Cassava

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Cassava (*Manihot esculenta* Crantz) is one of the most important calorie-producing crops in the tropics. It is called *mandioca* (Brazil, Paraguay, and Argentina), *yuca* (other Spanish-speaking countries), * tapioca* (Asia), and *manioc* (French-speaking Africa). Cassava originated in Latin America and has probably completed the major part of its diversification there (Leon, 1976).

The crop accounts for 59% of tropical root and tuber production (FAO, 1976). Its production is fairly well distributed among the tropical zones of America, Africa, and Asia. Approximately 300 million people in the tropics depend on cassava as a major source of their calorie intake (Nestel, 1973). Aside from human consumption, cassava has important uses as animal feed and for starch and alcohol production.

I. PARENTAL MATERIAL

All cultivated cassava belong to the species *Manihot esculenta* in the family *Euphorbiaceae*. The species is considered allotetraploid with 36 chromosomes that form 18 bivalents at meiosis (Umanah and Hartmann, 1973). The genus *Manihot* contains more than 100 species (Viegas, 1937).

Limited research has been done on the genetic and evolutionary inter-
relationship among these species. Only few wild species within the genus, for example, *M. glaziovii*, *M. saxicola*, *M. melanobasis*, *M. catingae*, and *M. dichotoma*, have been used in hybridization with cultivated cassava. Among these, *M. glaziovii* has produced outstanding results in introducing resistance to cassava mosaic disease (Jennings, 1970).

There is great germplasm variability within *M. esculenta* for several agronomically important characters such as root yield, harvest index, root dry matter content, HCN content, and root perishability after harvest.
(CIAT, 1973, 1974, 1975, 1976). Resistances to some of the major diseases and insects such as cassava bacterial blight (*Xanthomonas manihotis*), *Cercospora* leaf spot, *Phoma* leaf spot, and thrips have been identified (CIAT, 1975). The total germplasm variation within the species is far from being fully exploited. Presently, the major part of cassava hybridization is being done within the species.

Small germplasm collections are scattered among many tropical countries, but the collection at the Centro Internacional de Agricultura Tropical (CIAT) is the only one on an international scale. It has approximately 2,400 accessions collected throughout Latin America. The CIAT germplasm unit is helping to establish a large collection in Brasilia, Brazil. A good duplication of the CIAT germplasm is being established at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, in addition to native African germplasm.

**II. PLANT CULTURE**

**A. Field**

Cassava is successfully grown between 30° N Lat and 30° S Lat, from sea level to about 2,000 m, under annual precipitation regimes from 600 to 6,000 mm, and with a soil pH between 3.8 and 8.0. The species tolerates hot climates, but does not do well when daily average temperatures drop below 18 C. Commercial cassava production uses stem cuttings, and the roots are harvested between 8 and 18 mo after planting.

No systematic study has been conducted on the effect of environmental factors on flowering and seed set. Many genotypes flower reasonably well under a wide range of environmental conditions. The plants seldom bear receptive flowers during the first 6 mo. For tropical conditions, the majority of cassava cultivars flower from 8 to 16 mo after planting. Several cultivars have never flowered in 2 years of being in the field.

Flowering is rare during a long dry season, so that irrigation of the pollination field during the dry season is important. Large spacing between plants seems to give the plants a better chance to flower. Hand pollination is extremely difficult when cassava is planted at a commercial production spacing of 1 by 1 m; therefore, a planting distance of more than 1 by 2 m, is recommended.

**B. Growth Chamber and Greenhouse**

There is no information on the production of cassava in a growth chamber or greenhouse. A cassava plant, ready for pollinations, usually occupies more than 2 m² of area and is 2 m tall. Thus, considerable greenhouse space would be required.
III. FLORAL CHARACTERISTICS

A flower bud is formed every time the plant branches, however, most of the flower buds formed during early growth stages are abortive. Flowers cannot be obtained from nonbranching types. Cassava is monoecious. On a given branch, female flowers always open first and the male flowers follow after 1 or 2 weeks.

Both self and cross-pollinations occur naturally in cassava. There seems to be no physiological or genetic mechanism to prevent self-fertilization in normally flowering types. No cross-incompatibility has been found so far. The pollen are relatively large in size and sticky, therefore, natural pollination by wind is unlikely. Several species of wasps (mainly Polistes spp) and bees are the main pollinators in Colombia and West Africa, respectively (Hahn, personal communication).

Self-pollination varies between 0 and 100%, depending upon the genotypes and planting distance (CIAT, 1974). A distance of 30 m between pure stands of different genotypes was sufficient to prevent cross-pollination between two populations (CIAT, 1974). However, 500 m is suggested for a perfect isolation of two populations in genetic studies.

IV. ARTIFICIAL HYBRIDIZATION AND SELF-POLLINATION

A. Equipment

Large cloth bags measuring 20 by 25 cm are used to protect flowers from undesired pollen. Small cloth bags measuring 10 by 18 cm are used to catch matured seeds. The bags can be made of any cotton cloth of 60 to 80 mesh, and should have a string attached to close the mouth of the bag on the plant. Tags of 3 by 4 cm are used to identify pollinated flowers. Bottles of 3 to 5 cm in diameter and 5 to 8 cm high are used to transport male flowers during pollination.

