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CIAT CASSAVA GERMPLASM AND ITS USE IN ASIAN NATIONAL BREEDING PROGRAMMES

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INTRODUCTION

Cassava *(Manihot esculenta* Crantz) originated and completed the major part of its evolution in Latin America. It appears to have been developed as a crop simultaneously in various parts of the Americas, from Brazil to Mexico. This multi-centric origin, combined with the highly diverse ecological regions of South and Meso-America, has contributed to the very wide diversity of cassava germplasm in the western hemisphere. Cassava was widely distributed throughout the lowland tropics of the western hemisphere before the arrival of the Europeans in the 15th century, but did not exist outside the New World. However, in the post-Colombian era, the crop spread rapidly, first to Africa and later to Asia.

Presently cassava is a major calorie source in the tropics of Latin America, Africa and Asia, produced on approximately 13.9 million hectares, with annual average world-wide yield of about 8.8 tons/hectare (FAO Production Yearbook 34). Each of Africa and Asia produces nearly 40% of the world total productions. It is especially important as a low cost calorie source among the lowest income groups.

Because cassava is primarily a crop of small farmers, little effort has been directed to improving its productivity until recently. In the last decade, several national cassava research programes and two International Agricultural Research Centers (CIAT and IITA) have dedicated considerable effort toward developing a technology for increased production.

One of the basic functions of CIAT's cassava programme is to provide useful germplasm for national programs all over the world. Useful germplasm may be finished cultivars or materials for breeding and selection. The goal of varietal improvement at CIAT is to provide cassava genotypes that give high, stable and economically valid yield, using cultural practices that are within the reach of farmers of major cassava growing areas.

This paper discusses the particular role of germplasm in increasing cassava productivity, and especially CIAT's role through germplasm collection, evaluation, breeding and international exchange.

GERMPLASM COLLECTION AND CONSERVATION

The first large scale systematic collections of cassava at the international level were undertaken by CIAT in 1969. The present collection consists of more than 3,600 accessions from 18 countries (Table 1). Nearly all the accessions are, or at one time were, cultivars grown by farmers. Many national programs also maintain collections; among the largest are Brazil, Venezuela, Peru and Mexico. In spite of efforts already made in accumulating available germplasm into organized collections, considerable diversity apparently remains untapped. The International Board for Plant Genetic Resources (IBPGR) has made cassava a high priority crop for further collection, and recently convened a workshop to define collection priorities.

Since all cassava clones are apparently heterozygous; the only means by which the peculiar gene combinations can be preserved is through vegetative propagation. Collections have traditionally been maintained as field-grown plantings with periodic renewal through vegetative propagation by stem cuttings. Field maintenance, however, is costly in terms of land and labour, and a high risk in terms of disease and insect outbreaks. *In vitro* methods for cassava maintenance as plantlets grown in sterile nutrient medium in test tubes have recently been developed, and are now operational in CIAT. However, both the field and laboratory collections will be maintained as a security measure against any losses of valuable genetic material.

TABLE 1. ORIGIN OF ACCESSIONS IN CIAT'S CASSAVA GERMPLASM COLLECTION

Country of origin	Number of accessions
Argentina	16
Bolivia	3
Brazil	818
Colombia	1596
Costa Rica	131
Cuba	74
Dominican Republic	5
Ecuador	118
Guatemala	90
Malaysia	3
Mexico	64
Panama	39
Paraguay	102
Peru	247
Philippines	2
Puerto Rico	15
Thailand	1
Venezuela	242
CIAT hybrids	114
TOTAL	3680

GERMPLASM EVALUATION

Variability is the essential basis for genetic improvement of any crop. The major source of diversity for most crop breeding programs is still the pool of genes available in cultivars evolved over centuries of farmer's selection. In this respect, cassava has a very rich background. The diversity of conditions under which selection occurred (both natural and farmer's selection) produced a concommitant diversity of nearly any imaginable characteristic in cassava, including morphological traits, root yield and quality, disease and insect resistances and others.

Systematic evaluation of germplasm is a necessary prerequisite to developing a breeding strategy. Methodology of evaluation will depend upon conditions available for evaluation and ultimate goals of a programme. Since CIAT has a world-wide responsibility for production of cassava technology, with emphasis in Latin America and Asia, we must work toward technology adapted to very diverse conditions. Rather than attempting the impossible task of developing individual clones adapted across all edapho-climatic conditions, CIAT has subdivided cassava growing regions into six basic zones. These zones are differentiated principally on the basis of climatic and soil factor which appear to strongly influence the basic physiological adaptation of a clone. In turn, climatic and soil factors largely determine the disease and pest complexes of actual or potential importance. This definition of edapho-climatic zones is a preliminary one, and is being refined as more precise climatological and physiological data become available.

