Tropical root crops

Several plant species are important major food sources for the inhabitants of the tropical lowlands. Of these, the root and tuber producing species are the major source of energy in the form of carbohydrates. In this group of species the most important are: cassava *(Manihot esculenta* Crantz); sweet potato *(Ipomoea batatas* (L) Poir); yams (several species of *Dioscorea*); taro *(Colocasia esculenta* L. Schott); tania (several species of *Xanthosoma);* arracacha *(Arracacia xanthorhiza* Bank) and arrow-root (*Maranta arundinacea* L.). There are at least 28 botanical families, with species that produce roots, tubers, rhizomes or corms that are used for food or feed in the tropics. Cassava is probably the most widely cultivated starch-producing species in the lowland tropics of the world.

Research to improve these species and to develop efficient production systems has been extremely limited and has mostly been focused on the description of the origin, history and geographical distribution, with minor attention to botany, agronomic practices, plant protection, genetic improvement and utilization.

The Tropical Root Crops program of CIAT will study in depth the problems that limit production in the most important starch-producing species and will focus research on cassava, sweet potatoes, yams and probably taro with the idèa of understanding their limitations and potentials, and to try to develop improved varieties with higher nutritive value and the efficient agronomic practices required to raise yields subtantially.

CIAT's initial efforts concentrate on cassava and, as the program develops and more facilities become available, work will be started with other starch species.

Cassava

This plant, also known as manioc, mandioca, guacamote and yuca, is one of the major sources of carbohydrates for the inhabitants of the lowland tropics in the Western Hemisphere and Africa. Its present day distribution is worldwide in frost free latitudes, between 30° North and 30° South, at elevations ranging from sea level to 1,800 meters.

Cassava production

Production statistics are inaccurate as a large portion of the crop is consumed locally and does not enter the market. In Colombia, during 1967, cassava was produced on 150,000 hectares with a total production of 885,000 metric tons giving an average of 5.9 tons per hectare. Data available from FAO indicates that 83.2 million tons of roots were produced on 9 million hectares in 1964 giving an average of 9.2 ton/ha. Africa is the world's largest regional producer, while, individually Brazil produces more cassava than any other country.

Cassava is often described as a back-yard crop. Large acreages are seldom grown on a farm. In general, small plots are planted for the support of the family. However, there are areas in Brazil and Thailand, where the crop is grown to provide both for local requirements and as a cash-crop export to the temperate zones. It is cultivated in pure stands or in multiple cropping schemes with corn, bananas, yams and sweet potatoes.

Yields and nutritional value

As an unprocessed food, cassava roots are boiled or fried, or consumed as crude flour. Commercial products that can be derived from cassava include starch for paper sizing, laundry starch, adhesives and tapioca. Fresh or dried roots are used as animal feed.

Cassava is considered a prodigious producer. Although the world average is 9.2 ton/ha, some producing countries such as Brazil, Thailand, Cambodia and Bolivia, have national averages ranging from 14 to 18 ton/ha.

Where cassava is well tended as a plantation crop for commercial use, average yields of 24 ton/ha are common and yields of 50 to 100 ton/ha have been reported from individual plantings. One cultivar, Llanera, collected in the Eastern Plains (Llanos) of Colombia by ICA, has yielded more than 100 ton/ha in rich black soils in a 10-month period.

Cassava is a long-term crop, taking from 10 to 18 months or longer from planting to harvest. It contains 30 to 40 percent dry matter. Roots contain a relatively small amount of protein (usually, 0.5 to 1.5 percent) and minimal percentages of fat, vitamins and minerals. Analyses of 87 cultivars have shown the possibility of finding clones with a higher protein level. One of the collected cultivars contained 7.25 percent protein, (based on N^2 x 6.25 calculations, with zero percent moisture content). However, a portion of the total nitrogen present in cassava may be non-protein nitrogen of low nutritive value for single stomach animals. Amino acid content is similar to that of corn, methionine being low and threonine twice as high as in corn.

