CIAT in Focus
Crop Commitments

Cassava: A Crop for Hard Times and Modern Times

The Importance of Cassava

Cassava (*Manihot esculenta* Crantz) is a starchy root crop that has been cultivated in tropical America for more than 5,000 years. Introduced to Africa and Asia by Portuguese traders during the 16th century, it is now grown in over 90 countries and provides food and a livelihood for 500 million people in the developing world.

Cassava is planted on about 16 million hectares, with 50 percent in Africa, 30 percent in Asia, and 20 percent in Latin America. Total root production is around 152 million tons. Under favorable experimental conditions, cassava as a monocrop can yield as much as 90 tons of fresh roots per hectare. But it is usually grown in poor soils and harsh climates and in association with other crops, such as maize, beans, or cowpeas. Under these conditions average yields in tons of fresh roots per hectare are much lower: 9.6 tons worldwide; 7.7 tons in Africa; 12.7 in Latin America; and 12.9 in Asia.

Cassava is produced mainly by small farmers, who are often women heads of households, generally use traditional farming methods, and live in some of the poorest and most difficult areas of the tropics. The crop offers these farmers several major advantages. It is relatively tolerant of poor soils and seasonal drought and has an unrivaled ability to recover from damage by pests and diseases. In addition, it can be safely left in the ground for 7 months to 2 years after planting and then harvested as needed.

Once harvested, though, cassava roots spoil quickly and must be processed within 3 to 7 days to preserve their food value. The processing—cooking, grinding, drying, or fermenting, according to local custom—is also necessary to neutralize the varying amounts of cyanide produced by the plant. The processed roots are eaten in various forms: e.g., boiled, baked, fried, and as meal or flour.

Consisting of 30 to 40 percent dry matter, the root contains mostly carbohydrates, but it is also rich in vitamin C, carotenes, calcium, and potassium, though poor in protein. Cassava leaves, in contrast, contain high levels of protein, in addition to being rich in vitamins. In some parts of the world the leaves are consumed as a vegetable.

Cassava's role varies greatly in different parts of the world. In sub-Saharan Africa it is grown mainly by women and used mostly for food. There and elsewhere the crop has been important for preventing famine during times of drought and civil unrest. Moreover, since most processing of cassava into food is done on a small scale in rural areas, it is an important source of employment and income, especially for women.

In Asia and Latin America, the roots also provide raw material for small-and large-scale processing into livestock feed and starch. The starch is used in a wide variety of products, including paper, textiles, pharmaceuticals, and various foods, such as crackers, flavoring agents, noodles, and cheese breads. Though still grown chiefly by small farmers in the most marginal environments of these regions, cassava is rapidly being transformed from a traditional staple into a market-oriented commodity.

In Southeast Asia, much of the harvest is already being sold for industrial purposes through domestic and export markets, and Latin America is moving in that direction as well. In Colombia, for example, there is growing interest in producing dried cassava chips as a partial substitute for imported cereals used in animal feed. One new model for accomplishing this centers on integrated production and processing operations (termed locally *ingenios yuqueros*, or cassava mills), tied closely to poultry producers using cassava-based feed. Such trends represent valuable economic opportunities for the less-favored rural areas in which cassava is produced, and they give the private sector of Asia and Latin America a direct stake in cassava research for equitable development.

Research for Development

Challenge

The dual role of cassava in the developing world as both a food and industrial raw material presents research and development organizations that work on this crop with a dual challenge.

First, to help bolster cassava's food security role, researchers must increase and stabilize yields by developing genetic resistance to major pests and diseases (together with effective biological control strategies) and tolerance to abiotic stresses, such as drought and acid soils. Another important goal is to identify and exploit genetic mechanisms for slowing the deterioration of cassava roots after harvest. Moreover, these and other traits must be introduced into a wide variety of genotypes that satisfy the diverse tastes and preferences of the developing world's cassava consumers. These challenges are particularly urgent in sub-Saharan Africa, where rapid population growth ensures that the crop will become even more vital for achieving food security. In parts of Latin America as well, despite rapid urbanization and growth of industrial markets for cassava, the crop will continue to be a significant food source.