The strategy for evaluation of agronomic performance has been to identify sites within Colombia which appear to be representative of present and potential cassava-growing regions world wide, in terms of climatic and soil conditions and pest complexes. As a geographically diverse country, Colombia offers a very wide range of edapho-climatic conditions. Sites have been identified to represent five of the six zones. Only a subtropical region with low winter temperatures and fluctuating daylengths is lacking in Colombia.

The germplasm accessions are evaluated in all the edapho-climatic zones in Colombia. Growth and resistance data are taken throughout the growing cycle, but heavy emphasis is given to root yield and quality at the end of the season as an intergrated measure of the adaptability of the accession. Best clones continue through subsequent evaluation stages for the purpose of identifying the best adapted and most stable genotypes. The most important objective of multilocation testing is to identify parents which can contribute desirable traits in hybridization.

Results of germplasm evaluation were extensively reported by Kawano, *et al.* (1978a) and in CIAT Annual Reports. In summary, many germplasm accessions seem to be well adapted to traditional cultural practices in the areas where they evolved in balance with the biotic and abiotic factors of the ecosystem. Yield potential is generally low, and is expressed particularly as a low harvest index, i.e., an excessive top growth relative to root yield. The frequency of accessions with a high level of resistance to any given disease or insect of importance is generally low. Apparently in the evolution of cassava other factors such as cultural practices and isolation of plantings were equally important to genetic resistance in controlling pests. In order to achieve higher productivity under improved cultural practices, cassava must be improved for yield potential, disease and insect resistance and root quality. Thus, the CIAT cassava program's emphasis is on creating new improved genotypes through hybridization and selection.

IMPROVEMENT OF CASSAVA THROUGH BREEDING

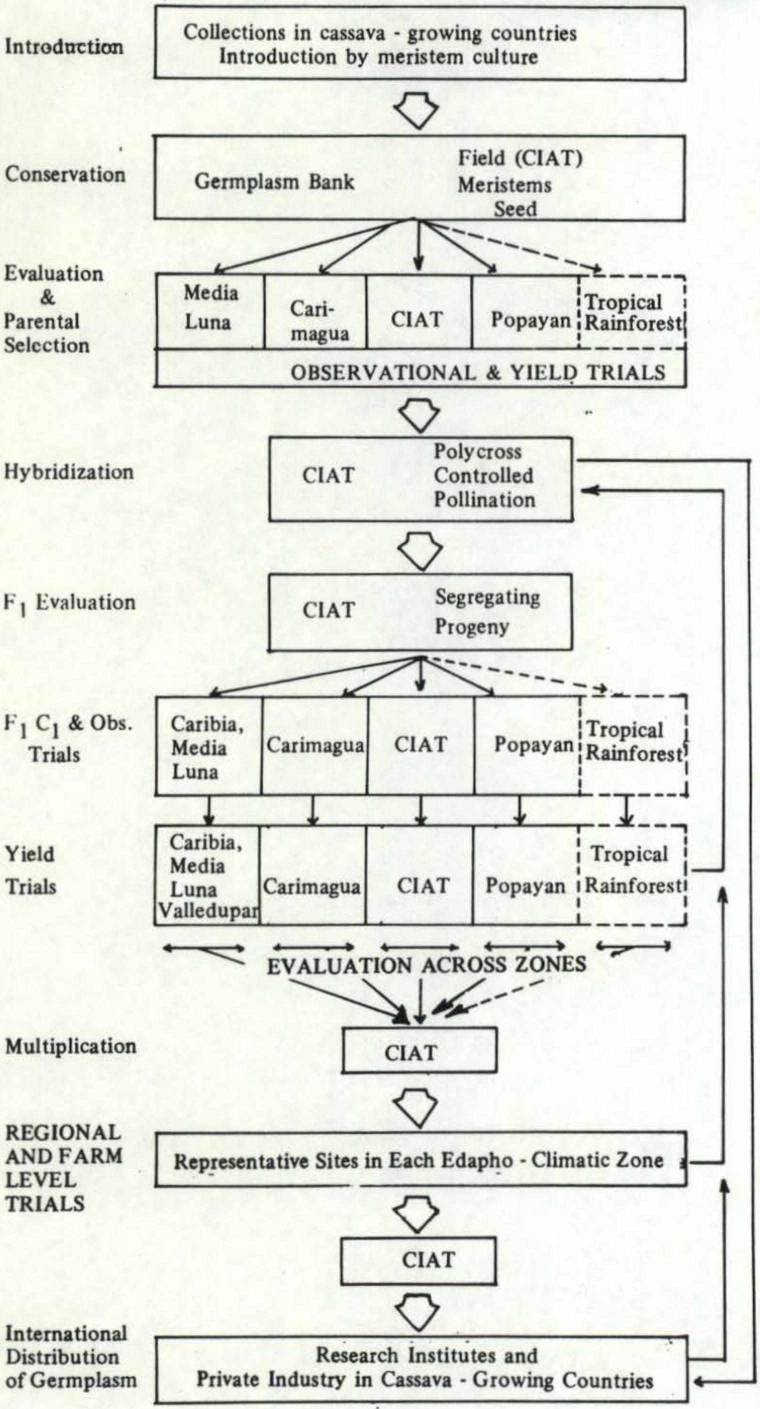
The objective of the cassava breeding program at CIAT is to deliver to national programme improved genetic material for local selection, based on the criteria developed by the national programme. The strategy for germplasm improvement by CIAT hinges on two underlying principles. First, CIAT has a priority for developing cassava technology for Latin America and Asia. This, coupled with the fact that cassava can be grown over a wide range of edapho-climatic conditions, implies that a wide diversity of germplasm will be required. Secondly, cassava has an advantage over many major crops in general adaptation to marginal conditions of rainfall and soil fertility. It is this advantage that CIAT has determined to particularly exploit in varietal development.

