Draft for Review
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PROJECT IP-3

IMPROVED CASSAVA FOR THE DEVELOPING WORLD

ANNUAL REPORT
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Centro Internacional de Agricultura Tropical
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IP-3 - Improved Cassava for the Developing World

Objective: To increase and stabilize cassava production in diverse environments by developing improved gene pools in cooperation with national programs.

Outputs: Sources of resistance or tolerance to major pests, diseases and abiotic stresses.
Sources of desirable root quality characteristics.
Gene pools for lowland humid, sub humid, semi-arid, highland tropics and subtropics.
Improved breeding methodologies, including farmer participatory approaches.
Networks and trained national personnel for effective dissemination of genetic material.

Benefits: New cassava varieties mainly benefit small-scale farmers by securing their food supply and raising their income. Improved germplasm also enables cassava processors to increase their profits and provides urban consumers with cheaper, higher quality products. In Africa and Amazonia, many of these benefits accrue to women, since they are mainly responsible for producing, processing and marketing the crop.

Strategy

Since cassava is grown in diverse agroecosystems, an important task for international research is to tailor improved germplasm to varied sets of conditions. Key traits are introduced or improved in cassava through a recurrent process of screening, selection and recombination at representative sites, based on feedback from farmers and colleagues at national programs within this strategy, the main tasks of the project are to:

- Establish and maintain pest colonies, develop ways to inoculate and culture pathogens, characterize germplasm for resistance to biotic stresses, and screen it for efficient use of nutrients.
- Alter cyanogen content within gene pools to suit different purposes, develop methods for controlling postharvest deterioration and genetically modify starch quality.
- Evaluate, select and recombine elite genotypes for specific agroecosystems and incorporate new screening methods and the participation of end users into breeding schemes.
- Gather feedback from the users of improved gene pools, organize training for national programs in Latin America and Asia, strengthen regional networks and disseminate scientific information.

Duration: 5 years

Cost and financing plan: US$ 590,310. Starting in 1997, 67% of the funds will come from CIAT's unrestricted core, and 33% from special projects.

Collaborators: CORPOICA; EMBRAPA; INIVIT (Cuba); INIA (Ecuador); FCRI (Thailand); IITA; NARS in Latin America and Asia.

CG system linkages:	Saving Biodiversity	50%
	Increasing Productivity	30%
	Protecting the Environment	10%
	Strengthening NARS	10%

Linkages to other projects at CIAT: PE-1; SN-1; SN-2; SN-3; SB-1; and SB-2

Donors: Ministry of Agriculture (Colombia); IFAD; DANIDA Agropecuaria Mandioca, (Venezuela)

IP-3. Improved Cassava for the Developing World

Objective: To increase and stabilize cassava production in diverse environments by developing improved gene pools in cooperation with National programs

OUTPUTS	*Genetic base of cassava and Manihot species evaluated and available for cassava improvement*	*Genetic stocks and improved gene pools developed*	*Assisting NARs in adaptive selection and deployment of improved cassava germplasm in Latin America and Asia*
BROAD ACTIVITIES	Identify and study sources and mechanisms of useful genetic variability in 2000 cassava genotypes for: Disease resistance (*bacterial blight, root rots*) Pest resistance (*whyteflies, mites, thrips* *Chilomima clarkei*) Root quality traits (*cyanide, post-harvest deterioration, Vitamins, minerals*) Physiological traits (*drought, nutrient use efficiency*)[1]	Development of genetic stocks Incorporation of wild germplasm into cassava genetic stocks Development of parental populations incorporating sources of local adaptation (i.e. resistance to African Cassava Mosaic Virus) Implementation of a recurrent selection program across 3 ecosystems by 1998 Propagation of mapping progenies, inter-specific hybrids and genetic stocks	Distribution of improved populations and/or genetic stocks to IITA, NARs and AROs in Asia and Latin America Cassava germplasm development for different ecosystems Improved varieties selected together with final users and diffused Adaptive selection involving farmers in semi-arid NE Brazil and Northern Colombia Upgrade yield capacity and adaptation of cassava breeding populations in Asia Germplasm development Breeding material distribution Varietal release and dissemination Economic effect of improved germplasm Poverty alleviation in relation to varietal adoption Natural resource management and cassava breeding Facilitate communication among cassava scientists

[1] Physiologist left during 1997. Results not reported

1997 Highlights

- Five cassava clones were resistant to CBB and SED in Carimagua and Villavicencio during five crop cycles.
- Potential varieties with complementary resistance genes for bacterial blight were identified.
- For the first time highly resistant varieties to root rot were selected which were more resistant than the ones selected and used in Brazil.
- Recombinant progenies from crosses involving whitefly resistant and susceptible parents are being evaluated for reaction in front of heavy whitefly infestation, and characterized molecularly in order to map genetic factors responsible for resistance.
- Twenty-four genotypes were selected out of the germplasm collection for having whitefly damage ratings below 2.0. Of these only 6 clones had both a damage and population levels below 2.0.
- Three genotypes, MPER 365, CM 5620-1 and SM 653-16 had low whitefly damage and low population evaluations at both CIAT and Nataima (both sites being hotspots for the pest).
- Ovipositional preference studies have corroborated results from field resistance studies. A progeny from a backcross between a resistant line and a donor parent, showed reduced levels of oviposition, indicating the possibility of further improvement in whitefly resistance.
- New sources of resistance to mites have been identified, some of them with stability across evaluation sites.
- A new methodology for screening of cyanide content was adjusted to allow the evaluation of large numbers of genotypes in an active breeding program.
- Significant maternal effects (cytoplasm) were determined in the inheritance of root cyanide content.
- The range of variability in micro-nutrient content in cassava roots will allow for a considerable improvement through selection and recombination. There are no significant correlations among micro-nutrient concentrations.
- Analysis of micro-nutrients in cassava leaves revealed concentrations 30 times higher than in roots, opening the possibility of using leaves as food supplement in marginal regions.
- Genotypes with as low as 1% deteriorated roots after 2 weeks storage were selected after screening 69 elite clones in 3 replications.
- Starch derived from selected genotypes can tolerate high acidity (pH 2.4) and freezing conditions (-20°C).
- A total of 163,093 recombinant seeds were produced at CIAT-HQ when counting together improved populations and genetic stocks. From that total, 123,557 seeds were distributed to National Programs and IITA (58 %), along with 362 in-vitro genotypes. CIAT-Thai program distributed 10,415 seeds to partners in Asia.
- During 1997, 20 elite experimental clones were selected for different ecosystems. The largest genetic gain was observed for the mid-altitude and highland ecosystems.
- Farmer participatory evaluation of advanced selections is an integral part of the cassava germplasm development schemes implemented in Northern Colombia and North-east Brazil.
- Out of CIAT transferred gene pools 3 new varieties were released in Brazil with resistance to predominant biotic constraints, 1in Cuba with production precocity; 3 new clones (OMR33-17-5 as KM 95, SM1157-3 as KM 95-3, and SM937-26) in Vietnam and 3 (CMP62-15 as VC6, CMP21-15 as VC7, and CM3422-1 as Lakan 4) in Indonesia.

- Genepool enhancement based on parental genotypes with higher root starch content, higher biomass, high harvest index, and better adaptation to drought-prone environment very actively continued at the CIAT/Thai collaborative breeding program and the resulting genepool materials became a most favored source of varietal selection at many national cassava breeding programs in Asia.
- New high yielding, high starch cultivars are disseminating rapidly in five countries in Asia mainly through the scheme of small farmer cultivating and large factory processing and the total area planted with these new cultivars is reported to be 0.82 million ha in the 1996/1997 planting season.
- The wide-spread adoption of new cultivars resulted in extra income, through additional sales of fresh roots and the better price paid and higher efficiency due to improved starch content, of US$214 million in 1996/97 and the total accumulated value of US$693 million in the past ten years.
- While a good portion of the additional economic effects caused by the adoption of new cultivars is entering directly to the household incomes of cassava farmers in many parts of Asia, the recent wide-spread varietal dissemination in North Vietnam testifies that improved cassava cultivar can generate equitable economic opportunities for bettering farm lives even in a scheme of smallest farmers (average farm size less than 0.5 ha).

OUTPUT 1: GENETIC BASE OF CASSAVA AND MANIHOT SPECIES EVALUATED AND AVAILABLE FOR CASSAVA IMPROVEMENT

Sub-project 1.1. Identification and study sources and mechanisms of useful genetic variability for disease resistance (bacterial blight, super-elongation disease and root rot)

Genotypes Characterized for their Reaction to CBB and SED in Carimagua and Villavicencio

At Villavicencio and Carimagua 345 and 387 cassava genotypes, respectively, were characterized for their reaction to CBB and SED, under natural disease pressure. These genotypes correspond to several crop cycles. 26.5 % were identified as resistant to both diseases (**Table 1.1** and **1.2**). From the group of varieties evaluated during five years, five clones were resistant to both diseases in the two locations (**Table 1.3**).

In April, different cassava clones were planted in Matazul (Puerto López, Meta), to evaluate disease pressure in order to consider the possibility of transferring field experiments from Carimagua to this location.

Table 1.1. Germplasm resistant to CBB and SED, evaluated during five crop cycles at Villavicencio.

VARIETY	YIELD (TON/HA)	VARIETY	YIELD (TON/HA)
CG 1355- 2	22.78	CM 7033- 3	19.44
CM 523- 7	20.97	CM 7037- 7	19.38
CM 1223- 1	23.75	CM 7069- 6	10.21
CM 1288- 17	23.13	CM 7073- 9	35.00
CM 3372- 4	21.88	CM 7251- 1	10.94
CM 4562- 7	12.85	CM 7274- 1	18.75
CM 4574- 7	17.50	CM 7341- 3	9.17
CM 5286- 3	20.42	M BRA 589	9.38
CM 5306- 8	24.58	SG 455- 1	8.13
CM 6290- 3	27.29	SM 593- 5	35.42
CM 6438- 14	22.29	SM 593- 8	18.75
CM 6683- 6	39.58	SM 627- 5	13.75
CM 6694- 8	12.64	SM 686- 25	14.38
CM 6790- 3	12.29	SM 979- 20	12.50
CM 6840- 4	8.13	SM 985- 9	23.13
CM 6855- 3	23.33	SM 1036- 8	26.67
CM 6921- 3	27.92		

Table 1.2. Germplasm resistant to CBB and SED, evaluated during five crop cycles at Carimagua.

