha)	No. of tubers/ 10m²	Disease score*	
				ACMV	CBB
II	820516	24.2	52	1.5	-
	821199	22.9	80	1.6	-
	820917	21.9	60	2.1	-
	820644	21.9	71	1.8	-
	Unimproved	9.6	28	2.9	-
III	397	28.7	100	1.0	-
	629	24.6	75	1.2	-
	575	20.9	83	1.1	-
	128	20.8	87	1.0	-
	Unimproved	19.6	68	3.1	-
IV	2727	9.6	59	1.4	1.4
	2346	8.6	60	1.0	1.6
	2104	7.3	32	1.9	2.0
	2643	7.2	56	1.2	1.7
	Unimproved	4.9	32	1.7	2.5

Source: Cameroon National Root Crop Improvement Program, Research Report.

Notes: t/ha = tonnes per hectare. m² = square meters.
ACMV = cassava mosaic virus. CBB = cassava bacterial blight.
*ACMV and CBB scales: 0-5; 0 = no symptoms, 5 = very severe symptoms. CBB is not a severe problem in zones II and III.

resistant cocoyam can be bred, the researchers are developing cropping recommendations—advising the use of healthy planting material and prescribing the proper density of plants for a given area.

Yam research has also scored some practical achievements. CNRCIP has identified five yam species for commercial production under different environmental conditions, including four varieties of *D. rotundata* (the yam of greatest economic importance) adapted to highlands, medium highlands, and lowlands; two varieties of *D. dumetorum*, one yielding well across different ecologies and one meant for lowlands; and one variety each of *D. cayenesis*, *D. esculenta*, and *D. alata*. These have been multiplied and distributed, together with information on proper cropping practices, to farmers at different altitudes in high-rainfall regions.

Table 4. Average yields of Cameroon's improved and unimproved sweet potatoes over 2 years

	Agroecological zone					
	I	II	III	IV	V	
Altitude (m)	1000	500	700	1200	500	
Rainfall (mm)	2000	2000	1500	1250	1000	
Vegetation	Savanna	Forest	Forest	Savanna	Savanna	
Clones						Mean
IRA 1112	27.5	26.1	27.6	22.8	17.8	24.4
Tlb 1	25.7	22.0	18.5	21.1	13.5	20.2
Unimproved	9.4	16.3	7.0	7.7	11.5	10.4

Source: Cameroon National Root Crops Improvement Program, Research Report.

The program also seeks to transform the productivity of traditional yam propagation, which uses setts as planting material—pieces of the same yam that is eaten. Seeking a cheap, reliable technique to break the bottleneck that the scarcity of planting or "seed" yams now presents, Nigeria's National Root Crops Research Institute (NRCRI) and IITA are improving the minisett technique—first developed by NRCRI—in which a "mother seed yam" is cut into small setts for sprouting and eventual production of seed yams. A 1000-gram yam propagated with the minisett technique, for example, can produce 40 large (or ware) yams 2 years later, while the traditional method would produce only 3 ware yams the first year and 9 setts the second year. The technique also speeds up the breeding cycle, allowing new varieties to be generated much faster. CNRCIP is attempting to refine the minisett technique to produce more uniform seed yams from setts.

Researchers are also working on the postharvest hardening problem of *D. dumetorum*, the yam most prized in the western highland. To date, the program has identified 20 clones or types that can be stored for 3 months; these will undergo further testing and the best will be released to farmers.

New Directions

Cameroon's success in root crops research has drawn the attention and support of other donors and international centers. The Government of Cameroon recently launched a new project called the Tropical Roots and Tubers Research Project (ROTREP), funded by USAID, to tackle outstanding, high-priority problems in root crops research. The objectives are to generate a rapid multiplication system using tissue culture techniques to reinforce the search already under way for a variety of cocoyam resistant to root rot disease; and to assess the postharvest losses of roots and tubers and recommend research areas.

In pursuit of these objectives, ROTREP will help train researchers in food technology, processing, storage, tissue culture techniques, and other topics. To support the research, ROTREP has sponsored a new tissue culture laboratory, based at Ekona Research Station. The laboratory will enable scientists to conduct more sophisticated research on

root rot resistance and rapid multiplication systems, particularly the attempt to foster more uniform sprouting by the minisett technique.

Another new direction for CNRCIP is research on Irish potato (*Solanum tuberosum*), which had received little attention until added to the program in 1985. Because of CNRCIP's success with other root crops, a researcher from the regional office of another CGIAR center, the Centro Internacional de la Papa (CIP) is now helping the program establish a base collection of germplasm and develop a system for disseminating planting material.

A Vigorous Effort to Diffuse Results

CNRCIP's major thrust at present is to test developed varieties on the farm and to multiply and distribute them to growers (*see* Figure 3). The program has prepared planters' bulletins for farmers and extension agents on cassava, yam, and sweet potato. More than 1000 farmers and extension workers have attended the program's courses on root and tuber production and utilization in the country's different agroecological zones (*see* Table 5). Farmers' field days are held at the research stations and in farmers' fields, from which participants depart with samples of improved varieties to plant. Planting material also reaches growers through a variety of impromptu channels; it is given to farmers visiting the research station for advice, or even handed out by researchers and extension workers passing through a local market. In these ways the new varieties have spread to countries bordering Cameroon.