Second, for Asia and much of Latin America, where the image of cassava as a poor man's staple food is changing, the crop must be made more competitive in relation to other sources of starch and animal feed. This means higher cassava productivity, lower production costs, and more efficient processing. Crop improvement must help achieve these goals by placing particular emphasis on higher root yields, increased starch content and improved quality, and possibly a plant type that better lends itself to mechanized production. Such traits are essential for ensuring that cassava continues to be an important source of income for rural families in the marginal environments where cassava is produced.

Recent advances in the technology front have brought both sets of goals well within reach, as described in the sections that follow.

Genetic resources

To fulfill a key requirement for cassava improvement, CIAT researchers evaluate the genetic base of the crop and make genetic resources available to colleagues around the world. For these purposes, the Center maintains in trust for the Food and Agriculture Organization (FAO) a collection of more than 6,000 cassava accessions. It consists of landraces from Latin America and Asia, of elite clones selected by CIAT and the International Institute of Tropical Agriculture (IITA) in Nigeria, and of several wild *Manihot* species.

Safeguarding, studying, and sharing this germplasm are fundamental responsibilities implied by CIAT's global mandate for cassava research within the Consultative Group on International Agricultural Research (CGIAR). To facilitate these tasks, Center researchers have formed a core collection, which is a smaller but representative subset of the entire cassava holdings. Our scientists give high priority to screening the core collection and wild *Manihot* species for useful genetic diversity.

Cassava is propagated vegetatively by means of stem cuttings. This allows farmers and researchers to fix in cassava clones whatever gene combinations that suit their purpose. But the cuttings are bulky and difficult to transport. Moreover, since phytosanitary regulations prohibit the movement of cassava stem cuttings across international borders (to prevent the spread of diseases and insects), special arrangements have to be made for storing and transferring experimental germplasm.

Since the late 1970s, CIAT has maintained the crop *in vitro* through tissue culture procedures, in which plant cuttings are regenerated in flasks or test tubes in artificial media. This complements the maintenance of cassava clones in the field at CIAT headquarters but with the advantage that cuttings produced in tissue culture are free of disease and insect pressures. One drawback to in vitro storage, though, is that individual plantlets can be maintained for only 8 to 22 months before they have to be recycled, making this procedure more expensive than long-term cold storage of, say, bean or forage seed. Even so, *in vitro* storage is vital for more secure preservation and safe international transfer of cassava clones.

In search of alternative methods, CIAT is conducting research on cryopreservation. This involves storing germplasm in liquid nitrogen at minus 196 degrees centigrade, a temperature at which biological activity effectively stops. So far, Center researchers have found no negative effects in clones grown out after this type of storage. Nonetheless, with a view to reducing the cost of *in vitro* storage, our staff also continue experimenting with ways to slow the metabolism of the *in vitro* plantlet so that it will require less frequent regeneration, while maintaining its viability over time.

Crop improvement

CIAT has conducted cassava improvement research since the mid-1970s. The main goal of this work is to help increase and stabilize cassava production in diverse environments and for different markets by developing improved gene pools in cooperation with national programs. Other important products of this research are new knowledge and tools that increase the efficiency of conventional cassava improvement.

The most important ecosystems for gene pool development are the semiarid (less than 800 millimeters of rainfall per year), subhumid (800-1,500 millimeters), and acid-soil savanna regions (1,500-3,000 millimeters). Other ecosystems of secondary importance in terms of cassava area and production are the humid tropical lowlands, midaltitude tropics, high-altitude tropics, and subtropics.