The program has incorporated these two basic tenets into all aspects of the varietal development process. Tailoring of genotypes to different environments is accomplished through selection for specific edapho-climatic zones, as described for germplasm evaluation. There is considerable overlap across the zones in terms of varietal adaptability, nevertheless this description serves as a guideline. A minimum input philosophy is adopted, whereby we emphasize a plant's inherent ability to resist or tolerate stress factors rather than modifying the environment to remove stresses.

Figure 1 presents an overview of the germplasm flow process in CIAT. As in most other vegetatively propagated crops, the basic breeding strategy is to select parents, produce large numbers of progeny either through open or controlled pollinations, and select and vegetatively propagate the progeny during various cycles. During the selection cycles the number of genotypes decreases and the precision of evaluation increases.

Various key characteristics of cassava, as a species, influence the system of genetic improvement: 1. wide segregation results among progeny of any cross due to high heterozygocity of all clones; 2. high inbreeding depressions occur with selfing or other forms of increasing the level of homozygocity; 3. by vegetative propagation, a genotype can be fixed at any stage of selection; 4. most characteristics in cassava are quantitatively inherited, principally with additive effects; consequently, a breeder can successfully select parents based on their *per se* performance under appropriate conditions; 5. normally a breeder has to consider various traits simultaneously, with each of those traits controlled by several to many genes (Kawano *et al,* 1978b). Consequently, overall progress in the genetic improvement of cassava is relatively slow.

FIGURE 1. GENERALIZED SCHEMATIC OF CASSAVA GERMPLASM FLOW IN CIAT



CHARACTERISTICS OF ADVANCED GERMPLASM FROM CIAT

CIAT began in 1973 an intensive evaluation of germplasm, and simultaneously the selection of parents. Hundreds of thousands of hybrids have been evaluated in the following years. CIAT produces between 150 and 200 thousand hybrid seeds each year. About 50 to 60 thousand are planted and selected in Colombia, and the remainder sent to national programme or placed in cold storage.

CIAT has made significant advances in understanding the appropriate breeding methodology for obtaining high yield potential mainly through manipulating harvest index and high levels of resistance to such diseases as bacteriosis *(Xanthomonas manihotis)*, superelongation *(Elsinoe brasiliensis)*, and concentric ring leaf spot *(Phyllosticta* sp.) and insects and mites such as thrips and green cassava mite *(Mononychellus* sp.). Factors affecting root quality, including dry matter content and HCN levels, are stressed in selection.