The program's outreach activities demonstrate the impact it has made so far, and show that financial and scientific commitment must continue if results are to reach more farmers. Since 1983 the Ekona Research Station, in the coastal lowland zone, has multiplied and distributed 520,585 cuttings of improved cassava—enough to plant 74.4 hectares of land. The program also began distributing its multiplied material of improved sweet potato varieties, particularly TIb 1, in 1983. In 1984, in response to demand, 13.4 tonnes of TIb 1 vines were distributed in small quantities to 60 farmers' groups; in 1987, 45 tonnes of vines from three varieties were given out to 45 farmers or farmers' groups. Once in farmers' fields, the new varieties continue to be multiplied by farmers and given to other farmers. The researchers and extension workers would like to distribute more material, but often find themselves without transport to reach farmers at the proper time.

The Ekona station also distributes material through workshops. A recent workshop on root and tuber production, storage and marketing was attended by 17 women community development leaders who came to Ekona from seven provinces, with their transport paid for by the Ministry of Agriculture. They returned home with samples of improved cassava and sweet potato to multiply in their areas. According to a CNRCIP researcher, "The women were surprised to see the disease-resistant plants and how quickly the cassava had bulked [produced tubers]—in fact, there was a scramble for planting material when they were leaving because of limited space on the bus!"

Researchers at Njombe Research Station, also in the coastal lowland zone, working in conjunction with Ministry of Agriculture extension agents, show how enthusiasm and a spirit of cooperation can overcome scarce resources. Root crops researchers at the station held a 3-day training course for 35 extension agents on production technology and rapid multiplication. Each agent identified five "leader farmers" back home with sizeable land holdings, who picked up planting material of improved varieties from the stations to