For six of these zones (the exception being the humid tropical lowlands), CIAT cassava researchers improve a gene pool for each ecosystem. This is done through recurrent selection at sites in Colombia representing the conditions of the target environments. Elite genotypes identified in the pools are distributed to national programs and used to initiate new cycles of selection. Some selection criteria (such as yield potential and dry matter content) are applied across zones, while others (e.g., resistance to particular diseases and pests) are specific to a given ecosystem. New sources of resistance to major biotic and abiotic stresses as well as genes for desirable root quality are continuously incorporated into the pools through recombination and selection. In addition, our breeders work closely with pathologists, entomologists, and physiologists to identify the mechanisms and processes responsible for expression of key traits, with the aim of improving them more efficiently.

From 1996 to 1998, a total of about 458,00 recombinant seeds were produced by our breeding scheme, of which some 253,000 were distributed to national programs in Asia and Latin America as well as to IITA. During this period the best selected parents yielded an average of 68 percent more than the check varieties across ecosystems. A large number of materials have been selected in semiarid environments through participatory breeding and sent to IITA for use in its cassava improvement program. This germplasm represents a valuable addition to the crop's genetic base in Africa.

Listed below are some of the main achievements of CIAT's collaborative research on cassava improvement:

- High-yielding germplasm has been developed that is specially suited to industrial requirements
- Genotypes with high levels of resistance to bacterial blight and super-elongation disease as well as good agronomic performance have been selected in eastern Colombia.
- Sources of resistance to different races of bacterial blight have been identified.
- Genotypes with high levels of resistance to various root rot pathogens have been identified and are being crossed to "pyramid" the resistance genes.
- Resistance to whiteflies has been detected and is being combined with desirable agronomic traits.
- Sources of resistance to green mites have proved stable across sites.
- Analysis of cassava roots and leaves for micronutrients has shown good potential for increasing levels of vitamins and minerals in the roots and leaves.
- Genotypes showing prolonged storability have been selected and are being crossed for use in the breeding program.

Biotechnology

Cassava improvement is complicated by the crop's long growth cycle, its heterozygous nature, and a lack of precise knowledge about its complex genetic structure. In an effort to reduce these barriers, CIAT scientists are developing various applications for new biotechnology tools. One promising avenue is genetic transformation to increase crop diversity through the insertion of genes for key traits into elite varieties. A more immediate possibility involves the use of molecular markers to improve the efficiency of field testing and selection for traits controlled by multiple genes.

In an important step toward this end, CIAT scientists have developed a molecular genetic map of cassava—the first such map ever to be generated for a major food crop outside the industrialized world. Preliminary analysis of qualitative trait loci (QTL) has revealed regions of the cassava genome that account for much of the phenotypic variance for key traits, such as reduced postharvest deterioration of roots, increased dry matter content, and resistance to cassava bacterial blight.

The next step, now under way, is to develop a more highly saturated map that will provide a basis for molecular tagging of genes controlling key traits and for marker-assisted selection. The effectiveness of these procedures will depend on our success in adapting and applying methods for molecular characterization of cassava germplasm. It is particularly important that we be able to identify markers for genes involved in important metabolic processes, such as postharvest deterioration of cassava roots.

Our goal is to make molecular characterization techniques into practical breeders tools for genetic improvement. Initially, our scientists will use these techniques to deal with traits (such as African cassava mosaic virus) for which they cannot select effectively at sites in Colombia. Once marker-assisted selection has proven effective at that level, it can be incorporated into the routine selection of progenies for recurrent selection.

Partnerships

The research initiatives and achievements described above have given rise to an intricate fabric of collaborative relationships involving international centers, national programs, farmer organizations, and private companies. Their joint labors have gone far toward reversing previous neglect of a crop on which nearly one out of every 10 people in the entire world depends.

International institutions

As mentioned previously, CIAT has a global mandate for cassava within the CGIAR system. The Center serves African producers primarily through cooperation with IITA, which has a regional mandate for research on this crop.

In work on cassava pests and diseases, CIAT scientists also work closely with colleagues from the French Institute of Research for Development (IRD), some of whom are based at Center headquarters in Colombia. This and other institutions, together with the UN's Food and Agriculture Organization (FAO), have recently developed a global strategy for cassava development under the auspices of the International Fund for Agricultural Development (IFAD).