During the past ten years, significant improvement has been made in yield capacity both under high yielding and stress conditions. It has been often observed that genotypes selected under high input conditions did not perform well under low input conditions. By selection under low yielding environments, and perhaps due to characteristics of cassava germplasm *per se*, we seem to be relatively free from this so called "experiment station syndrome" (Kawano and Jennings, 1983). Genotypes carefully selected through evaluations under low input condition seem to adapt well to different geographic areas within the same macro edapho-climatic zone.

MEANS OF GERMPLASM EXCHANGE

Three types of germplasm materials, i.e., germplasm accessions, hybrid clones and hybrid seeds are available in the form of 1. stakes, 2. meristem cultures and 3. true seeds.

Advantages and disadvantages of each method are:

1. *Stakes :* **Advantages** – Availability of background information from previous evaluations; minimum of facilities required to receive and manage material; vegetative propagation preserves exact genetic constitution; and allows agronomic evaluation in the first cycle after introduction. **Disanvantages** – Highest danger of transmission of insects and diseases compared with other means; tolerate a limited time of shipment; high weight and volume result in inconveniences and high cost of shipment; and shipment of great number of genotypes is not easy.

2. *Meristem cultures :* **Advantages** – Availability of background information from previous evaluation; reduced danger of transmission of insects and pathogens; relative ease of transport; and vegetative propagation preserves exact genetic constitution. **Disadvantages** – Require basic facilities for recuperation of mature plant; require trained personnel in handling; delay in initial agronomic

evaluation of introduced material; and handling great number of genotypes is least easy.

3. *Seeds :* **Advantages** – Long storage period, high potential for introducing wide genetic diversity; lowest danger of transmission of diseases and insects, ease of transportation. **Disadvantages** – Require trained personnel in managing a selection program, and lesser availability of background information on each seed-derived plant from previous evaluation due to segregation.

Introduction of germplasm always involves a combination of potential benefit and potential risk. Benefit may be the result of increased productivity of a crop. This must be weighed against the risks of accidentially introducing pests or pathogens. Neither the benefits nor the risks are easily assessable. Lozano and Jayasinghe (1982) presented pathological problems disseminated through sexual or asexually propagated materials.

CIAT has been actively distributing germplasm materials for testing and utilization by national programs. Emphasis in recent years has shifted from sending clonal materials to sending seeds from selected parents. Sending stakes internationally has been halted. As national cassava breeding programs are strengthened, seed will continue to increase in importance as a means of exchange of genetic material. Crosses will continue to be more precisely tailored for the conditions of national programme through incorporating feedback information.

CIAT intends to remain a primary resource of genetic diversity in cassava with the national programme taking an increasing role in local selection and incorporation of improved characteristics into the local cultivars.

GERMPLASM DISTRIBUTION TO ASIAN NATIONAL CASSAVA PROGRAMMES

During the past 10 years, CIAT has offered cassava germplasm as well as training/communication opportunities to Asian cassava researchers. These activities contributed to improvements and the establishment of national cassava research programs in many countries. Today, the majority of the genetic materials handled by these national programs originated in CIAT.

Sexual seeds have been the major means of germplasm transfer, occasionally supplemented by meristem cultures. More than 100,000 hybrid seeds from approximately 1,800 crosses have been distributed to eight countries.The strategy evolved from sending any Latin American germplasm to any interested program in the early years to providing seed population of better defined parents for the specific needs and capacity of each national program in recent years.

UTILIZATION OF GERMPLASM IN NATIONAL PROGRAMMES

In many national programs, these seed populations are regarded as sources for immediate varietal selection, while programmes such as that in Thailand have also selected parents from the seed populations for their hybridization programs. These materials are being processed through evaluation steps in each national program.

Common breeding objectives of Asian cassava programs are; substantial yield increase to acquire higher competitiveness against other plant sources of carbohydrate, early maturity to give additional alternatives to the production system; higher root dry matter or starch content, and diversification of cultivars to gain resistances to diseases and pests.