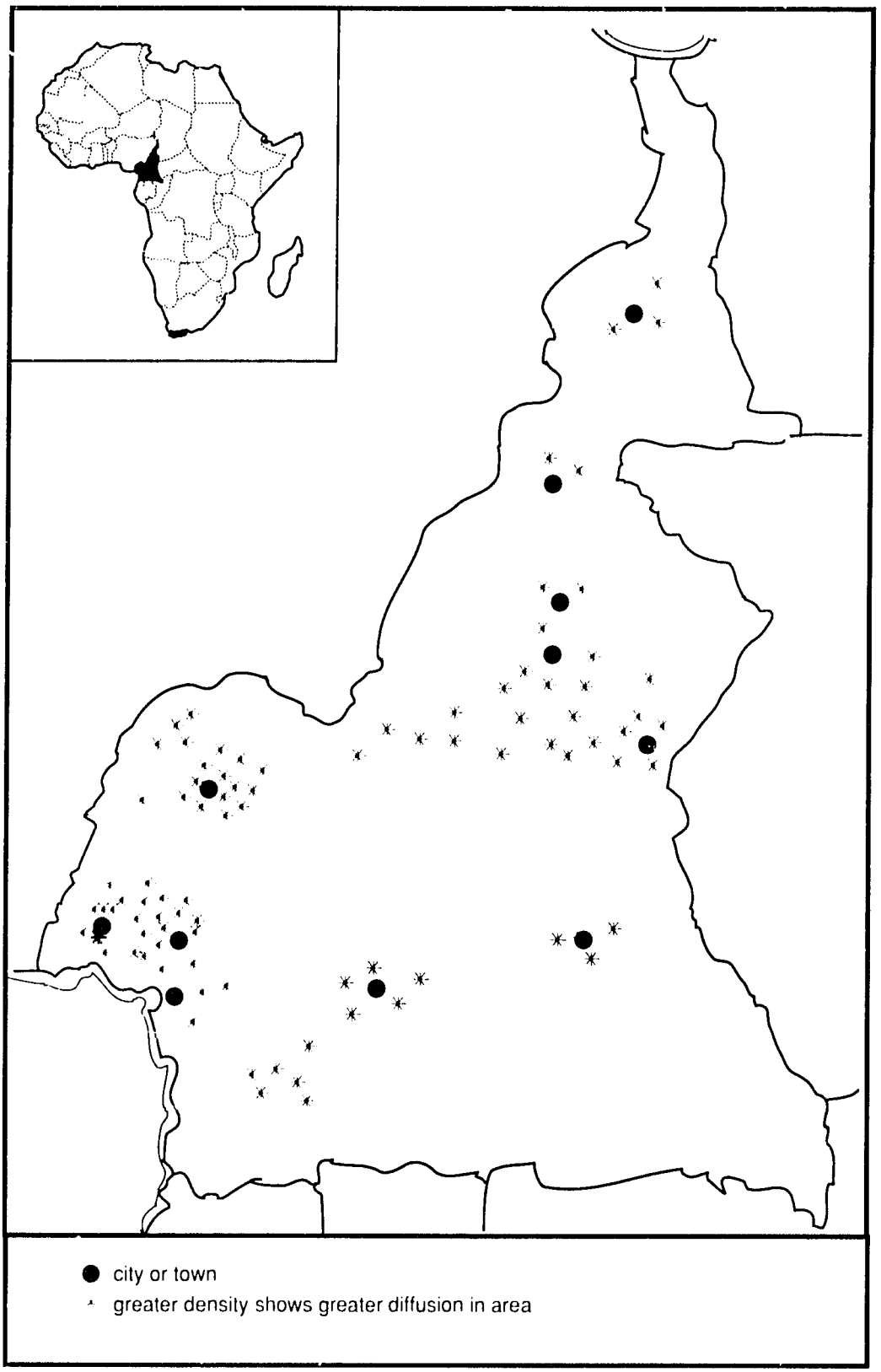


Figure 3. Diffusion of improved root crops (cassava, sweet potato) in Cameroon

multiply in their own fields. The research station and extension service provided the vehicles, while the farmers paid for the fuel to drive them. In return for reaping the benefit of higher production, these farmers shouldered the responsibility to distribute extra planting material to smaller-scale farmers in their neighborhood.

Table 5. Numbers of farmers and extension agents on CNRCIP training courses

	Year		
	1983-84	1985-86	1987-88
Extension agents	140	76	139
Farmers	-	558	393*

Note: * Up to August 1988.

The minimal human and financial resources available to serve the region's dispersed population, reachable only by a rudimentary network of largely unpaved roads, makes CNRCIP's achievement in distributing improved varieties there particularly remarkable. In a few short years, improved sweet potato varieties TIb 1 and IRA 1112 became the first new food crop technologies ever to be disseminated in the region. They were enthusiastically acclaimed by farmers for their high and stable yields, resistance to disease and weevils, and good taste. The wildfire spread of these varieties has paved the way for other new technologies, such as three elite varieties of yam (two white and one water yam), which have been multiplied with the minisett technique and distributed across the region.

Cassava, however, is the major target of root crops research in Adamaoua, reflecting its dietary significance. The major cassava breeding site is Meiganga (*see* Table 1); material in more advanced stages is further tested at two other sites, Mbe and Mbang Birni, providing a range of locations representing the region's different environments.

Reaching Adamaoua's Farmers

Where the thick forest of southern Cameroon gives way to savanna, the Adamaoua region begins: a rolling expanse of plateau brooded over by dark volcanic remnants, and populated by semi-sedentary livestock herders living at an average density of 6 people per square kilometer. Most of the approximately 800 scattered settlements shelter fewer than 1000 people, and many have fewer than 200 inhabitants.

The people of Adamaoua, for whom cassava is the primary carbohydrate staple, had been neglected by food crop researchers until 1981, when CNRCIP turned its attention northward, and an IITA researcher began experiments to select improved sweet potato, cassava and yam varieties for the area.

Adamaoua's cooler and drier climate calls for a different type of cassava than the varieties suited to southern Cameroon, for the crop must grow for a longer period to produce an acceptable yield. Farmers plant in April when the rains begin, and prefer to harvest when plenty of sunlight is available to dry the cassava pulp. Indeed, if the weather is dry, women may peel, ferment, and dry the cassava in the field, carrying home the processed chips, which are much lighter than the raw tubers. But cassava planted in April cannot mature sufficiently by the time sunny weather arrives in October, so breeding efforts focus on developing varieties that can be harvested at 18 months—the following October. Three

Enthusiastic Reception

When a Ministry of Agriculture extension agent brought planting material of new IRA cassava varieties to Muyuka, a small town near Njombe, a group of women farmers tried out the material. After the trial, the group's leader gave an enthusiastic evaluation: "We like 'em papa, time no day!" she exclaimed (roughly, "We like them so much that there's no time to explain why!"). Her group of 50 farming women then pooled their labor to plant a multiplication field of the new varieties. Eventually, each will take a portion of cassava stems to multiply on her own farm. The farmers explained that they like the cassava because it matures faster than the old types (in 10 months instead of 12), yields much higher, and resists diseases. They also appreciate the new cassava's denser canopy cover, which shades out weeds and so saves the women labor. They have registered only one complaint about the new varieties: their planting material has been disappearing increasingly as other farmers learn to appreciate its performance and help themselves.

improved sweet cassava lines were quickly selected from IITA breeding material and distribution began in 1985; the lines yield 25 to 50% more than traditional varieties, even under the most unfavorable growing conditions.

The new sweet potato varieties Tlb 1 and IRA 1112 have begun to make a twofold impact on the Adamaoua region, not only providing a more stable supply of subsistence food but also raising farmers' incomes. Before the introduction of these varieties in 1984, farmers grew the low-yielding local sweet potato mainly for home consumption. The new varieties began to spread from every on-farm trial, and farmers established multiplication nurseries that produced 200 vines from each vine slip planted. Now, village markets around Ngaoundere, Adamaoua's largest town, sell produce of both varieties during the harvest season, and the crop provides families with a new source of cash income.

The new varieties have spread from Adamaoua to eastern Cameroon, from vine cuttings distributed to 100 farmers in 1985. By 1987, about 10 or 15 farmers in each of more than 75 villages were growing the varieties on plots of one-quarter of a hectare or less. All of them had obtained the vines through other farmers' multiplication efforts. Vines are also being disseminated over the Garoua area north of Adamaoua, from the fields of a single farmer who brought the new varieties back to test in his locality.