VARIETY	YIELD (TON/HA)	VARIETY	YIELD (TON/HA)
CM 4574- 7	36.67	CM 6855- 3	34.58
CM 4826- 4	23.33	CM 7305- 4	32.22
CM 5286- 3	38.96	M VEN 25	13.89
CM 6631- 4	14.58	SG 104- 57	46.04
CM 6633- 3	42.92	SM 676- 11	10.42
CM 6653- 4	35.00	SM 686- 25	15.00
CM 6664- 4	22.36	SM 985- 9	38.75
CM 6694- 6	56.25		

Table 1.3. Germplasm resistant to CBB and SED, evaluated during five crop cycles at Carimagua and Villavicencio.

VARIETY	VILLAVICENCIO	CARIMAGUA
	YIELD (TON/HA)	
CM 4574- 7	17.5	36.7
CM 5286- 3	20.4	39.0
CM 6855- 3	23.3	34.6
SM 686- 25	14.4	15.0
SM 985- 9	23.1	38.8

Cassava genotypes characterized for their reaction to CBB under greenhouse conditions and different pathotypes.

A group of 55 genotypes were characterized for their reaction to CBB under greenhouse conditions. Each variety was inoculated with 10 pathotypes of *Xanthomonas axonopodis* pv. *manihotis* from different edapho-climatic zones in Colombia and Venezuela. At the greenhouse, young cassava plants were inoculated by stem puncture with an aliquot of $1X10^5$ CFU/ml bacterial suspension. Disease severity was recorded at 7, 14, and 21 days after inoculation. All strains were highly virulent and the three most virulent strains (Villavicencio 2, CIO 277 and SantoTomás 1B) were isolated from Villavicencio (Meta, Colombia), Boca del Pozo (Monagas, Venezuela) and Santo Tomás (Atlántico, Colombia), respectively. Eight varieties were intermediate resistant to 60-80% of the used pathotypes (**Table 1.4**). Nineteen varieties were susceptible to all pathotypes. Based on previous experiments, the results obtained at the field and greenhouse, showed similar trends.

Table 1.4. Reaction of cassava varieties to ten strains of *X. axonopodis* pv. *manihotis* (Disease reaction: R, resistant; I, intermediate and S, susceptible).

VARIETIES	ISOLATES[1]									
	Vill 2	Vill 132	Vill 372	S.Tomás 1A	S.Tomás 1B	Cio 421	Cio 10	Cio 261	Cio 277	Cio 285
CM 6855- 3	S	S	I	R	I	I	I	I	S	S
M NGA 2	I	I	I	R	I	S	S	I	S	S
M BRA 902	S	I	S	R	I	S	S	I	I	S
M VEN 77	I	R	I	S	S	S	S	I	I	S
M BRA 886	I	S	S	I	I	I	I	I	I	I
CM 3555- 6	S	I	I	I	I	S	S	I	I	I
SG 107- 35	I	S	I	S	I	I	I	I	S	I
SG 104-284	I	I	I	I	S	S	I	I	I	S
CM 1491- 5	S	I	I	S	I	S	I	I	S	I
CM 523- 7	S	I	I	I	I	S	I	I	S	S
CM 849- 1	S	I	S	I	S	S	I	I	S	I
CM 6438- 14	I	I	S	S	S	S	I	I	S	I
M COL 1468	S	S	I	S	S	S	I	I	I	I
CG 1- 37	S	S	S	I	S	I	S	S	I	I
SG 915- 1	S	S	I	I	S	I	S	S	S	S
CG 1355- 2	S	S	I	I	S	I	S	S	S	S
CM 472- 4	S	I	S	S	S	S	I	S	S	I
CM 1016- 4	S	S	S	S	I	S	S	I	S	I
CM 3306- 4	S	S	I	S	I	I	S	S	S	S
M CUB 74	S	S	I	S	S	I	S	S	I	S
M COL 1684	S	S	I	S	S	S	S	S	S	I
SG 104-264	S	I	S	S	S	I	S	S	S	S
CG 959- 1	S	S	S	S	S	I	S	I	S	S
CM 7310- 1	S	S	S	S	I	S	S	S	S	I
CG 6- 71	S	S	I	S	S	S	S	I	S	S
SM 627- 5	S	S	S	I	S	S	S	S	I	S
M COL 2215	S	S	S	S	S	S	S	I	S	S
M COL 1505	S	S	S	I	S	S	S	S	S	S
M NGA 19	S	I	S	S	S	S	S	S	S	S
CM 1335- 4	S	S	I	S	S	S	S	S	S	S
CM 1585- 13	S	I	S	S	S	S	S	S	S	S
CG 917- 5	S	S	I	S	S	S	S	S	S	S
M VEN 218	S	S	S	S	I	S	S	S	S	S
CM 3306- 9	S	S	S	I	S	S	S	S	S	S
CM 2772- 3	S	S	S	S	S	S	S	S	S	I
CM 3306- 19	S	S	I	S	S	S	S	S	S	S

[1] Villavicencio 2; Villavicencio 132; Villavicencio 372; S.Tomás 1A (Atlántico); S.Tomás1B (Atlántico); Cio 421 (Cauca); Cio 10 (Brasilia, Brazil); Cio 261 (Venezuela); Cio 277 (Venezuela); Cio 285 (Venezuela).

Germplasm accessions characterized for their reaction to Phytophthora root rot at greenhouse level.

We characterized 429 germplasm accessions for reaction to Phytophthora root rot at greenhouse level, inoculating the stems from 20-cm height plants with *Phytophthora drechsleri.* Thirteen varieties were tolerant to the aggressive strain P12 and will be evaluated in different root rot endemic regions.

750 cassava varieties have been established in the field for Phytophthora root rot, CBB and SED projects.

Collection of microbial strains assembled and made available to CIAT partners: 80 *Phytophthora* spp., 700 strains of *X. axonopodis* pv. *manihotis*, 86 strains of *Fusarium* spp., 30 strains of *Sphaceloma manihoticola* and 55 strains of *Diplodia manihotis*.

Sub-project 1.2. Identification and study sources and mechanisms of useful genetic variability for pest resistance (whiteflies and mites)

Stable host plant resistance offers a practical long-term solution for maintaining reduced pest populations. Sources of resistance have been identified for mites, lacebugs, whiteflies, thrips, burrower bugs, and other arthropod pests of cassava. Immunity has not been identified for any pest, but available levels of resistance, combined with other pest management tactics, can be used to reduce pest populations. In recent years HPR research has concentrated on whiteflies and mites, and resistance studies have been initiated with the stemborer, *Chilomina clarkei*.

Germplasm evaluations for HPR are being carried out at several locations, depending upon natural pest populations and adequate facilities and collaboration. Evaluations are done on the Atlantic Coast of Colombia, at Pivijai and Media Luna; at the CORPOICA station at Nataima, Tolima, and at CIAT.

Whiteflies: Germplasm Evaluation at CIAT-HQ.

Cassava clones were evaluated at Nataima, Tolima, and CIAT for resistance to whiteflies (*Aleurotrachellus socialis*). For the third consecutive year whitefly populations at CIAT were high. The reasons for these recent eruptions in whitefly populations at CIAT, where previously populations have always been low, is not understood. These high populations have resulted in considerable foliage damage and have permitted the evaluation of approximately 2250 cassava clones, distributed in the cassava germplasm collection (vigor levels I and II) during 1997. HPR evaluations are based on both a plant damage scale and a whitefly population scale. Both scales employ a 1 to 6 rating; 1 = low damage or low population, 6 = severe damage and high populations. Whitefly population scales are based on counts of eggs, pupae and adults.

Using the damage and population scales, 2247 clones were evaluated. These consisted of 1589 clones from "vigor I" and 658 clones from "vigor II". Based on the damage scale in Vigor I, 118 clones (7.4%) were selected for low damage levels (1.0 to 2.5); 1151 (72.4%) for intermediate damage level; and 320 (20%) for high damage levels **(Fig. 1.1)**. For vigor II, 37 clones (5.6%)

resulted in low damage levels; 519 (78.9%) in intermediate damage level, and 102 (15.5%) in high damage levels **(Fig. 1.2)**. Combining the data 155 clones (6.9%) resulted in low damage levels and will continue to be evaluated.

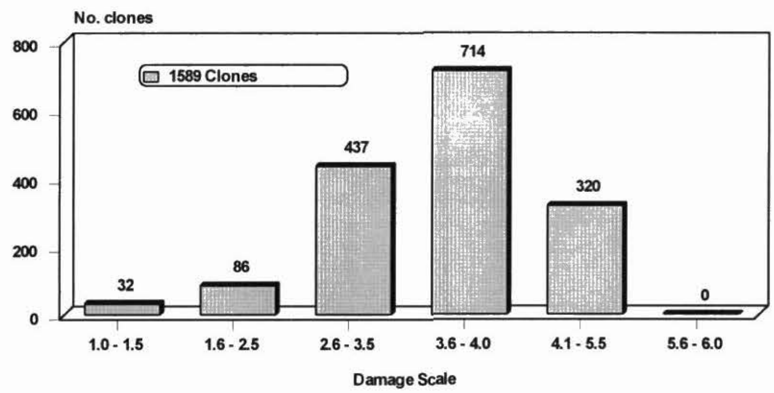

Figure 1.1. Cassava germplasm evaluations (vigor I) for whitefly (*A. socialis*) damage (1=no damage; 6=severe damage) at CIAT, 1997.

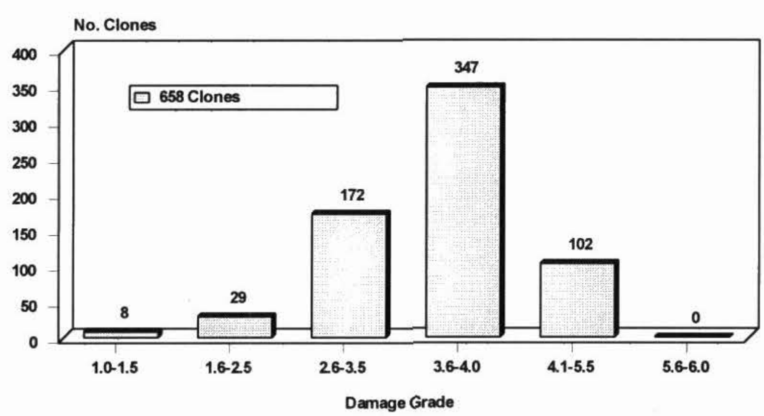

Figure 1.2. Cassava germplasm evaluations (vigor II) for whitefly (*A. socialis*) damage (1=no damage; 6=severe damage) at CIAT, 1997.