Cassava leaves are rich in protein. One survey of varieties showed a range of 3.7 to 10.7 percent protein on a fresh weight basis and of 21 to 36 percent on a dry weight basis. Essential amino acids are well represented, having a deficiency only in methionine. Lysine content of 5.6 to 8 percent is acceptable.

There are toxic and non-toxic cassava varieties. Toxicity results from the presence of hydrocyanic acid (HCN) which is derived from linamarin, a glucoside. Another glucoside, lotaustralin, can be present also in minute amounts. Sweet or non-toxic varieties have a content of less than 50 mg of HCN per kilogram of fresh roots, while bitter, toxic types have well over 100 mg per kilogram of fresh roots.

Varietal improvement

Cassava has been largely overlooked by research workers in temperate climate countries. No tropical country, where the crop is grown in large quantities, has organized and maintained an improvement program of satisfactory scope and duration to produce significant results.

The genus *Manihot* has probably some 150 to 200 species, all native to the new world. Although, it is likely that the majority of these so-called species would be cultivars rather than distinct species. Several experiment stations have collected and do maintain varieties of the cultivated species, *M. esculenta*. At present, fairly large collections are located in Brazil, Malagasy Republic, Uganda, Congo, Colombia and India. However, it appears that most workers have not gone beyond the evaluation of their collections and multiplied and distributed their better materials.

Hybridizations within the cultivated species and inter-specific crosses have been rarely attempted. For example, during the period 1932-1942, efforts were made in Java to increase root protein content through intra-specific crosses between *M. esculenta* and *M. saxicola*. Some resulting clones initially contained more than 2 percent protein but these were reported to regress to normal levels (0.8 to 1.5 percent) after continued propagation. It was concluded that there was little chance to increase protein content through selection following hybridization. In view of the considerably higher protein content observed in cassava collected in the Colombian Llanos, it would seem worthwhile to repeat this work. Moreover, former yuca research workers report that individual protein analyses have reached 9 percent or more in related *Manihot* species.

A more succesful breeding project has been reported from the Malagasy Republic where workers sought resistance to mosaic, a serious virus disease. Numerous partially controlled pollinizations resulted in 15,000 to 20,000 seedlings per year. These were screened for mosaic resistance and starch content. The resulting varieties were claimed to be resistant to mosaic, to show increased adaptability to low fertility soils and to have increased yields from 12 to 30 ton/ha.

Agronomic practices

Actually, very little is known about the value of improved cultural practices in relation to varietal types. Cassava supposedly responds in yield to applications of P_2O_5 and K_2O, but there is a possibility that this is more closely related to native soil fertility than to a fertilizer-variety interaction.

Nearly all reports stress the fact that applications of nitrogen fertilizers do not increase cassava root yields. All workers agree that stem and leaf weight show a positive response to nitrogen. Furthermore, limited spacing studies indicate that optimum spacing, on low fertility soils, is closer than that on soils with normal fertility. This fact combined with the general unresponsiveness in root production to applied nitrogen would suggest that the fertilizer response is impeded by mutual shading resulting from excessive vegetative development.

Cassava diseases

The lack of attention to cassava diseases is illustrated by the observation that, in 1966, *The Review of Applied Mycology* published two references to cassava diseases, 17 to carnation diseases and 234 references to research on tobacco diseases.

In general, the literature implies that diseases and pests are not important on cassava, although sound information on disease and pest losses is scarce. Mosaic, one the three of four known virus diseases of cassava, was estimated in 1956 to have caused an 11 percent loss in the British African colonies. Fields with 100 percent mosaic infection yielded one ton or less per hectare.

Strategy to improve cassava production

Cassava has a great potential as a major food and feed source and as raw material for industry in the tropical lowlands. The development of this potential merits a strong research effort.