In 1987 alone, 32,464 setts of yam were distributed to 436 farmers, along with 119,700 sweet potato vines and 4200 cassava cuttings. Distribution of all three root crops continues, although demand by Adamaoua's farmers far exceeds what CNRCIP can supply.

Training extension workers and leader farmers is a key feature of the distribution effort. "Training of leader farmers gives a more stable impact than just distributing a variety," explains a CNRCIP researcher. "When farmers see other farmers using a new multiplication technique, they take it up more readily than if they see a scientist doing it with special resources."

Since IRA's infrastructure in the region is minimal, with the staff of two consisting of an IITA agronomist/breeder and a Cameroonian national scientist, the program uses every possible means to distribute varieties by collaborating with other institutions, including international voluntary organizations, church groups and schools. CNRCIP researchers

"Nothing passes 'em!" exclaims a farmer near Ngaoundere, in the Adamaoua region, about new sweet potato varieties TIb 1 and IRA 1112. In 1986, the farmer planted 10 ridges (each from 25 to 40 meters long) with the varieties, expanding to 100 ridges in 1987 and to more than 600 in 1988. The farmer's wife is just as excited with the 150 ridges she has planted. The farmer passed cuttings of the new varieties on to a neighbor, who now also grows the crop for commercial sale. The farmers explain they prefer to grow sweet potato rather than yam for several reasons: sweet potato produces a higher yield in a shorter period of time for less labor, it can be cooked and eaten more simply, and its cultivation does not require stakes—a scarce commodity in this savanna area.

work especially closely with local Ministry of Agriculture extension agents on farmer trials and multiplication, as well as on special studies such as a market survey and an investigation of cassava processing by Adamaoua women, for which a woman extension agent's assistance was essential. To reach the scattered population, the program is decentralizing and stabilizing the distribution network, establishing small multiplication plots near streams in some villages, to overcome the need to transport planting material long distances from a central multiplication site.

Rwanda: African's Future in Miniature

Rwanda, the "country of a thousand hills", is one of the smallest (26,000 square kilometers) and most densely populated countries in Africa, with 480 people per square kilometer of cultivable land. Almost all arable land—approximately half of the country—is already intensively farmed, while the young population of 5.6 million is growing rapidly at 3.6% a year. Comparatively few people live in cities—virtually all of those working in agriculture, 93% of the population, are subsistence farmers.

Rwandans cherish privacy, and families live in individual compounds rather than villages, scattered over the hilltops and slopes amidst their banana plants and coffee and crop fields. Every hill and valley, no matter how small, is known by name. The garden-like landscape is rich in wildlife, especially birds, which a chemical-based agriculture would largely eliminate.

In the wet season, sweet potatoes cover the hillsides

Most of Rwanda lies above 1300 meters in altitude. The country has two rainy seasons, the first from mid-February to May and the second from October to December, with a dry season of approximately 3 to 4 months from June to August or September. Total annual rainfall is fairly stable, but its uneven distribution can plague farmers, particularly if rain fails at critical stages, such as sowing time and when crops are in the process of forming grain, pods or tubers.

Agriculture Intensified

The average farm size, already less than 1 hectare, is predicted to diminish by the year 2000 to 0.71 hectare, as holdings are successively divided among each family's children. The land scarcity has pushed cultivation into areas traditionally used for grazing and forests, and soil erosion is a serious problem on steep cultivated hillsides. The country's soils are highly degradable and deficient in organic matter.

Rwanda's extremely intensive organic agriculture produces food, fodder, and tree crops using few inputs from outside. Cash crops such as banana (used in making beer as well as eating) and coffee are usually managed by men, while food crops are grown by women.

A single farm may support more than 20 crops, including trees, as well as animals such as goats and chickens. Complex systems of crop rotation are followed; most fields support several crops, whose total yield exceeds the harvest that would be realized from monoculture. Mixed cropping provides food security, insuring against irregular rainfall and pest or disease outbreaks.

The goal of food self-sufficiency is far from an empty slogan in Rwanda, which has experienced at least six famines this century. Around 95% of the country's agricultural land supports food crops; about 18% of this is under root crops, whose high productivity per unit area makes them one of the best means to produce food energy on limited land. Root crops quickly became established in Rwandan agriculture for their food security benefits. For about 70% of Rwandans, the major staple root crops are sweet potato, grown on 120,000 hectares, and cassava, grown on 50,000 hectares. These crops are likely to rank even higher as farming is increasingly forced onto marginal land unsuited to other crops—wet valley bottoms and the semi-arid and eastern lowlands.

Sweet Potato Scores High

The sweet potato was introduced into Rwanda in the eighteenth century, and its widespread use by the country's farmers—including cultivation at the world's highest altitude for the crop—testifies to its value as a food crop. Rwandans, in fact, probably eat the most sweet potatoes per person in the world. Farmers follow an ingenious system of rotation, growing sweet potato higher up the slopes in the wet season, and down in the valley bottoms during the dry period, where vines can be kept alive near streams. Alternating the fields in which the crop is grown reduces pest problems, and the second planting of the crop at the end of the rainy season provides a dependable source of nourishment in the dry season when other foods are scarce. Despite sweet potato's value as a drought-hardy and nutritious staple, only a few other African countries besides Rwanda--such as Burundi, Uganda, and Tanzania--use it as an important root crop.