Based on the whitefly population evaluations, in vigor I, 51 clones (3.2%) had low populations (less then 50 whitefly adults and immature per leaf), 406 (25.6%) had intermediate population levels (< 1000 per leaf), and 1132 (71.2%) had high populations **(Fig. 1.3)**. For vigor II, 17 (2.6%) resulted in low population levels, 193 (29.3%) at intermediate levels, and 448 (68.2%) at high levels **(Fig. 1.4)**. The combined results show that 68 clones (3.2%) had low population levels, 559 clones (26.6%) had intermediate levels, and 1580 clones (70.3%) had high population levels.

Fifty-five clones (2.4%) had a combined low damage and low population levels; that is damage and population ratings below 2.5. Of these, 43 clones (2.7%) were in vigor I and 12 (1.8%) in vigor II. Of these only 6 clones had both a damage and population levels below 2.0. Twenty-four clones had a damage rating below 2.0. These evaluations are based on natural field populations of whiteflies and may include escapes. Selected clones from these evaluations will be evaluated in subsequent years and at additional sites.

If we use a damage rating of 3.0 as the cut-off point than 1880 clones, 83.7% are above this level and can be classified as susceptible and eliminated from further evaluation.

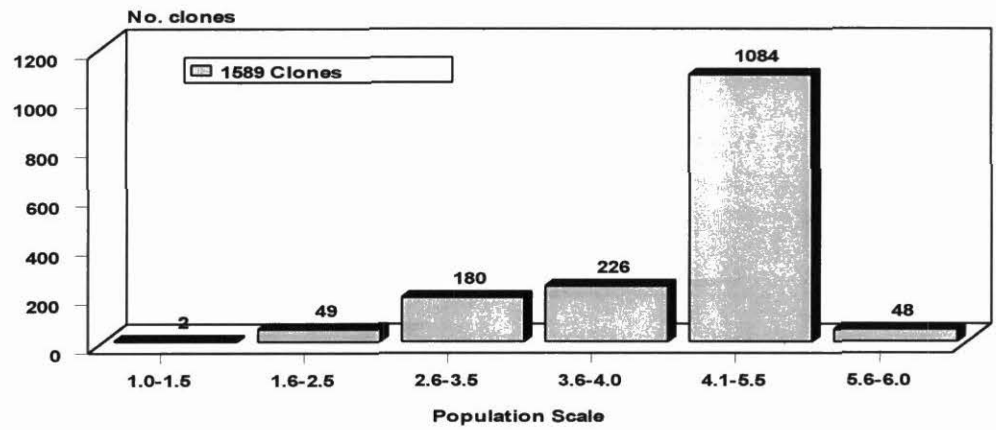

Figure 1.3. Cassava germplasm evaluations (Vigor I) for whitefly (*A. socialis*) resistance using pest population ratings (1=no whiteflies; 6=>1000 per leaf) at CIAT, 1997.

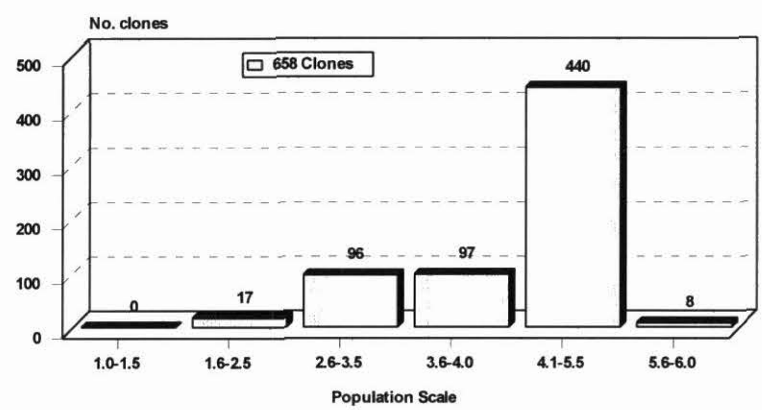

Figure 1.4. Cassava germplasm evaluations (Vigor II) for whitefly (*A. socialis*) resistance using pest populations ratings (1=no whiteflies; 6=>1000 per leaf) at CIAT, 1997.

Germplasm evaluation for whitefly resistance in CORPOICA, Nataima.

After three years of low whitefly populations at CORPOICA, Nataima, Tolima, during 1997 populations increased sufficiently to evaluate cassava germplasm. Three field evaluations, using natural pest populations, and a combined damage and whitefly population scale were carried out on 297 selected cassava clones.

Results show that selection pressure was high; 95.3% of the clones had a damage rating above 2.6 **(Fig. 1.5)**, 74% of these were above 3.6. Only 14 clones (4.7%) had a damage rating of 2.5 or lower. High whitefly populations are supported by the fact that only 8 clones (2.7%) had population levels of 2.5 or lower while 69% of the clones had populations above 4.0. In addition, these populations were evenly distributed throughout the field. The susceptible clone CMC-40 was planted every 10 rows and these rows had a damage level above 4.0. Three clones, MPER 365, CM 5620-1 and SM 653-16 had low damage and low population evaluations at both CIAT and Nataima. This trail will be harvested before the end of 1997.

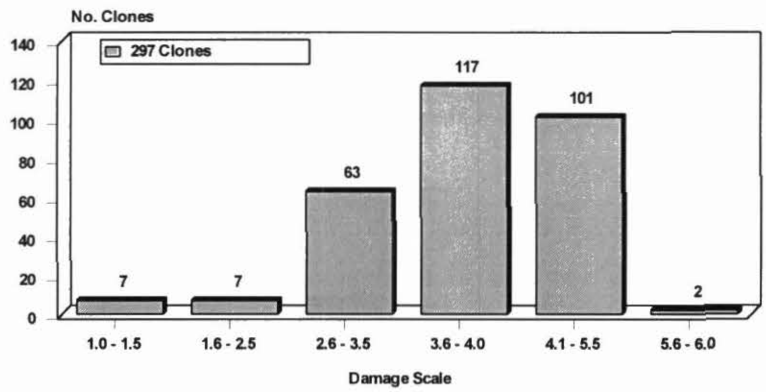

Figure 1.5. Cassava germplasm evaluations for whitefly (*A. socialis)* resistance (Damage scale, 1=no damage; 6=severe damage) at CORPOICA, Nataima, El Espinal, Tolima, 1997.

Studies on yield depression due to whitefly incidence

Selected clones from previous whitefly resistance evaluations were evaluated in a yield depression trial at CORPOICA, Nataima. The study consisted of 39 clones in rows of 10 plants, planted in six blocks. Three blocks receive periodic pesticide application, 3 blocks remain non-treated. In this way the differences in yield between treated and non-treated can be used as an additional measurement of resistance.

This trial has not yet been harvested but preliminary results show that 10 clones of the non-treated plots- have damage ratings below 2.5, 9 clones at the intermediate level of 2.6 to 3.5, and 20 clones with damage ratings above 3.5. The clone MECU 72 was included as the resistant check. Damage (1.3) and populations (1.1) were very low on this clone. CMC-40 was the susceptible check and damage (5.0) and populations (4.1) levels were high.

It should be noted that nearly all of these clones were selected in previous evaluations for having low damage ratings. Present results indicate that approximately 50% of these clones are susceptible and can be removed from further evaluations. These results also show that when natural field populations are used, it is necessary to gather data over several years. Clones with the lowest damage ratings were MPER 34, CM 8424-4, MECU 72, MPER 266, MPER 365, MPER 216, CM 8424-38, MPER 221, and CM8424-37.

Evaluation of selected genotypes at regional trial level in CORPOICA, Nataima

Previous evaluations and research has established that the cassava clone MECU 72 is highly resistant to whiteflies, and the clone MBRA 12 has "field resistance." A cross between these clones resulted in four hybrids being selected for resistance to whiteflies and good agronomic/culinary characteristics. CORPOICA is now interested in releasing one or more of these hybrids as commercial cultivars. Prior to hybrid release, ICA requires a series of regional trials in several locations. This trial consists of 8 cultivars, the two parents MECU 72 and MBRA 12, four progeny CG 489-34, CG 489-31, CG 489-4 and CG 489-23, the regional farmer's cultivar and CMC 40, the susceptible check. CORPOICA personnel, using methodologies developed with CIAT, are managing the trails and recording whitefly damage and population data. The trial will be harvested toward the end of 1997.

Preliminary results based on damage and whitefly populations indicate a good performance from the whitefly resistant hybrids **(Fig. 1.6)**. Whitefly populations and damage were highest on the susceptible check, CMC 40, the regional variety and MBra 12. Damage is lowest on MECU 72 and CG 489-31, and slightly higher on CG 489-34, CG 489-4 and CG 489-31. Whitefly populations also follow this trend.

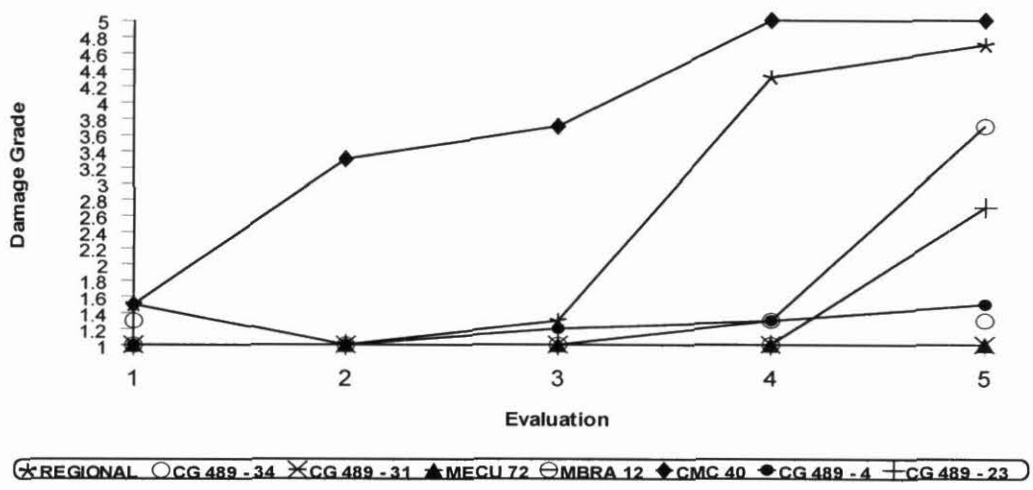

Figure 1.6. Damage to selected cassava cultivars caused by the whitefly, *A. socialis* in a Regional Trail at CORPOICA, Nataima, El Espinal, Tolima, 1997.