In the Philippines, well selected clones from CIAT seed populations showed superiority over local cultivar not only in root yield but also in root dry matter content and resistance to mites (Table 2). Traditionally cassava was relatively unimportant human food in the Philippines and local cultivars were adapted mainly to backyard plantings. Now that large scale cassava plantings for starch production and animal feeding are the new national needs for replacing imported carbohydrate sources, new types of

TABLE 2. CASSAVA CLONES SELECTED FROM ADVANCED YIELD TRIAL, PRCRTC, VISCA, LEYTE, 1984/85

Clone	Parents	Root dry yield (t/ha)	Root fresh yield (t/ha)	Root dry matter content (%)	Plant type	Root shape	Mite attack
Selected							
CM 3320-11	M Bra 12 x CM 523-7	4.6	13.8	33.4	4	2	3
CM 3340-3	CM 342-170 x CM 586-1	5.5	17.1	32.4	2	3	5
CM 3341-4	CM 342-170 x CM 523-7	5.1	15.4	32.9	3	4	5
CM 3380-30	CM 586-1 x CM 523-7	6.9	20.6	33.3	5	4	1
CM 3422-3	CM 630-122 x CM 728-2	5.4	16.3	33.0	2	3	2
CM 3504-8	CM 728-2 x CM 523-7	4.3	11.9	36.3	4	4	3
CM 3504-9	CM 728-2 x CM 523-7	6.1	20.2	30.2	3	4	2
CM 3590-1	CM 859-12 x M Col 22	6.8	19.8	34.3	5	4	2
CM 3816-4	CM 1191-9 x CM 523-7	5.6	16.0	35.0	3	3	4
Control							
CM 323-52	M Col 22 x M Mex 59	3.4	10.9	31.6	4	4	4
M Col 1684		3.3	11.3	29.1	3	3	3
CMC 40		3.4	10.1	30.1	2	4	4
Golden Yellow (local)		1.9	6.3	30.6	5	1	3

genotypes are required to respond efficiently to large scale planting scheme with different agronomic treatments. The initial results are highly promising in the Philippines and similar results are being obtained also in Indonesia.

In Thailand, large scale cassava production for processing into animal feed and starch, though managed nearly totally by small farmers, have been highly successful in recent twenty years. A significant part of this success is due to the availability of an excellent local cultivar, Rayong 1. Because of the superb adaptation of Rayong 1 to large scale production under local edapho-climatic conditions, the immediate yield superiority of CIAT germplasm is not as readily demonstrated as in other countries. Nevertheless, from the earliest CIAT seed population, a new cultivar with higher starch content than Rayong 1 was selected and released with the name Rayong 3. Some selections from crosses between Rayong 1 and CIAT clones seem to give superior yield at early harvest as well as at normal harvest (Table 3).

TABLE 3. YIELDS OF RAYONG 1 AND TWO PROMISING HYBRID CLONES AT VARIOUS PLANTINGS AND HARVESTINGS IN RAYONG, THAILAND.

Planting data	Harvested at (month)	Root dry yield (t/ha) of		
		Rayong 1	CMR 24-14-1308	CMR 24-63-43
May 1983	8	5.5	8.1	9.3
May 1983	12	5.4	7.7	9.7
Jan 1984	8	6.6	8.6	9.5
Jan 1984	12	10.2	11.7	12.8
May 1984	6	6.7	8.6	8.4
Sept 1984	8	4.6	3.4	4.1
Oct 1984	8	7.4	11.5	10.5
Nov 1984	8	7.6	6.1	8.8
	Average	6.75	8.21	9.14

* CMR 24-14-1308: a selection from CM 407-7 x Rayong 1 cross.
CMR 24-63-43: a selection from M Col 1684 x Rayong 1 cross.

** Data source: Rayong Field Crop Research Center, Department of Agriculture, Thailand.

Cassava bacterial blight (CBB) caused by *Xanthomonas campestris* pv. *manihotis* and brown leaf spot caused by *Cercosporidium henningsii* are the only cassava diseases commonly observed in Thailand. Rayong 1 is moderately susceptible to these diseases, although the real yield reduction by these diseases is not well established. The majority of CIAT clones are more resistant to CBB than Rayong 1 both in Thailand and Colombia. This is expected because CBB resistance has been one of the important selection criteria in preparing advanced CIAT germplasm to be distributed to national programmes. Some of the CIAT clones show good resistance to brown leaf spot in Thailand. This may have happened due to wide genetic variation contained in Latin American germplasm. This suggests that CIAT germplasm may serve as a safeguard against future outbreaks of diseases and pests in addition to its immediate contribution to the current selection programmes.

Both theory and experience seem to amply support that Latin American germplasm in general and CIAT advanced breeding populations in particular can enrich Asian cassava varietal improvement programmes. Nevertheles, our experiences also suggest that while Latin American germplasm on the whole offers much abundant genetic variation, it contains genes for local adaptation in much lower frequencies than the local germplasm. Thus, in advanced national breeding programmes, crosses of well selected CIAT germplasm with elite local cultivars would be the most desirable breeding populations.

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