Farmers prepare sweet potato fields by hoe; 90% build large ridges, beds, or mounds of soil which permit good drainage and aeration, and hence the healthy formation of tubers. Planting is generally done between October and March. When planting is carried out in March, at the end of the dry season, one problem is finding sufficient planting material. Those with access to valley bottom plots (about 40% of farmers) can maintain vines in moist soil until planting time.

In the dry season, it's the valley bottoms

Farmers do not fertilize their sweet potato, and only a small percentage weed their fields even once (a practice attested to by the Rwandan proverb, "Only those with nothing to do weed sweet potato fields."). Sweet potato is often intercropped with one or more other plants, including cassava. Only 12% of sweet potato is marketed--a figure that underscores the crop's subsistence role. Rwandans generally eat the crop boiled; roasted tubers are mainly eaten by children.

Sweet potato yields are kept low by diseases, particularly *Alternaria* leaf blight in wet seasons and a virus complex in dry periods. Another pest is the sweet potato weevil (*Cylas* spp.), which tunnels into tubers, paving the way for bacterial and fungal rot, both underground and during storage. Rwandan farmers recall having lost all their planting stock of some favorite varieties to diseases and pests in their fields.

"Only the rich can afford to wait for late-maturing varieties," runs a Rwandan proverb, referring to another drawback of unimproved sweet potatoes: their late maturity. Poor soil fertility, acidic soils, and erosion also contribute to low yields, and farmers lack enough high-quality vines when they need them most.

Cassava Cultivation Expands

Like many Africans, Rwandans rely on cassava as a carbohydrate staple, deriving from it about 8% of their food energy. As well as being grown for subsistence consumption on the farm, cassava is a significant cash crop. Its ability to endure the dry season and grow in marginal soils has led to the expansion of its cultivation.

Farmers prepare cassava plots by hoe, with most planting done following other crops in a rotation rather than after fallow. A 1984 survey showed that 65% of Rwandan farmers grow cassava, frequently in association with other crops. They cut stems from the previous year's crop into segments, and plant them without fenilizer or compost. At harvest time, the tubers are uprooted by hand or with a hoe.

Farmers grow both high-cyanide and sweet, low-cyanide types of cassava. The high-cyanide cassava is processed by dry or wet fermentation (the latter by soaking tubers in water in clay pots or in a hole near a river for 2 to 3 days), then sun-dried into pulp for storage, or ground into flour at commercial mills or by hand. Consumers prefer dried pulp and flour to be white rather than brown or grey. Flour is mainly cooked into a porridge called *ubugari*, eaten with beans, meat, fish, peanuts, or vegetables. The low-cyanide cassava is boiled or eaten raw as a children's snack. "Some families eat cassava every day, and the grinding mills in Kigali are always busy," observes a researcher.

Resistance is the best remedy

About 71% of cassava growers sell almost half their harvest. Balancing baskets of processed pulp on their heads, farmers trek long distances to the town market held once or twice a week, from which dealers truck cassava to larger cities for resale.

Many of the local cassava varieties are poor yielding and slow to mature. In addition, farmers' fields have little genetic diversity, with only two unimproved varieties dominating production across the country. The overwhelming reliance on one variety in a particular area increases the risk of crop loss due to a pest or disease outbreak. Furthermore, many farmers use diseased planting material procured from the infected crop of the previous year. Cassava green mite is the crop's worst enemy, infesting about 70% of the cultivated area, and cassava mealybug, found elsewhere in Africa, has now reached the country. Three diseases—African cassava mosaic virus, bacterial blight, and *Cercospora* leaf spot—also plague the crop. A further problem is that local types are not well adapted to the high-altitude areas into which cultivation is now expanding.

Designing a Model Research Program

To help Rwanda's farmers feed their families, the country has established a well-directed root crops research program staffed by enthusiastic scientists with a practical orientation. In a relatively short time the program has screened a wide range of germplasm from IITA to select high-yielding varieties suited to a range of environments. The country has also made impressive strides in training farmers and extension workers, and distributing new varieties.

Rwanda's roots and tubers program was set up in 1979 in the Institut des Sciences Agronomiques du Rwanda (ISAR). By 1983, ISAR had become increasingly concerned about the serious losses of root crops to pests and diseases and wished to reap some of the benefits of IITA's research experience with these crops. This led to an agreement between IITA, IDRC, and the Government of Rwanda to establish a research project to improve cassava and sweet potato production in the country.

Although Rwanda's subsistence food crops had as yet received little donor assistance, IDRC saw the country's root crops research as a good investment. The government was firmly dedicated to assisting the rural areas, and the country's dense population gave farmers a keen incentive to boost yeilds. IDRC was also attracted by the government's strong commitment to building an indigenous research capacity, and thus supported the posting of an IITA agronomist/breeder to advise Rwanda's program. In 1983, at the start of IDRC assistance, the program had four researchers, a number that has grown to seven. Since donor assistance began, the government has increased its own support for the program.

The first task was to increase the base collection of genetic material by collecting germplasm within the country and importing it from IITA and elsewhere. The IITA scientist advised the Rwandan researchers on establishing a breeding strategy, including how to produce new hybrid lines, following up on the basic root crops training they had already received at IITA. The program rapidly established a system to breed new varieties on a scale matched by few other African countries; instead of beginning the cassava breeding cycle with 200 hybrid seeds, for instance, as they had done in the past, the breeders started with 30,000 hybrid seeds.