Evaluation of cassava genotypes in fields of polycrosses at CIAT-HQ

A polycross block of 28 clones with 14 plants of each cultivar was designed. Cultivars were selected for their resistance to the cassava mite, *Mononychellus tanajoa*. Due to the heavy whitefly populations at CIAT during 1997, these cultivars were evaluated for whitefly damage and populations. All 392 plants were evaluated.

Results show very high whitefly population levels and considerable plant damage. Pest populations were above 4.1 on all cultivars, indicating that these cultivars are highly preferred for oviposition and as a food source. Damage levels were correspondingly high. No cultivar had a damage rating below 3.6; 23 of the 28 cultivars had a damage rating above 4.1. These results indicate that although these cultivars have resistance to mites, they, and probably their progeny, will be susceptible to whiteflies.

Studies on ovipositional preference

Ovipositional preference of whitefly adults on selected clones is used as an additional measurement for host plant resistance. These studies are carried out in the greenhouse by placing one plant of each clone in a circular design in 6 fine mesh cages and releasing 1500 whitefly adults into each cage. Whiteflies are allowed to oviposit for 72 hours when plants are removed, cleaned of all adult whiteflies and brought into the laboratory, where with the aid of a stereomicroscope, eggs are counted. Ten clones were evaluated; 9 had previously been selected as promising for resistance and these were compared to CMC 40 the susceptible check.

Results show that oviposition on CMC 40 was more than double that of any other clone **(Table 1.5)**. The average number of eggs per plant on CMC 40 was 2278; the second highest was 866 eggs/plant on MGUA 7. Oviposition on MBRA 856 was only 224 eggs per plant. As expected oviposition was low on MECU 72 (356) and its resistant progeny CG 489-4 (623) and CG 489-34 (573). The clone CM 8509-5 is the result of a backcross between MECU 72 x CG 489-34; oviposition on this clone was lower than either of the parents and an 85% reduction from the susceptible check. A surprising result is the low oviposition on MBRA 12 (290 eggs/plant). In previous experiments this clone showed higher oviposition rates.

Table 1.5. Ovipositional preference on cassava clones selected for resistance to the whitefly, *A. socialis,* in greenhouse studies at CIAT, 1997.

Clone	No. eggs per plant	% difference in relation to control
CMC 40 (control)	2278	100.0
MGUA 7	866	62.0
MCOL 2025	682	70.0
CG 489-4	623	72.6
CG 489-34	573	75.0
MECU 47A	556	75.6
MECU 72	356	84.0
CM8509-28	342	85.0
MBRA 12	290	87.0
MBRA 856	224	90.0

Screening cassava germplasm for resistance to mites

The CIAT cassava germplasm collection is systematically being evaluated for resistance/ damage to cassava mites, especially the green mite (CGM) *Mononychellus tanajoa*. A total 4495 clones have been evaluated; 13% of these, 599 clones, have been selected for continued evaluation.

Whitefly populations were so high at CIAT during 1996-97 that adequate populations of CGM for germplasm evaluations did not develop. However 515, of these selected clones have been evaluated at Pivijai and 133 clones continue to display moderate levels of resistance. This is 3.0% of the total germplasm evaluated and about 26% of the germplasm selected as promising for resistance at CIAT. Mite populations at Pivijai are usually more severe than CIAT and combined with the drier climate and poorer soils may account for a higher selection pressure. Based on these results as well as yield and dry matter content, 26 clones have been selected for a polycross experiment planted at CIAT. The objective of this study is to evaluate the progeny from open pollinated crosses for resistance to the cassava green mite (*M. tanajoa*).

Mite damage evaluations were done for cassava yield trial (GY 9623, 122 clones) and a regional trial (GY 9612, 20 clones) established as part of the germplasm enhancement activities within this project at CIAT. From the yield trial 14 clones were selected as promising for resistance. From the Regional Trial, 6 clones were selected **(Table 1.6)**. The clone SM 643-17 has now been selected from five trials, indicating stable resistance.

Table 1.6. Selected hybrid clones from cassava yield trial and regional trial for mite resistance (CIAT, 1997).

Trial	Clones	
I Yield Trial	CM 6698-3	SM 1447-4
	CM 6740-7	SM 1513-2
	CM 7614-7	SM 1647-1
	CM 8024-2	SM 1750-16
	CM 8151-1	SM 1896-3
	CM 8370-14	SM 1902-3
	SM 909-25	MCOL 945
II Regional Trial	CM 6370-2	SM 909-25
	CM 6740-7	SM 643-17
	CM 7514-7	SM 1210-4

Sub-project 1.3. Identification and study sources and mechanisms of useful genetic variability for root quality traits

Development of screening methods and evaluation of genetic variability in cyanogenic potential of cassava.

The objectives of this work were to: a) Optimize a procedure for the preparation of linamarases from root peel and leaves; b) adjust sample preparation in order to simplify and provide greater precision to the "dip-stick" method; c) evaluate a broad range of genotypes with the adjusted methodology; and d) understand the mode of inheritance of cyanogenesis in cassava.

Freshly collected leaves and roots from 4-6 month-old plants from cassava accessions in the germplasm collection maintained at CIAT were used for enzyme preparation and evaluation of linamarin content. Linamarase from leaves and root peels was prepared according to the method of Yeoh et al (1997; J Sci Food & Agric, in press). Linamarase activity was determined according to Essers et al (1993), while glucosidase activity was evaluated through the procedure published by Yeoh (1989, Phytochemistry 28:721-724).

Two types of samples were studied using the enzyme-based dip-stick method for the determination of cyanide potential (Yeoh & Eagan 1997): a disk (6 mm by 1 mm) from the mid section of 5 individual roots from a particular genotypes; and an extract obtained by the combination of samples from proximal, middle and distal regions of 3 peeled roots and homogenised. Root slices were weighted in a glass test-tube containing 0.5 ml water and crashed with a rod ; while for the extract, 0.4 ml was mixed with 0.1 ml 2M K_2HPO_4 in a test tube. An enzyme-based dip-stick was quickly inserted and the test tube sealed air-tight with a rubber stopper. All tubes were left at room temperature (26-30^{o} C) overnight. The picrate paper was removed from the dip-stick and soaked in 2.5 ml water to elute the color. The absorbance read at 510 nm. The cyanogenic potential was expressed as mg HCN kg root^{-1} dry wt, using linamarin as the reference compound. The cyanogenic potential of the root extract was also estimated using the spectrophotometric method of Essers et al (1993, J Sci Food & Agric 63:287-296).

Leaf enzyme preparations from 34 cassava varieties yielded 23 to 103 U g-1 leaf fresh weight and purity of 2-5 fold. Preparations from peel of 14 cassava varieties gave lower yield, ranging from 1 to 10 U g^{-1} peel fresh weight (**Table 1.7**). Kinetic properties of the enzymes from both leaf and peel showed overall similarity in terms of their Km values and pH dependent activity. Some differences were observed in their stability to drying. Leaf linamarases showed greater variability (7 to 58% activity retention) compared to the peel enzymes (31 to 51%). Although enzyme preparations from both sources could be used for the determination of cyanide in cassava, those from the leaves were preferable because of the high yield and activity.

The concept of an enzyme-based dip-stick for the determination of cyanogen level in cassava (**Fig. 1.7**) was first reported by Yeoh et al. (1996, Biotechnology Techniques 10:319-322); to be used mainly in the determination of cyanogenic potential in cassava flour (Yeoh and Egan, 1997; Food Chemistry, in press). At that time, it was also proposed that the method could provide a simple and less laborious analysis of cyanogen content in cassava roots. A rapid and consistent preparation of samples was achieved by first removing a root disc with a cork borer, then sliced with a simple cutting device comprising 2 blades

Table 1.7. Linamarase isolated from cassava leaves and root peels, extremes and average.

Genotype	Amonium sulfate fraction		Phenyl Sepharose CL-4B fraction		Purity fold	Recovery (%)	Yield (U g^{-1} leaf fresh wt.)
	Total linamarase (ukat)	Specific activity (ukat mg^{-1})	Total linamarase (ukat)	Specific activity (ukat mg^{-1})			
Leaves							
CM 6370- 2	0.90	0.16	0.77	0.43	2.7	86	23
MCR 89	3.99	0.44	3.46	1.33	3.0	87	103
Average	3.39	0.40	1.25	0.99	2.5	74	60
Root peels							
CG 402-11	0.05	0.03	0.03	0.08	2.7	60	0.9
MPER 245	0.46	0.21	0.33	0.72	3.4	72	10.0
Average	0.14	0.08	0.10	0.14	2.9	68	2.9

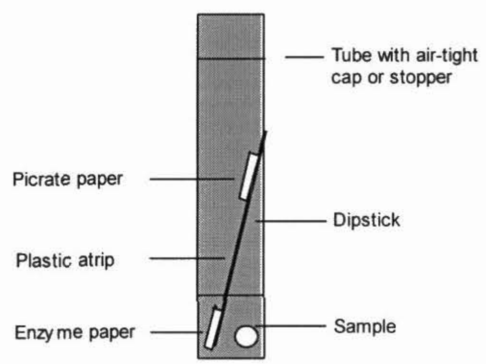

Figure 1.7. Design of enzyme-based dip-stick and experimental set-up.

separated by a spacer prepared with Whatman 17 Chr chromatography paper. Each root slice weighed about 0.10± 0.1 g.

Cyanogenic potential (expressed as mg HCN/kg root fresh weight) of 40 cassava varieties was determined using the enzyme-based dip-stick protocol, and trying to adjust the most convenient sampling methodology. Cyanogenic potential ranged from about 2 mg to 590 mg HCN/kg root. Twenty-seven varieties gave values that were comparable to those of control (using root extract). Some varieties were underestimated (**Table 1.8**). For these varieties, values similar to control were obtained by simply crushing the root slices (**Table 1.9**). Determination of cyanogenic potential based on 5 roots per variety compared well with those using composite root extracts prepared from 3 roots (r=0.81). Semi-quantitative estimation of cyanogenic potential for 122 cassava varieties was also carried out by comparing the color of picrate paper against those of

Table 1.8. Effect of incubating root slices in phosphate buffer pH7 for the analysis of cyanogenic potential in cassava genotypes.