CIAT has established the following goals in order to develop economic production systems for increasing food production in the tropics. These goals are:

a) To explore and collect cultivars and related wild species of *Manihot* in the countries where variability is present, with emphasis in the primary centers of origin (Northern South America and Middle America), in order to establish a germ plasm bank representative of the world's variability.

b) To classify and evaluate the genetic variability of the collected material as a basis for future work. The germ plasm bank will constitute a reservoir of breeding material available to researchers throughout the world for the improvement of this important tropical crop.

c) To identify superior cultivars that can raise present yield substantially.

d) To find production systems that maximize the efficiency of planting methods; control of pests, diseases and weeds; adequate fertilizer application and harvesting procedures.

e) To develop more practical and efficient systems of drying and using cassava as human food, animal feed and for industrial use, with emphasis in economic mechanization schemes that can be used by small or large growers.

f) To obtain superior varieties through plant breeding with higher yield capacity, increased starch and protein content and nutritional quality of the roots; with resistance to diseases (particularly, mosaic) and adapted to cultivation in heavy soils, and with levels of HCN content in accordance with the final use of the roots (food, feed or industry).

g) To provide practical training in varietal collection, evaluation, improvement and testing as well as in crop production methodology and in plant protection, to young scientists from major cassava producing areas.

h) To exchange information, materials and scientists with other national and international institutions concerned with the improvement of cassava throughout the world.

Research activities

Collection of cassava material

In May 1969, CIAT started a systematic collection of genetically diverse cassava materials present in Colombia. CIAT obtained the cooperation of the Secretaria de Desarrollo y Fomento del Valle, this organization appointing the Director of the Cauca Valley Botanical Garden to work with CIAT in the collection procedure.

A general collection plan was prepared and a special form designed for this purpose. One CIAT trainee and a botanist of ICA were trained in collection techniques. Through the efforts of the collection team, a total of 611 cultivars of cassava were collected in 20 Departments of Colombia. All materials collected were planted at CIAT's farm and an intensive program of observation and data gathering has been underway since. Information is being obtained on sprouting, branching, growth patterns, foliar characteristics and other morphological characters to be used later for classification purposes. The collection of cassava cultivars will be actively continued during 1970 and initiated in other tropical countries in Latin America, in cooperation with national programs and organizations.

Plant Protection

Aware of the importance and dangers represented by pests and diseases, particularly those caused by virus, when conducting plant introduction schemes, CIAT initiated a cooperative project with the plant pathologists of ICA.

The Plant Protection program was designed to develop an efficient plant quarantine scheme that will insure the prevention of introducing contaminated materials into Colombia. It has been agreed that introductions from foreign countries will be quarantined by ICA, in an insect free and especially adapted greenhouse at the Tibaitata station. CIAT, in cooperation with ICA, is training a young agronomist in the techniques of plant quarantine.

The success of an initial breeding program is based upon the genetic variation available to the breeder. The first step, therefore, should be the establishment of a germ plasm bank. The introduction of genetic material of cassava, which is vegetatively propagated, brings the danger of the importation of pests and diseases, particularly of viruses not present in the host country. To prevent this possibility, several experiments were designed to find a suitable way to inactivate viruses without severely damaging the buds of the cuttings.

Hot-air and hot-water treatments were applied to cuttings 20 cm long. The hot-air temperatures included from 50 to 56°C, at 2°C intervals, for 8 hours. Thirty percent of the cuttings germinated at 50°C but not at temperatures beyond 52°C.

It was concluded that cuttings could be treated safely at 52°C for 20 min, as well as at 50°C for 60 min, with hot water. Although virus or virusses, mycoplasma-like organisms and bacteria may be inactivated by this treatment, it will be necessary to repeat it to insure a complete virus-free stock. After the treatment the cuttings must be protected with a fungicide to avoid root-rots and stem-rots during germination.

The introduction and storage of large quantities of cuttings may bring about a problem of germination and decay. To gain some experience on this matter, studies are underway to determine the best conditions for long storage periods which include different temperatures, chemical treatments and wax protection.

Attempts are being made to identify and characterize a bacterial disease of cassava present in the northern part of Colombia.

Multiple cropping

A multiple cropping experiment with cassava was started in November 1969. The purpose of this program is to evaluate the possibility of growing a relatively short season crop, like soybeans or corn, during the initial establishment phase of the cassava plants. Soybeans or corn were planted between the cassava rows. Both crops were planted at the same time. To allow comparison, cassava was also interplanted between and within soybean rows which had been planted about 45 days earlier.