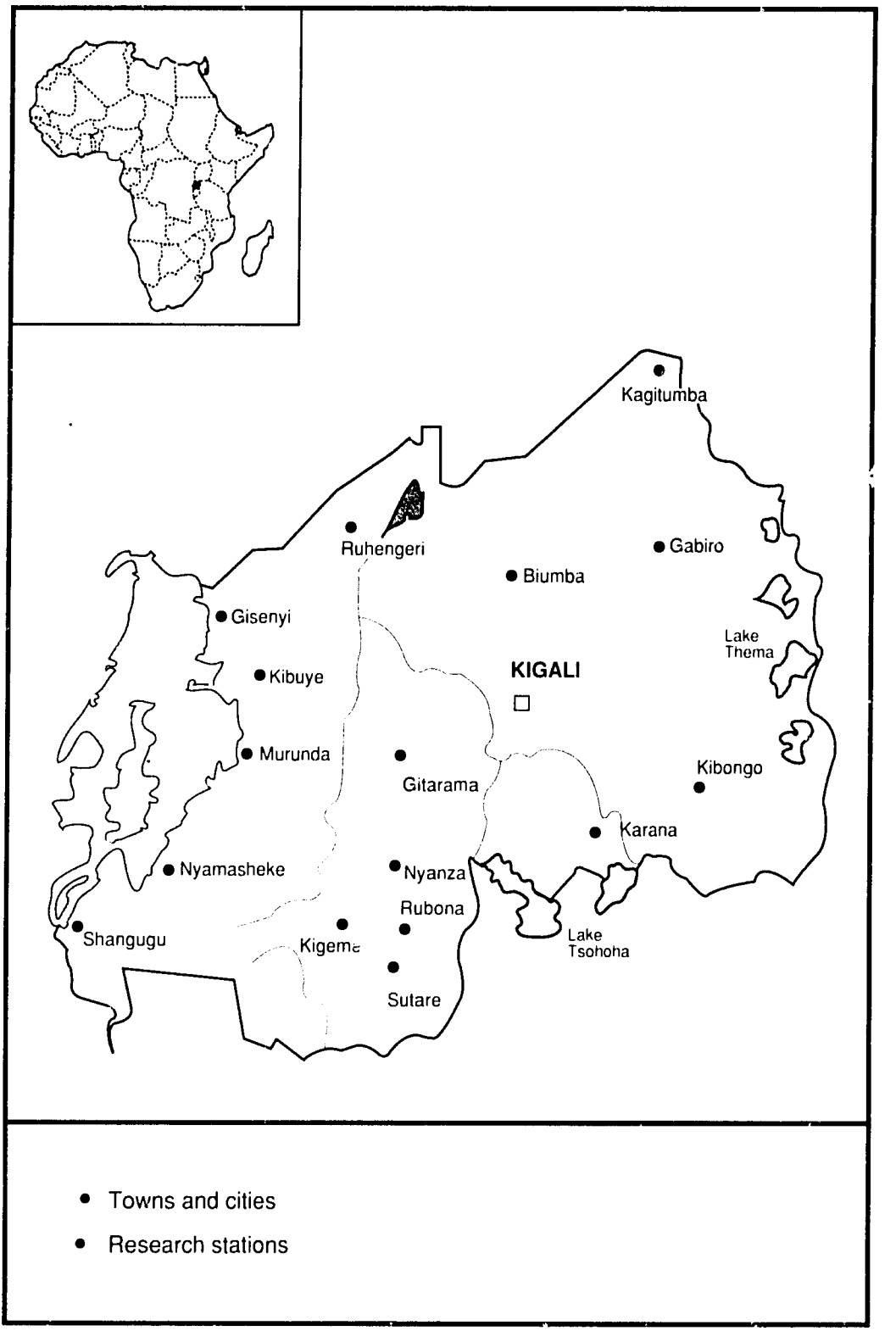


Figure 4. Cities and research stations of Rwanda

The root crops program is based at two sites (*see* Figure 4) that typify the country's major root crop growing areas. Sweet potato breeding, focused on early-maturing varieties resistant to weevils, sweet potato virus complex and *Alternaria* leaf blight, is carried out at ISAR headquarters at Rubona Research Station near Butare. Cassava breeding, aimed at high-yielding varieties that resist green spider mite and perform better at high elevations (above 1650 meters above sea level), takes place primarily at Karama Station in the drier, semi-arid part of the country. Testing of lines at various locations ensures identification of those best adapted to each area.

The research strategy encourages interaction between breeders and farmers, an orientation that the pre-1983 program lacked. As a Rwandan scientist recalls, "Before, for 4 years we would run a trial; after that we would sit down and decide what to do next." Donor support for a vehicle provided the mobility to "get down into all those valley bottoms and talk to farmers," as one researcher put it. In 1984-85, the program surveyed sweet potato and cassava producers nationwide, conducting long interviews with 72 randomly selected farmers. Women were interviewed on the processing and marketing of the crops, while men were asked about land preparation techniques and economic or other constraints to production.