Genotype	Sample type and reaction condition		
	Root slice in phosphate pH7	Root slice in water	Root extract in phosphate pH7
	Mg HCN/kg root fresh wt[1]		
MCUB 74[2]	42 ± 8	31 ± 2	72 ± 15
MTAI 1[2]	25 ± 13	23 ± 9	87 ± 26
MCOL 1684[2]	87 ± 26	80 ± 20	146 ± 45
MBRA 881[2]	136 ± 34	139 ± 30	237 ± 8
MBRA 162[2]	125 ± 22	88 ± 17	243 ± 27
CM 507-37[2]	121 ± 27	84 ± 7	247 ± 19
MCR 35[3]	4 ± 1	4 ± 1	4 ± 1
CG 402-11[3]	17 ± 3	23 ± 6	25 ± 3
MVEN 25[3]	263 ± 14	269 ± 35	260 ± 52
MVEN 297A[3]	365 ± 72	376 ± 81	368 ± 62

[1]Values (mean ± SD) were on 5 samples from one root; [2]Variety showed under-estimated value with root slices; [3]Included as control.

Table 1.9. Effect of crushing root slices for varieties that showed under-estimation of cyanogenic potential with intact root slices.

	Sample type and reaction condition	
	Crushed root slice in water	Root extract in phosphate pH7
Cassava genotype	Mg HCN/kg root fresh wt.[1]	
MCUB 74	47 ± 5	36 ± 4
MCOL 1468	181 ± 30	150 ± 40
CM 507-37	174 ± 42	167 ± 30
MBRA 881	220 ± 20	167 ± 14
MBRA 162	171 ± 47	204 ± 35
MTAI 1	190 ± 42	207 ± 50

1Values (mean ± SD) based on 5 samples from one root.

known standards; results showed a strong correlation with spectrophotometric method (r=0.79) (**Fig. 1.8**).

Analyses of 101 progenies arising from 6 crosses between cassava varieties of different cyanogenic potential showed cyanide content ranging from 120 to 1941 mg HCN kg root-1 dry wt, and also hinted at maternal influence in the inheritance of cyanogenic potential. The frequency of observing progenies with low or high cyanogenic potential appeared to depend on the female parent (**Table 1.10**). The levels of β-glucosidase activity in the progenies, however, seemed to follow the parents with lower enzyme activity suggesting some kind of dominance. Correlation between cyanogenic potential and the enzyme activity was weak. This study also demonstrated that the enzyme-based dip-stick method for the determination of cyanogenic potential was reliable, reasonably accurate and useful for large number of samples.

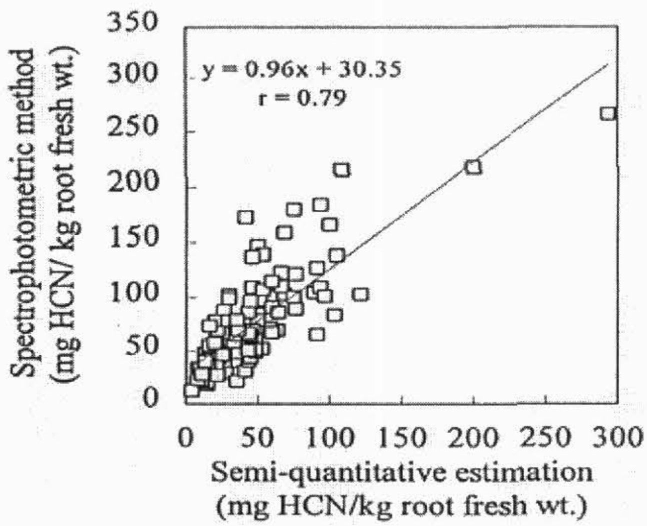

Figure 1.8. Comparison between semi-quantitative and spectrophotometric analyses of cyanogenic potential in 122 cassava varieties.

Table 1.10. Distribution of cyanogenic potential among progenies from various crosses studied.

Family	Female	Male	#	Dry Matter %	Mean ± SD	Cyanogenic potential Frequency (mg HCN kg root^{-1} dry wt) <400	401-699	700-999	>1000
CM 8432A	CM 507-37	CG 996- 6	15	35.6	759±501	4(27)[2]	4(27)	4(27)	3(20)
CM 8432B	CG 996- 6	CM 507-37	26	39.8	486±390	13(50)	7(27)	4(15)	2(8)
CM 8433A	CG 996- 6	CM 4063- 6	26	42.5	652±272	6(23)	9(35)	8(31)	3(12)
CM 8433B	CM 4063- 6	CG 996- 6	20	39.7	718±301	3(15)	7(35)	6(30)	5(20)
CM 8443A	CM 507-37	CM 4013- 1	11	38.1	794±402	2(18)	4(36)	2(18)	3(27)
CM 8443B	CM 4013- 1	CM 507-37	12	40.2	679±447	4(33)	3(25)	3(25)	2(17)

[1]Low cyanogenic potential variety used as female parent. [2]Value in parenthesis refers to per cent.

Exploring the Genetic Potential and Stability of Micronutrient Content in Cassava

The objective of this project for 1997 was to evaluate the potential of cassava leaves and roots as a source of minerals and vitamins for human nutrition.

Carotene content in leaves, was determined at CIAT, using the procedure described in 1996 Annual Report. Dry and grinded samples of roots and leaves were sent to the Univ. of Adelaide for the simultaneous analysis of several minerals. A sampling studied was conducted on 2 cultivars, over 2 reps, sampling 2 plants, 2 tissues (roots and leaves), 2 samples per plant, and 2 type of samples (grinded or whole sample). A group of 20 genotypes was evaluated for mineral concentration both in roots and leaves, following recommendations from the sampling study.

B-carotene concentrations in leaf tissue ranged from as low as 15 mg/100 gr to as high as 105 mg/100 gr. In average, cassava leaves can have 30 times the carotene concentration found in the roots of yellow cassava. Selecting the genotypes with the highest concentration of carotenes in the leaves will allow to supply the daily requirements (between 3 and 4 mg) of vitamin A for an average person, with just 5 grams of fresh leaves or 2 grams of dry leaf flour.

Results showed that experimental error for the determination of mineral concentration can be reduced to reasonable levels (F for pooled samples across plants and reps, still significant) by sampling 2 plants per replication and pooling at least 2 roots per plant (previously washed and peeled) and 10 developed leaves from the upper third of the plant. This study also showed a high positive correlation between mineral concentration in roots and leaves of the same genotypes for Zn and Mn; while for Ca the correlation was highly negative. For other minerals, variability in concentration was independent in roots and leaves.

Applying the previously described sampling procedure, a set of 20 genotypes planted in 4 reps was sampled at 6 month after planting to evaluate the concentration of minerals in both leaves and roots. The coefficient of variation (CV%) was high for the concentration of Fe in leaves and for Mn and Na in the roots. Again, the sampling process avoided soil contamination since the CV for roots was lower than the CV for leaves. Differences due to genotypes were significant ($P<0.05$) for all minerals evaluated in cassava leaves, except for Fe. In the case of minerals in the roots, all but Fe, Mn and B were significant ($P<0.05$). Except for Na and K, concentration of minerals in leaves is higher than in the roots. For Na roots showed higher concentration, while for K the range was similar. Correlation between leaves and roots were not significant, although they were always positive with the exception of Ca. Somehow, against what was expected, correlations among nutrients across leaves and roots was not significant, either. These results appeared to indicate that we can improve the concentration of each nutrient independently of the others, and in the leaves independently from the roots. We will have to carefully choose the nutrients we would like to increased the concentration through genetic means, in order to maximize genetic gains for them. The limited variability observed in Fe concentration, will require to study a broader spectrum of genotypes including other *Manihot* species.

Evaluation of cassava starch performance under acidity and freezing stress

The objective of the present work was to evaluate starch from a representative range of genotypes, under two conditions; acidity (pH 2.4) and freezing (-20° C), stored during 6 weeks. This information is important to set future research objectives and to learn more about the range of starch resistance that we can encounter within our germplasm collection.

Starch from nine genotypes was used in this study. Those genotypes were selected out of a larger group, based on the range of amylose content. The genotypes were: MCOL 1684; CM 3306-4; MBRA 62; MMEX 59; CG 915-1; MVEN 77; MPER 196; MVEN 25; and CG 165-7. Starch was extracted manually.

Gels were prepared as starch suspensions containing 5% starch were prepared in distilled water, with the addition of sodium benzoate at 0.1%. The suspensions were prepared in a Brabender viscoamylograph starting at 25° C and ending at (0° C, with an increment in temperature of 1.5 C/minute.

In order to evaluate resistance to acidity; once gels reached ambient temperature, they were acidified at pH 2.4 with the addition of chlorhydric acid 0.5 N, and 35 ml of the gel were stored in 50 ml centrifuge tubes, capped, and at 4° C during 2, 4, 5 and 6 weeks prior to evaluation. Resistance to freezing was evaluated in 50 ml centrifuge tubes, 40 ml of gels were stored, capped, at –20° C during 1, 2, 4 and 6 weeks, prior to evaluation.

Syneresis was measured in 10 ml centrifuge tubes, where 5 g of gel from each treatment were weighted. Syneresis was measured by the weight of liquid separated from the gel after centrifuging at 1000 g during 15 minutes at 20° C, and it was expressed as percentage of the total weight.

In acid medium starches should preserve its physical appearance, structure and viscosity during processing and storage, like in the case of thickening agents for sauces. Results from this study showed that cassava starches presented an increase in viscosity after the second week of storage, with the tendency to stabilize after that, with the exception of starch from MMEX 59 and MCOL 1684 (**Fig. 1.9**) . Gels did not show changes in their structure, and no liquid was released (syneresis) during the different periods of storage.

In **Fig. 1.10**, changes in viscosity during storage of gels at –20° C can be observed. During the first week of storage, al samples showed a reduction in viscosity, with MVEN 77 and CG 165-7 presenting the greatest reduction (11.7 cp and 10 cp respectively), and showing syneresis at weeks 4 and 6. After 4 weeks in storage syneresis for MVEN 77 and CG 165-7 was 4.4 % and 13.7 %, while after 6 weeks, it was 4.3% and 22.8%, respectively. Results demonstrated a relationship between amylose content and the retrogradation process (syneresis). Starch produced from MPER 196 and MVEN 25 presented the greatest stability during storage time.