B. Preparation of the Female

After a little experience, the breeder can determine with relative ease in the morning which particular female flower will open that day (Fig. 1). The surest way to distinguish them is to open one petal of an unopened female flower in the morning. If a drop of nectar is seen on the basal part of the pistil, the flower will open in the afternoon of the same day (Fig. 2).

Emasculation is not usually needed because female and male flowers are separate. Male flowers open 1 to 2 weeks after the female flowers opened within the same inflorescence. By the time male flowers open, the female flowers of the same inflorescence have developed into fruits or have died.
Fig. 1—Female flowers of cassava that will open in the afternoon of the same day. The pistil is enclosed within the corolla.

Fig. 2—A drop of nectar in the female flower is the surest indication that the flower will open shortly.
Female and male flowers usually begin to open from 1200 to 1400 hours and remain open for about 1 day (Fig. 3 and 4). To prevent stray pollinations, the flower branches are covered by large cloth bags which also identify the female flowers to be pollinated during the day (Fig. 5).

C. Pollination

Recently opened male flowers are picked off the branch during the first hours of the afternoon and carried in small bottles. Pollination can be done most efficiently between 1300 and 1700 hours. Because both female and male flowers are large and the pollen is sticky, pollination is easy and requires no special tool (Fig. 6). One male flower can be used for the pollination of three female flowers.

After pollination, the female flowers can be covered with a large bag or left exposed. Success rate is higher if the female flowers are left exposed after pollination in some genotypes. The possibility of hybridization by stray pollen seems to be very low once the stigma is pollinated, even if the female flowers are left exposed after pollination. Each flower branch on which the pollination is made is marked with a tag indicating the cross combination, date of pollination, and number of female flowers pollinated.

If the female flowers are exposed after pollination, they must be covered with a small bag 1 or 2 weeks after pollination. By this time the pollinated female flowers will have developed into young fruits. The bag protects young fruits from fruit fly attack and catches mature seeds which fall off naturally about 3 mo after pollination.

One female flower can produce up to three seeds, however, it is difficult to obtain an average of 2.0 seeds per female flower. In 1973 when the cassava hybridization was started at CIAT, an average of 0.60 seeds per female flower was obtained. In 1977, it was improved to 1.39 seeds per female flower (32,000 hybrid seeds obtained from 23,000 female flowers pollinated). Selection of a good female parent is one of the most significant reasons for this improvement. About 150 female flowers can be hand-pollinated daily by one person.

Cassava is a highly heterozygous species and has extremely high inbreeding depression (CIAT, 1974). After one cycle of selfing, some plants are so weak that they cannot produce enough male and female flowers for further hybridization. Thus, selfing is not a major part of hybridization programs in cassava.

D. Factors Affecting Efficiency

Matching flowering dates of genotypes to be hybridized may be a problem. Flowering on a single plant usually lasts for more than 2 mo, therefore, planting parental genotypes every 2 or 3 mo is a practical solution. Male flowers usually outnumber female flowers, which frequently make the number of female flowers available for pollination a limiting factor for mass production of hybrid seeds. In practice, genotypes to be used as female parents are planted in larger numbers and at more planting dates.
Fig. 3—Open female flowers at the stage for pollination. The multibranched stigma is in the center of the flower.

Fig. 4—Male flower with pollen on the anthers.
Fig. 5—Branches with female flowers to be pollinated on the same day are covered with a cloth bag in the morning.

Fig. 6—Pollination is easy and requires no special tool.
Fig. 7.—Within a week after pollination, the female flower develops into a round-shaped fruit which contains up to three seeds and reaches full size in another 2 weeks.

The stigma remains receptive for up to 24 hours and dried pollen remains viable for 6 days. Eight to 19 hours are required for fertilization to occur (Chandratna and Nanayakkara, 1948). It is easiest and probably most efficient to pollinate female flowers that have just opened with pollen taken from male flowers that have recently opened. Pollen taken from a normally developed male flower is highly effective, regardless of genotype. On the other hand, genotypes differ significantly in their ability as female parents in terms of number of seeds set per female flower. A good genotype can give an average of up to two seeds per female flower pollinated, while some poor ones never give more than 0.4 seeds per female flower. Selection of highly fertile genotypes as female parents is a critical factor.

V. NATURAL HYBRIDIZATION

When a cassava breeder chooses natural hybridization as a major tool of his hybridization work, male-sterile genotypes should be used. Two types of male-sterility are common in cassava. In one type, male flowers drop before they reach maturity. In the other, male flowers fully develop, but the anthers do not contain pollen. Populations derived from natural pollinations of male-fertile genotypes include a higher proportion of inferior plants (presumably the result of selfing) than populations derived from natural pollination of male-sterile genotypes.
VI. SEED DEVELOPMENT, HARVEST, AND STORAGE

Within a week after pollination, the female flower develops into a round-shaped fruit containing up to three seeds and reaches full size in 2 weeks (Fig. 7). About 3 months after pollination, the fruits crack and the mature seeds can be harvested.

Newly harvested seeds demonstrate a tendency for dormancy. When seeds are stored at about 24 C, acceptably high germination is obtained 3 to 12 months after harvest. When seeds are kept at room temperature for more than 2 years, germination percentage drops drastically. When seeds are stored at 5 C and 60% relative humidity, no germination loss occurs in 3 years (IITA, 1976).

REFERENCES

Viegas, A. P. 1937. Estudos sobre a Mandioca. Instituto Agronomico do Estado de Sao Paulo, Brazil.