"This survey really helped us to consider the farmers' needs in our research," says a Rwandan scientist. Initially, for instance, researchers did not believe farmers particularly valued early-maturing sweet potato, but the survey showed quite the reverse—so breeders identified genetic sources of earliness and began breeding for that character. Farmers rated taste as extremely important, so breeders realized that any improved variety must taste at least as good as, if not better than, the old types. The survey also documented that cassava was under widespread attack by mosaic virus, to the extent that some farmers even believed the viral symptoms to be normal characteristics of the plant.

IITA and national program scientists have done the job with farmers' feedback and cooperation

Since 1986, one researcher has been charged full-time with the on-farm testing of new varieties, and the enthusiastic welcome he receives from the farmers he visits testifies to his success. The program's scientists consider testing by farmers an integral part of research.

Besides building ties to indigenous farmers, Rwanda's scientists look beyond their national boundaries. One of the tasks of the IITA advisor in Rwanda was to establish links between IITA-trained root crops researchers in the region, so Rwanda became the first headquarters of the East and Southern Africa Root Crops Research Network (ESARRN), supported by IDRC and USAID. Now headquartered in Malawi, the network unites 15 countries in order to improve root crops research capabilities in the region. The IITA advisor, posted to Malawi after Rwanda's program had become firmly established, coordinates network activities and produces the group's bulletin. The network assists in the exchange of information and germplasm between national programs, and can help in directing research and introducing new technologies. Network scientists visit each other's programs to evaluate research progress and germplasm collections, and conduct in-country training courses. Since 1980 the network has held three regional workshops.

Reaping Research Results

Rwanda's root crop breeding program follows clearly defined, logical procedures. Early in the breeding cycle, varieties are tested at many different locations in order to select lines adapted to the country's different environments. Having identified good varieties, Rwanda is now placing great emphasis on the rapid multiplication of superior lines for quick distribution to farmers (*see* Table 6).

Research on sweet potato has produced two superior lines which are planted at Rubona Station to furnish, on a year-round basis, healthy, high-quality planting material to a network of secondary multiplication sites around the country. While farmers' unimproved varieties can take 5 to 8 months to reach maturity, the program's 10 new sweet potato varieties (*see* Table 7 for examples) mature on average in 4–5 months, allowing production of two crops (possibly even three) a year.

Seven superior cassava lines have been multiplied at both research stations, and are now being tested widely in on-farm trials (*see* Table 8 for examples). Producing up to 45 tonnes per hectare, these lines resist diseases and pests, particularly viruses and the green spider mite. Four of them are bitter, and mature in 15 to 18 months; one is adapted to lowlands and three to medium altitudes. The three sweet varieties mature in 9 to 12 months; one is adapted to lowlands and the others to medium altitudes.

The root crops program has also created an in-country network, considered a model among national programs in tropical Africa, to multiply and distribute its new varieties through collaborative links with development projects and schemes all over the country. The program cooperates with any institution or person willing to provide land for multiplication, including army bases, schools, and commercial growers.

Dissemination begins with primary multiplication of healthy planting material on the research stations. The best material is distributed to development projects for secondary multiplication, and also directly to leader farmers. ISAR conducts special courses in rapid

Table 6. Numbers of new ISAR varieties released to farmers

	Year				
	1983	1984	1985	1986	1987
Cassava	2	-	-	-	7
Sweet potato	2 late-maturing	3 late-maturing	3 early-maturing	-	-

Note: ISAR = Institut des Sciences Agronomiques du Rwanda.

Table 7. Performance of Rwanda's improved and unimproved sweet potato varieties on farmers' fields (1986-86)

Variety	Mean yield* (t/ha)	Resistance to *Alternaria* leaf blight **
Improved		
Mugande	11.3	1.7
K51	12.1	1.8
Muvatoro	13.4	1.1
Unimproved	7.0	2.3

Source: Institut des Sciences Agronomiques du Rwanda, Annual Report, 1987.
Notes: *Mean of two seasons over four locations. t/ha = tonnes per hectare.
**Scale of 1-5, where 1 = very resistant and 5 = very susceptible.

multiplication techniques for technicians from development projects. The trainees then establish multiplication nurseries in their projects, passing on material and techniques to farmers in their areas.

In 1985, root crops researchers held Rubona Station's first farmers' field day in the 30 years since the station was established. Farmers learned about new varieties and received samples of improved planting material. Field days are now a regular feature at both Rubona and Karama, attended by 100 to 200 farmers selected by development project representatives and transported to the stations in an ISAR-supplied bus (*see* Table 9). (Other ISAR programs have followed the lead, holding field days on their own crops.) The program also publishes brochures in simple language which outline procedures for multiplying cassava, yam, and sweet potato.