OUTPUT 2. GENETIC STOCKS AND IMPROVED GENE POOLS DEVELOPED

Development of genetic stocks and parental populations incorporating sources of local adaptation (i.e. resistance to African Cassava Mosaic Virus)

A total of 163,903 recombinant seeds were produced during 1997 (**Table 2.1**). Parental populations aimed at specific ecosystems or continents represented 77% of the total seed. As we describe later, those populations represent the basis for our cooperation with National Programs and IITA. The development of genetic stocks is gaining importance through the years. Genetic stocks are produced based on the recombination of a set of genotypes that excel for a particular trait, and we would like to upgrade that trait beyond its natural range of variation (i.e. look for transgressive segregation in broader adaptation). Stocks developed for inheritance studies or to support molecular mapping of specific traits are developed by the recombination of contrasting

Table 2.1. Recombinant seed produced within the project (Oct. 1996 – Oct. 1997)

Parental population	***Controlled crosses***	**Open pollinated crosses**	***Total***
1996 B			
Asia	6535		6535
Bacterial blight	1565		1565
High carotene	1088		1088
Africa		95144	94144
Sub-total:	**9188**	**95144**	**104332**
1997-A			
Wide adaptation	1354	22601	23955
Africa	1655		1655
Resistance to ACMV	22		22
Asia	1111		1111
Dwarf plant type	40		40
Cooking quality	1027	7385	8412
Cyanide inheritance	2406		2406
High carotene	204		204
Semi-arid tropic		11552	11552
Sub-humid tropic		4017	4017
Highland tropic		6197	6197
Sub-total	**7819**	**51752**	**59571**
TOTAL:	**17007**	**146896**	**163903**

genotypes (i.e. cyanide inheritance). Other time our aim is to pyramid genes responsible for different sources of resistance (i.e. bacterial blight). As we shift our emphasis from applied breeding to more basic research supporting breeding (i.e. molecular marker assisted selection), genetic stocks will become even more important. Parental population development in the future, will concentrate more in targeting specific crosses between genotypes selected by NARS and complementary sources of genetic information from our genetic enhancement program or our global germplasm collection.

Implementation of a recurrent selection program across 3 ecosystems

Reduction of available resources to develop comprehensive breeding programs for different ecosystems, and the previous history of genetic up-grade for individual ecosystems, led us to design a recurrent selection program that takes advantage of selection for broader adaptation, while maintaining opportunities for selection of more narrowly adapted germplasm. The proposed scheme is presented in **Figure 2.1**. Aside from representing a more rational use of resources, it shortens the breeding cycle by 1.5 to 2 years compared to the traditional scheme. The ecosystems involved in the recurrent selection program are: the lowland subhumid tropics (Media Luna – M); the acid soil savannas (La Libertad – L) and the mid-altitude tropics (Palmira – P). The major climate, soil and biotic constraint characteristics for those ecosystems are presented in **Table 2.2.** A total of 399 segregating progenies, belonging to 5 self-pollinated and 12 cross-pollinated families were evaluated along with the 12 parental genotypes involved in all the crosses. Those parents were selected based on their adaptation to specific ecosystems or indications of broader adaptation to at least two of them. Evaluation was done in 20-plant plots, with 2 reps, for a set of pre and post-harvest traits, although discussion here is based on dry matter yield per hectare (DM/ha), as an indication of adaptability.

Table 2.2. Main characteristics of sites used for progeny evaluation within the recurrent selection program.

	Media Luna	**La Libertad**	**Palmira**
Altitude (masl)	10	337	1000
Mean temperature	27.2	27.0	23.8
Rainfall			
1996-97 A	1120	2672	951
1996-97 B	890	2370	869
Soil characterisitcs			
PH	6.3	4.1	7.6
Organic matter %	1.7	5.8	4.1
P (ppm)	5.1	25.1	32.8
K (me/100g)	0.15	0.25	0.7
Ca (me/100g)	1.9	0.9	22.8
Mg (me/100g)	0.45	0.3	19.3
Texture	Clay-lime	Lime-clay	Clay-lime
Main biotic constraints	Bacterial blight	Bacterial blight	Mites
	Mites	Super-elongation	Whiteflies
	Stemborers	Trhips	trhips

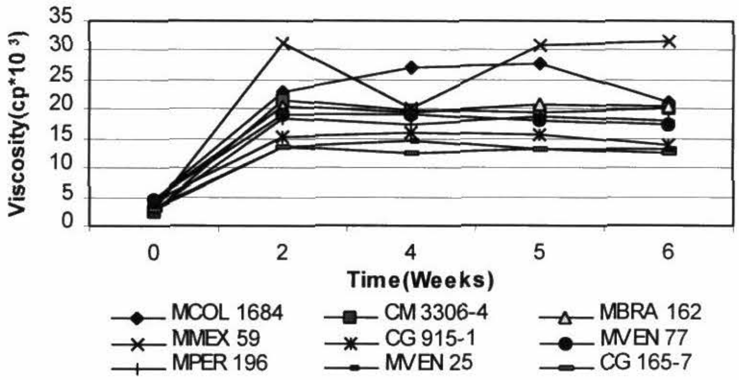

Figure 1.9. Cassava starch gel viscosity during storage in acid medium

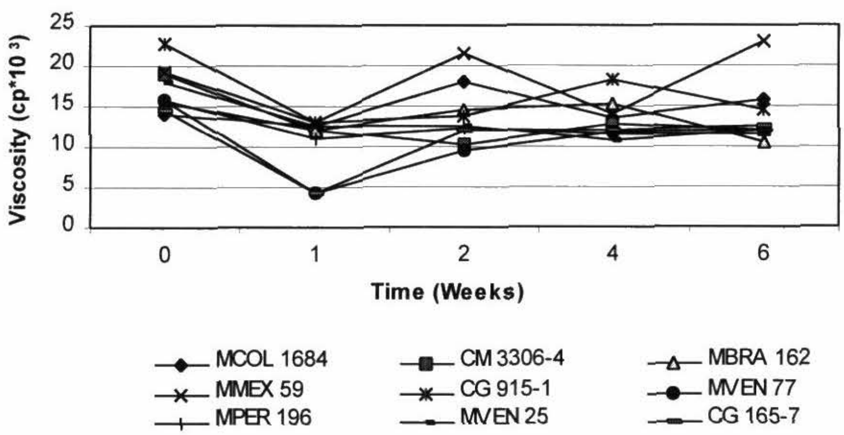

Figure 1.10. Cassava starch gel viscosity during freezing

Figure 2.1. Proposed scheme for cassava recurrent selection across 3 major ecosystems.

Year	Evaluation stage	# plants & reps	Ecosystems
1	F1	1 pl, 1 rep	Mid-altitude
2	Clonal evaluation	10 pl, 1 rep	Mid-altitude
3	Preliminary yield trial	20 pl, 1 rep	Mid-altitude/Acid soil savannas/Sub-humid
4	Advanced yield trial	20 pl, 2 reps	Mid-altitude/Acid soil savannas/Sub-humid
5-6	Recombination	On-farm research	

Analysis of variance homogeneity resulted in no significant differences among sites. Correlation among genotypic performance between sites was not significant (P-L: 0.12; P-M: 0.03; and L-M: 0.04), indicating that the sites represent a set of different growing conditions. We can assume then, that genotypes selected for their broad adaptation will not be the result of any site homology, but it will depend on their capacity to adapt to a broader range of conditions.

A total of 18 genotypes were selected for adaptation to the 3 evaluation sites, while 88 genotypes showed good adaptation to at least 2 sites (**Table 2.3**). It is important to highlight that progenies from MTAI 5 (Rayong 90) showed an excellent performance across sites, with the ability to adapt well to the most stressful site (Media Luna). Other progenies showed specific adaptation across 2 sites (i.e. CM 8602 for P & L). Those genotypes with broader adaptation will be incorporated in a crossing block to generate recombinant seed for the second cycle of selection. Selected genotypes with adaptation to 2 sites will be combined by hand-crossing, in order to develop more progenies with broader adaptation. Further evaluation during the following crop cycle, will reveal those materials that can be selected for specific adaptation and incorporated into on-farm or regional trials.

Table 2.3. Genotypes selected for broad adaptation within a recurrent selection scheme.

Genotype	Female parent	Male parent	DM (t/ha) Mid-altitude	DM(t/ha) Acid soil savannas	DM(t/ha) Sub-humid
18 genotypes selected for mid-alt., acid soil sav., sub-humid					
AM 271-13	CM 4729- 4	CM 4729- 4	5.75	8.35	3.08
CM 8593-11	CG 996- 6	CM 3372- 4	8.15	5.70	2.62
SM 2059-20	CM 5902- 2		9.80	8.81	2.44
SM 2059-22	CM 5902- 2		6.63	8.15	2.35
SM 2069-18	SM 494- 2		7.30	7.00	3.94
SM 2069-20	SM 494- 2		6.98	9.81	4.73
SM 2069-34	SM 494- 2		9.00	11.12	2.85
SM 2166-17	SG 536- 1		8.61	5.96	4.00
SM 2166-19	SG 536- 1		9.93	6.77	4.32
SM 2166-24	SG 536- 1		7.76	5.79	3.29
SM 2168- 4	SG 787-10		6.70	10.40	3.88
SM 2168-23	SG 787-10		7.71	5.80	2.52
SM 2075- 2	CM 3372- 4		8.97	10.33	3.95
SM 2075- 4	CM 3372- 4		8.35	7.70	4.78
SM 2075- 6	CM 3372- 4		8.15	7.53	3.66
SM 2081- 4	CM 4729- 4		8.32	9.57	5.71
SM 2102- 2	MTAI 5		9.43	8.79	6.36
SM 2102-34	MTAI 5		8.74	10.49	4.98
SM 2102-35	MTAI 5		8.09	10.38	8.04
Average			**8.13**	**8.33**	**4.08**
45 genotypes selected for mid-altitude and acid soil savannas			8.24	7.86	
15 genotypes selected for mid-altitude and sub-humid			8.63		4.43
28 genotypes selected for acid soil savannas and sub-humid				8.60	4.28

Propagation of mapping progenies, inter-specific hybrids and genetic stocks

The molecular map was originally developed on 90 individuals from the family CM 7857, resulting from a cross between MNGA 2 (TMS 30572) and CM 2177-2 (ICA-Cebucan). The progeny was later on extended to 150 individuals in order to get a greater order of saturation in the map. The whole family is being multiplied and evaluated at CIAT and Villavicencio. Planting material obtained will be used for an extensive evaluation trial next cycle. Present planting will be characterized for the reaction in terms of post-harvest deterioration, bacterial blight and super-elongation disease.