Networks and national programs

CIAT has played an active role in cassava research networks and has formed especially close ties with the few developing countries that possess strong cassava improvement programs. For example, collaboration with the Colombian Corporation for Agricultural Research (CORPOICA) and the Brazilian Agricultural Research Enterprise (Embrapa) has led to the development of an approach to participatory cassava breeding, which is relevant to many other cassava-producing countries.

In Asia CIAT has supported cassava development through a regional network, which has greatly increased the exchange of improved germplasm and other research products, contributing to impressive developments in some countries, notably Thailand, Vietnam, and Indonesia. Thailand's Food Crops Research Institute (FCRI) has shown a special commitment to collaborative development of cassava germplasm. Other programs in the region, including the Chinese Academy of Tropical Agricultural Sciences (CATAS) and Vietnam's Institute of Agricultural Science (IAS), are making rapid advances as well.

To realize the tremendous promise of biotechnology for cassava improvement, CIAT helped found the Cassava Biotechnology Network (CBN) in 1988. It links advanced research institutions and widely dispersed national or regional programs with each other and with producers and consumers. CBN includes about 300 cassava biotechnology researchers, of whom two-thirds are in developing countries. The Network has three main objectives: 1) integrating the needs of cassava farmers, processors, and consumers into biotechnology research priorities; 2) fostering research linkages around high priority topics, and 3) exchange of information and genetic materials.

A new model for collaboration

In 1999 representatives from private and public institutions in Bolivia, Colombia, Cuba, Ecuador, and Venezuela signed into existence a new, self-financing consortium that will boost research for cassava development throughout Latin America. This is the Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA), of which CIAT and France's Center for International Cooperation in Agricultural Research for Development (CIRAD) are also founding members. Each national member of the consortium will contribute a yearly quota, based on the country's annual production of the crop. Member organizations (which include associations of industries using cassava as well as research institutes) will define a common agenda for the regional research and development activities they jointly finance.

Industrialized country institutions

One way in which CIAT supports its national partners is to bring expertise available in industrialized countries to bear on the challenges of cassava research for the developing world. For example, in work supported by the University of Uppsala in Sweden, Center scientists and their research partners in Sweden and several African countries are using molecular marker techniques to quantify the genetic diversity of cassava in Africa. They will then compare this with the diversity of cassava's wild progenitors and of the domesticated crop in its South American center of origin to determine the scope for broadening the genetic base of cassava in Africa. Similarly, CIAT researchers are working with the University of Bath in the UK on the problem of physiological deterioration in cassava and with the University of Adelaide in Australia on analysis of cassava's micronutrient content.

Impact

Twenty-five years after cassava breeding was begun at CIAT, few well-designed studies have been conducted to measure the impact of variety adoption. But the information available does allow us to make safe estimates, which suggest that the impact has been considerable.

Since 1970, the national programs of 14 countries in Asia and Latin America have released 62 new varieties based on improved germplasm from CIAT. Our estimates show that in 1998 about 659,000 hectares were planted to new varieties in Asia and 133,000 hectares in Latin America and the Caribbean. Good estimates of variety adoption are available for sub-Saharan Africa as well, but it is not clear how much of the germplasm in these varieties came from CIAT.

The cumulative value of the increased production derived from new varieties is estimated in 1990 US dollars at more than $432 million in Asia and $81 million in Latin America and the Caribbean. These gains are the result of increased yield and in Asia of higher starch content as well. The economic impact of new germplasm has been greatest in Thailand, where 52 percent of the cassava areas is planted to CIAT-related varieties and increased production is valued at $391 million. In Latin America the biggest beneficiaries have been Haiti ($33 million), Brazil ($17 million), and Cuba ($11 million). The internal rate of return to cassava improvement at CIAT is estimated at 12 percent for Latin America and 75 percent for Asia.