Possible new directions for the root crops program include strengthening the staff with more doctoral-level scientists and improving cooperative links with Rwanda's university researchers. The scientists also hope to improve maintenance of the program's sweet potato and cassava germplasm accessions. Over the years, diversity diminishes as lines

Table 8. Performance of Rwanda's improved and unimproved cassava varieties (1986-87)

Variety	Yield (t/ha)		Resistance score*	
	With ISAR agronomic practices	With farmers' practices	Cassava mosaic disease	Green spider mite
Improved				
U.Y.T. Bulk 1977/11	30.8	24.0	1.0	2.0
Creolinha	28.0	22.4	1.0	2.5
Kiryumukwe	23.5	19.8	1.0	2.5
Unimproved				
Gitamisi (sweet)	23.6	10.7	2.0	3.5
Gacyacyali (bitter)	13.6	10.0	2.5	3.5
Overall mean	23.9	19.4	1.5	2.8

Source: Institut des Sciences Agronomiques du Rwanda, Annual Report, 1987.
Notes: t/ha = tonnes per hectare.
* Scale of 1-5, where 1 = very resistant and 5 = very susceptible.

Table 9. Approximate numbers of leader farmers, extension agents, and project technicians trained in rapid multiplication techniques by ISAR

	1984	1985	1986	1987
Extension agents and project technicians	9	20	30	30
Leader farmers	50	100	100	100

maintained in the field are lost to disease—a problem that a tissue culture facility would help remedy.

On the research side, the program is focusing on developing cassava varieties resistant to mealybug. Given the 22 to 40% increase in root crop production that the program's new varieties are predicted to achieve, another new thrust will be to develop better processing techniques to handle the increased harvest.

New hopes to plant with

Rwanda's major cassava breeding site is Karama Station 1.5 hours from Kigali on a rough unpaved road, with radio communication and an irregular electricity and water supply. Despite the limited facilities, the program has made impressive progress in breeding better-yielding varieties that farmers accept. Here, the cassava breeder, just returned from an intensive course in root and tuber production at IITA in Nigeria, examines a sample of healthy cassava germplasm from IITA's tissue culture laboratory, which he will use in his work together with the seeds he brought back.

Implications for Africa

The success of root crops research in Rwanda has particular relevance for other African countries. Rwanda, with its high population density, provides a sobering picture of the conditions in store 20 years from now for other, larger African countries with fast-growing populations: fragmentation of land holdings, expansion of agriculture onto marginal lands, and severe soil erosion. Rwanda's small size has simply forced it to confront its environmental limits sooner than much of Africa.

The confrontation has been a healthy one for the state of the country's agriculture. A nationwide campaign is beginning to ensure that soil and water resources will no longer be squandered but carefully conserved at farm level. Measures to control erosion and enhance fertility include terracing, the digging of pits, and the widespread use of organic farming. Animal manure and weeds are returned to the land after composting. So far, instead of creating a disaster, the country's growing rural population has provided the necessary labor to intensify agriculture—and, most significantly, to do so without relying on large inputs of chemicals, an achievement unmatched by any of the world's developed countries. Rwanda's intensive agriculture suggests that African countries can find affordable and sustainable alternatives to the traditional extensive bush fallow system, now in decline. As regards root crops, other countries should also benefit by Rwanda's experience with sweet potato—a drought-tolerant crop that can be grown in acidic valley bottoms and on dry marginal lands with few inputs from outside and with minimal labor.

Conclusion

The challenge of feeding Africa's people is as complex as it is awesome, calling for a creative and flexible approach that enlists farmers in the development of a more sustainable agriculture. The experience of the root crops researchers of both Rwanda and Cameroon, half a continent apart, have some attractively practical lessons for neighboring nations. Backed by sustained international donor assistance through the early stages of building their programs and supported increasingly by national governments committed to improving local food crops, these scientists have forged cooperative bonds with farmers and extension personnel to create a network for developing and disseminating new varieties and growing techniques. Their research programs have used personnel from a variety of disciplines and a comprehensive system of research sites to breed crops for the diverse agroecological conditions of their countries. Both countries have also tapped the expertise of IITA to strengthen their research programs.

Farmers of some of Cameroon's most isolated plateaus and Rwanda's most densely populated valleys are now growing new varieties, which their countries' researchers have developed in order to ensure more reliable harvests.

However, still more remains to be achieved: both countries' research programs are at a delicate stage in their development. Technologies in the research pipeline will require unfaltering commitment to develop fully. Equally important, the task of multiplying new lines and distributing them to farmers is far from complete and will continue to require support, in order to fulfill the promise of more food from agricultural research.

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cover	Cameroon: H. J. Pfeiffer
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p10 (top)	Cameroon: L. Simarski
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About IITA

The goal of the International Institute of Tropical Agriculture (IITA) is to increase the productivity of key food crops and to develop sustainable agricultural systems that can replace bush fallow, or slash-and-burn, cultivation in the humid and subhumid tropics. Crop improvement programs focus on cassava, maize, plantain, cowpea, soybean, and yam. Research findings are shared through international cooperation programs, which include training, information, and germplasm exchange activities.

IITA was founded in 1967. The Federal Government of Nigeria provided a land grant of 1,000 hectares at Ibadan, for a headquarters and experimental farm site, and the Rockefeller and Ford foundations provided financial support. IITA is governed by an international board of trustees. The staff includes about 180 scientists and professionals from some 40 countries, who work at the Ibadan campus and at selected locations in many countries of sub-Saharan Africa.

IITA is one of the nonprofit, international agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR). Established in 1971, CGIAR is an association of about 50 countries, international and regional organizations, and private foundations. The World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP) are cosponsors of this effort.

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