OUTPUT 3. ASSISTING NARS IN ADAPTIVE SELECTION AND DEPLOYMENT OF IMPROVED CASSAVA GERMPLASM IN LATIN AMERICA AND ASIA

Distribution of improved populations and/or genetic stocks to IITA, NARs and AROs in Asia and Latin America

A total of 123,557 seeds corresponding to 857 families, and 362 genotypes in-vitro were distributed during 1996 from CIAT-HQ to our partners in Latin America, Asia, IITA and AROs (**Table 3.1**). The salient feature of this year shipments have been the massive introduction of germplasm to Africa (IITA), representing 57% of the total shipments. Previously we sent F1 crosses between Latin American germplasm and elite genotypes from IITA selected mainly as resistant to African Cassava Mosaic Virus (ACMV). The frequency of selection for resistant progenies was considerably low in the F1's, although it was higher than the frequency of selection within progenies of pure Latin American origin. In 1995, after a joint CIAT-IITA, meeting it was decided that in order to increase the frequency of resistant genotypes within segregating progenies, BC1 families, instead of F1, should be introduced. A big effort was launched at CIAT, which resulted in the shipment sent this year. Our interest in increasing the frequency of resistant genotypes is to allow a more proper selection for other important traits that Latin American germplasm can contribute to Africa (i.e. low cyanide, high dry matter, good cooking quality, etc.). Susceptibility to ACMV has covered up all the potential genetic contribution of Latin American germplasm, in the past.

Table 3.1. Germplasm distributed to different research programas in the world (Oct. 1996-Oct. 1997).

Continents	*Genotypes / crosses*		*Plants / seeds*	
Latin America	44	192	222	17015
Asia From CIAT-HQ	14	567	67	36008
From CIAT-Thai				10415
Africa (IITA)	276	170	276	70534
Europe + USA	28		292	
Total	**362**	**929**	**857**	**133972**

Cassava germplasm development for different ecosystems

As part of the re-structuring of our germplasm development project, during 1996-97 cassava breeding activities for the semi-arid ecosystem were discontinued in Colombia. CIAT is attending the responsibility for that ecosystem through the joint work being developed with EMBRAPA in NE Brazil. As resource dedicated to cassava germplasm development at CIAT continue to decrease, a similar alternative may be explored for other priority ecosystems.

Experimental trials were harvested in 4 ecosystems: sub-humid lowland tropics, acid soil savannas, mid-altitude and highland tropics. A total of 63 trials were established during 1996-97 covering an area of 49.4 has; 40% involving basic breeding trials; 6% regional trials and 54% multiplication lots. Genetic progress observed for each ecosystem was 31% for sub-humid tropics; 58% for acid soil savannas; 97% for mid-altitude tropics; and 110% for highland tropics. Agronomic performance of 20 elite genotypes is presented in **Table 3.2**.

Table 3.2. Agronomic performance of elite experimental genotypes selected in 1997 for different ecosystems, along with the local check varieties.

Genotype	Female parent	Male parent	Root yield t/ha	Root dry matter (%)	HCN
Sub-humid (Santo Tomás)					
SM 1665- 2	MCOL 1505		26.3	31.8	8.0
SM 1438- 2	MTAI 8		25.1	35.4	9.0
SM 1427- 1	CM 3997- 1		22.0	32.4	8.5
SM 1511- 6	CG 915- 1		22.0	34.8	8.5
SM 1433- 4	MBRA 191		21.4	32.8	7.5
Check variety			17.6	33.8	6.5
MSD (5%)			6.4	4.0	
Acid soil savannas (Villavicencio)					
SM 1828-11	CM 2772- 3		29.9	34.7	6.5
SM 1821- 7	CG 1139- 2		29.5	36.1	8.0
SM 1553-23	CM 2952- 2		29.3	35.3	7.0
SM 1820- 8	MVEN 77		27.3	35.6	7.5
SM 1823- 7	CM 523- 7		27.2	33.0	5.5
Check variety			18.9	33.5	6.8
MSD (5%)			8.4	3.5	
Highlands (Cajibio)					
CM 7430- 1	CM 481- 3	CG 401- 6	33.2	36.4	3.5
CM 7438- 1	CM 481- 3	MCOL 2261	32.9	35.3	4.0
CM 7595- 1	MCOL 2261	CG 406- 6	31.8	34.4	2.0
SM 853- 7	CG 358- 3		28.4	33.8	2.5
CM 7436- 7	CG 403-18	MCOL 2261	28.3	32.9	3.5
Check variety			16.9	31.7	3.5
MSD (5%)			13.7	3.0	
Mid-altitude (Quilichao)					
SM 1460- 1	CG 1139- 2		37.3	35.4	9.0
SM 1927- 9	MIND 39		35.8	36.6	6.5
SM 1689-18	CM 5253- 1		33.6	35.8	6.5
SM 1820-10	MVEN 77		33.2	33.8	9.0
CM 6740- 7	MCOL 1505	MPAN 51	31.4	34.0	5.5
Check variety			16.4	32.6	8.5
MSD (5%)			10.2	5.2	

Those genotypes are already incorporated in crossing blocks to develop future parental populations. In order for National Programs to have access to them, they will be indexed, put in-vitro and multiply for shipment during next year.

Selections from last year advanced yield trials were evaluated in regional trials in all ecosystems (except the highlands where the trials were established this year) as part of special projects financed by the Ministry of Agriculture and some of them with financing and good participation of the private sector. There is a considerable interest from the processors in the selection of genotypes that are more suitable for starch or dry cassava production. Root yield was lower than the previous crop cycle due to excessive rains during mid-season, particularly in the acid soil savanna ecosystem. **Table 3.3** summarizes results from the three ecosystems in comparison with the best check variety (usually a genotype selected from our program and release not more than 5 years ago). The mid-altitude region showed again a good potential for cassava production and it is where the industry is starting to develop; followed by the Northern part of Colombia.

Table 3.3. Average and best genotypes performance in regional trials for different ecosystems in Colombia.

Ecosystem	Genotype with high yield & good stability	Average root yield (t/ha)	Root dry matter content (%)	Regression coefficient
Sub-humid[1]	CM 7514- 8	22.5	35.0	1.15
	Trials mean	19.4	33.2	
Acid soil savannas[1]	CM 6921- 3	12.5	37.4	0.98
	Trials mean	7.3	31.9	
Mid-altitude[1]	CM 5655- 4	31.5	36.6	1.28
	Trials mean	26.4	36.7	

[1]Average of 4, 6 and 4 regional trials, respectively.

Adaptive selection involving farmers in semi-arid NE Brazil and Colombia

This project was started in 1990 as a pure breeding project and has evolved through the years to become a more integrated, on-farm, participatory project for the development of the crop in semi-arid regions. We have completed now the first year of the second phase. At this time we have: participatory farmer evaluation of advanced genotypes as a routine procedure within the breeding scheme; knowledge on selection criteria used by farmers to accept or reject new varieties; deeper knowledge on cassava production and processing systems in the semi-arid; a group of scientists trained in participatory methodologies; a group of varieties preferred by farmers and under multiplication; an effective interaction with other projects in the region; and germplasm transferred to Sub-sahelian Africa.

Within 4 years, participatory farmer evaluation became the core of the project with experimental station breeding activities feeding into it. After analyzing information from 2 cycles of participatory evaluation there is a list of general farmer selection criteria, which may have some resemblance to what we breeders usually look in our experimental trials (i.e. productivity, although expressed in different terms), but spells out more specific concerns from the farmers (**Table 3.4**).

Complementary criteria, include some that are location specific, like white roots for Araripina farmers; or good foliage production for farmers in Quixadá who use it to feed animals during the dry season. Now that we have a pretty consistent list, we will concentrate in those criteria and simplify the field book, in order to make the process of participatory evaluation a more efficient one.

One of the features that our methodology has distinguished itself from others in the area of participatory research, is the capacity to analyze the information and provide feedback to the breeders in terms that are similar to the ones they use. The cumulative probability of having a particular genotype in a given farmer preference order, is a practical way of visualizing how the materials are performing in a given area. For example in Quixadá, we have that 3 genotypes (BGM 195; BGM 260 and BGM 549) had consistently a higher probability of appearing within the first positions in terms of farmer preference (**Fig. 3.1**). **Table 3.5** present the list of materials selected by farmers in each of the 4 regions. Our objective within the following year is to study the homology of those regions with others in NE Brazil, in order to know the possibilities for further diffusion of those genotypes.

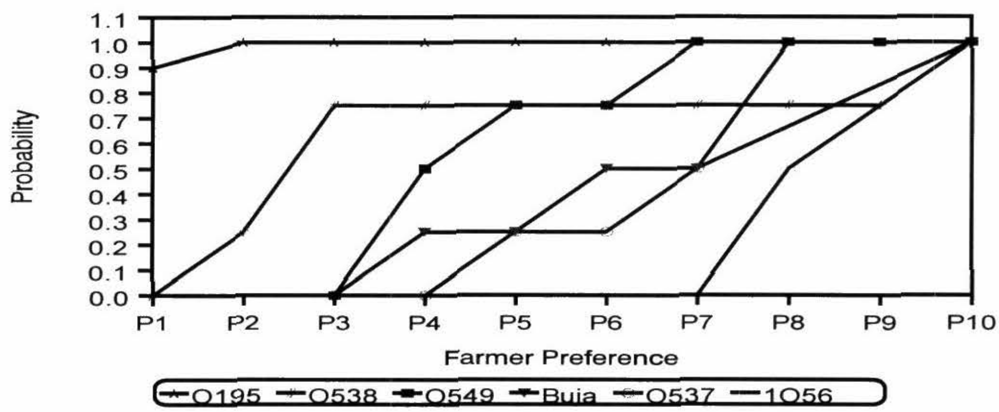

Figure 3.1. Cumulative farmer preference for cassava genotypes evaluated in Quixadá (1995-97).

We explored a new avenue this year for farmer participatory evaluation. We invited a group of 6 expert farmers to the experimental site in Quixadá, for them to select, from an intermediate stage trial, those genotypes that will be evaluated on their farms the following crop cycle. They consistently selected genotypes with good production potential at 16-mo harvest (**Table 3.6**). Some of them were selected for having good dry matter content according to their testing methodology (chewing; nail; cracking the roots, etc.).

Table 3.4. Selection criteria applied by farmers in the semi-arid region of Brazil for the selection or rejection of new cassava varieties.

Main selection criteria
• Germination
• Quality and final farinha yield
• Number of enlarged roots
• Planting material production
Complementary selection criteria
• Harvesting facility
• Facility to peel
• Lack of root constrictions
• External root color (white in Araripina)
• Parenchyma color (white)
• Small to medium plant size
• Foliage yield (high in Quixadá)

Table 3.5. Genotypes selected by farmers with high levels of preference, and being multiplied in the region.

Quixadá	**Araripina**	**Petrolina**	**Itaberaba**
BGM 0260	BGM 0002	BGM 0537	BGM 0869
BGM 0195	BGM 1303		BGM 0538
BGM 0549	BGM 1380		BGM 0576
	BGM 0153		BGM 0812

Breeding activities have been re-structured. Early generations (F1C1) are only evaluated in Quixadá and Araripina; intermediate generations (clonal and preliminary yield trials), are evaluated in those two sites plus Itaberaba; and at final evaluation stages Petrolina is also considered.

Table 3.6. Characteristics of genotypes selected by farmers in the experimental station of Quixadá.

Genotypes	**Root yield (t/ha)**	**Foliage yield (t/ha)**	**Dry matter (%)**
BGM 0812	23.7	16.2	33.8
BGM 0834	30.5	19.8	30.4
BGM 0841	21.1	15.9	31.0
BGM 1012	26.4	20.9	29.5
BGM 0851	20.4	13.6	32.7
BGM 0924	18.3	19.3	24.6
BGM 1030	28.4	13.8	26.9
Local check	12.5	14.2	29.4

Most advanced trials are harvested at 16 to 18-mo; while early and intermediate stages are harvest at 12-mo. In the case of Araripina, greater importance has been given to the evaluation and selection of white-root genotypes with better plant type and root dry matter content than the local check (Trouxinha). Improvement in root yield ranged from 25% to 100% depending on the year, when considering all selections (**Table 3.7**); although the top 5 white-root selections ranged from 44% in PYT to 158% in CET, while the top 5 dark-root selections ranged from 74% in PYT to 196 in CET. Dark-root genotypes seemed to have a greater yield potential and root dry matter content than white-root genotypes.

Table 3.7. Performance of selected germplasm in Araripina (1995-97).

	Mite attack severity		Root yield (t/ha)		Root dry matter (%)	
	CET	PYT	CET	PYT	CET	PYT
Genotypes	95/96	96/97	95/96	96/97	95/96	96/97
White-roots						
92184/15	2.0	2.0	22.4	15.0	33.4	37.2
92214/11	3.0	2.0	21.2	15.7	32.8	39.5
92215/08	3.0	2.0	23.6	12.3	35.1	39.6
92215/29	2.0	2.0	22.4	12.7	32.6	35.5
92241/22	2.0	1.5	20.0	13.7	35.0	37.1
Dark-roots						
92117/02	2.0	2.0	28.0	14.0	35.2	39.2
92143/02	3.0	3.0	25.0	12.0	36.5	40.5
92219/01	2.0	2.0	24.0	15.7	33.4	37.5
92231/30	2.0	2.0	29.2	22.0	31.4	37.2
92246/64	2.0	1.5	20.0	13.0	35.5	39.5
Trial mean	2.8	2.1	14.2	10.3	33.4	36.8
Mean of selections	2.7	2.1	17.0	10.3	34.4	36.3
Mean of Trouxinha	2.2	1.9	8.5	8.8	30.1	35.5

Training of Brazilian personnel in participatory breeding evaluation. The project trained 24 extension agents and field technicians within the PROSERTAO project in Sergipe. That personnel is in charge of evaluating sources of resistance to root rots in conjunction with desirability for farmers. We have also trained 5 CNPMF's scientists in data analysis and interpretation from participatory evaluation trials. Through the feedback information each scientist can take decisions on which technology component should be substituted and which introduced.

In Southern Brazil, 11 staff from EPAGRI (State Program from Santa Catarina) were trained in trial evaluation with farmers, data analysis and interpretation. That personnel works in other crops as well as cassava. It is one of the regions where the farmer participatory evaluation process has been applied to other species, and even to technologies different from varieties.

Support to farmer participatory evaluation and germplasm diffusion in the Hillsides of Colombia. A one-year special project, funded by the Ministry of Agriculture, was started in April 1997 for speeding up the process of on-farm evaluation, multiplication and diffusion of cassava germplasm in the mid-altitude and highland tropics of Cauca Department. Bacterial blight is one of the main biological constraints to production in the region. Two genotypes selected as resistant to CBB (CG 402-11 and SM 524-1), along with two other with tolerance to the disease (MCOL 2261 and SM 526-3) are established in 17 participatory evaluation trials in farms situated from 1000 to 1700 masl. Results from this evaluation will allow to collect information on farmer selection criteria in the region, main crop management practices, and the range of adaptation of the pre-selected genotypes. Parallel to that activity, multiplication lots have been established at experimental station and farms in the region, in order to speed up the diffusion of those genotypes that will be preferred by farmers. A regional evaluation of elite genotypes in the pipe-line has been establish at two altitude levels, 1500 and 1700 masl. Selection from this trials will feed on-farm evaluations in the following cycles.

This project takes part of a broader project, aiming at an integrated development of cassava in the highlands of the region. Our involvement in this project, is allowing us to maintain germplasm development activities for the Highland ecosystem, which is relevant for Eastern Africa. Cassava germplasm for the Highland ecosystem has always showed very specific adaptation. Germplasm developed for lowland tropics have no possibilities of adapting to the highlands.

Development of an effective planting material production and distribution system. During the crop cycle 1996-97, activities were conducted for the development and implementation of decentralized cassava planting material production and distribution scheme in Northern Colombia. The project is supported by the Ministery of Agriculture of Colombia. Although the activity may not be completely considered within the scope of activities for an International Center, the implementation of such scheme can serve as an experience to replicate and a training ground for other programs in Latin America. A total of 20 has of certified lots, 3 has of registred lots (both in Northen Colombia), 1 ha of basic lot (Palmira), and 100 in-vitro indexed plants from each of the farmer selected and local cultivars, were established. Approximately 2,000,000 prime-quality stakes were produced and distributed to projects in different strategic sites in the region.

One of the main constraints for the implementation of an ideal multiplication scheme is the conflict between optimal harvesting time and planting time. Most cassava in the region is harvested before April and planting is usualy done in May June. Root quality deteriorates after March, due to re-growth. Farmers usualy give priority to roots, since they are their main source of income; therefore a compromise had to be reached. The crop was harvest at least 1 month before planting and stems were stored. Planting in the projects receiving the stakes was delayed and complicated by drought, and in spite of the prime-quality of planting materials, several fields have moderate stand. The project will continue for another cycle, in order to bring the in-vitro derived planting material to the target region. A total of 35 technical support staff participating in multiplication projects in the region was trained in production and management of cassava planting material, and a network was formed to share information and planting material.

Improved varieties select together with final users and diffused

Brazil: **Tiangúa** (Selection from a cross made at CIAT, involving SM 975-1). This variety was selected as resistant to witches-broom (super-brotamento) in the State of Ceará (Serra de Ibiapaba). The disease constitutes the main constraint to cassava production in the region, affecting 80 % of the plantations and reducing cassava yields in 40% for those highly affected areas. Tiangúa was selected both at experimental station trials, and at participatory on-farm evaluation trials, as being an genotype with precocity. It produces 44% more yield than the local check at 12-mo harvest.

Caitité: It was selected for the coastal areas of the State of Bahía. It comes from a cross made at CIAT between ICA-Catumare (CM 523-7) and CM 825-3. It produces 53% and 32% more yield than the local check (Cigana Preta) at 10 and 12-mo, respectively, in farmers fields. The average farinha yield was 33%, the highest in a set of elite evaluated genotypes, which is a reflection of a salient trait of ICA-Catumare (excellent root dry matter content).

Bibiana: This variety was selected from a cross between MCOL 1684 and MVEN 52, for the coastal areas of Bahía. Under normal conditions, it yields 13% and 26% above the local check (Cigana Preta) at 10 and 12-mo, respectively. The main feature of Bibiana is its resistance to root rot caused by Fusarium. Selected in Bahía, is now being tested in Sergipe as part of the IFAD-funded PROSERTAO project, where root rots represent the main biotic constraint for cassava production.

Cuba. **INIVIT Y-93-4**: Selected from segregating progenies targeted to acid soil savanna ecosystem, introduced from CIAT; this variety shows a high root yield potential (48 t/ha, compared to 36 for the local check Señorita), together with good production stability. Although it was selected for the central region of Cuba, recent testing in other areas revealed its broad adaptability. Its main use is for human consumption, although its high root dry matter content will make it appropriate for processing also (starch or dry cassava).

Upgrade yield capacity and adaptation of cassava breeding populations in Asia

Germplasm development

In our operation at the Thai/CIAT collaborative cassava breeding program at Rayong Field Crop Research Center major physiological yield components, such as biomass and harvest index, are quantitatively measured at every stage of evaluation/selection. Thus, following the population mean of whole entries at a certain evaluation stage year after year leads to a reliable assessment of the selection progress over a period of time. Mean of the clonal population being evaluated at the advanced stage of regional trials appears to be the best indicator of our selection progress as a whole. At this stage a good number of advanced materials are evaluated in a multi-locational scheme and the clonal entries represent the possible change that can take place in near future by the release of these entries, as well as the level of breeding materials (hybrid seeds) our CIAT/Thai collaborative program can offer to other national programs and CIAT/Colombia.

An additional advantage of taking population means rather than the yield data of the best performer is to minimize the error factor. The very high yield of a top performer could not usually be repeated, because the major portion of phenotypic value was of non-genetic nature.

This significant yield increase in the actual dry root yield of the breeding population in the past 15 years (by more than 150%), must have been attained not only by the genetic effects but also by the improvement in field management of the yield trials during the same period. The comparison of the population mean with the mean of the control (Rayong 1) gives a clearer picture. The highly convincing genetic improvement in the dry root yield level of breeding population (**Fig. 3.2**). Of the total genetic improvement a larger proportion (about 2/3) corresponds to the improvement in fresh root yield, and a smaller but very significant proportion (about 1/3) corresponds to the improvement in root dry matter content (**Fig. 3.2**).

Fresh root yield results from the product between biomass and harvest index, where the former represents the integrated assimilation activity of the plant, while the latter represents the division of

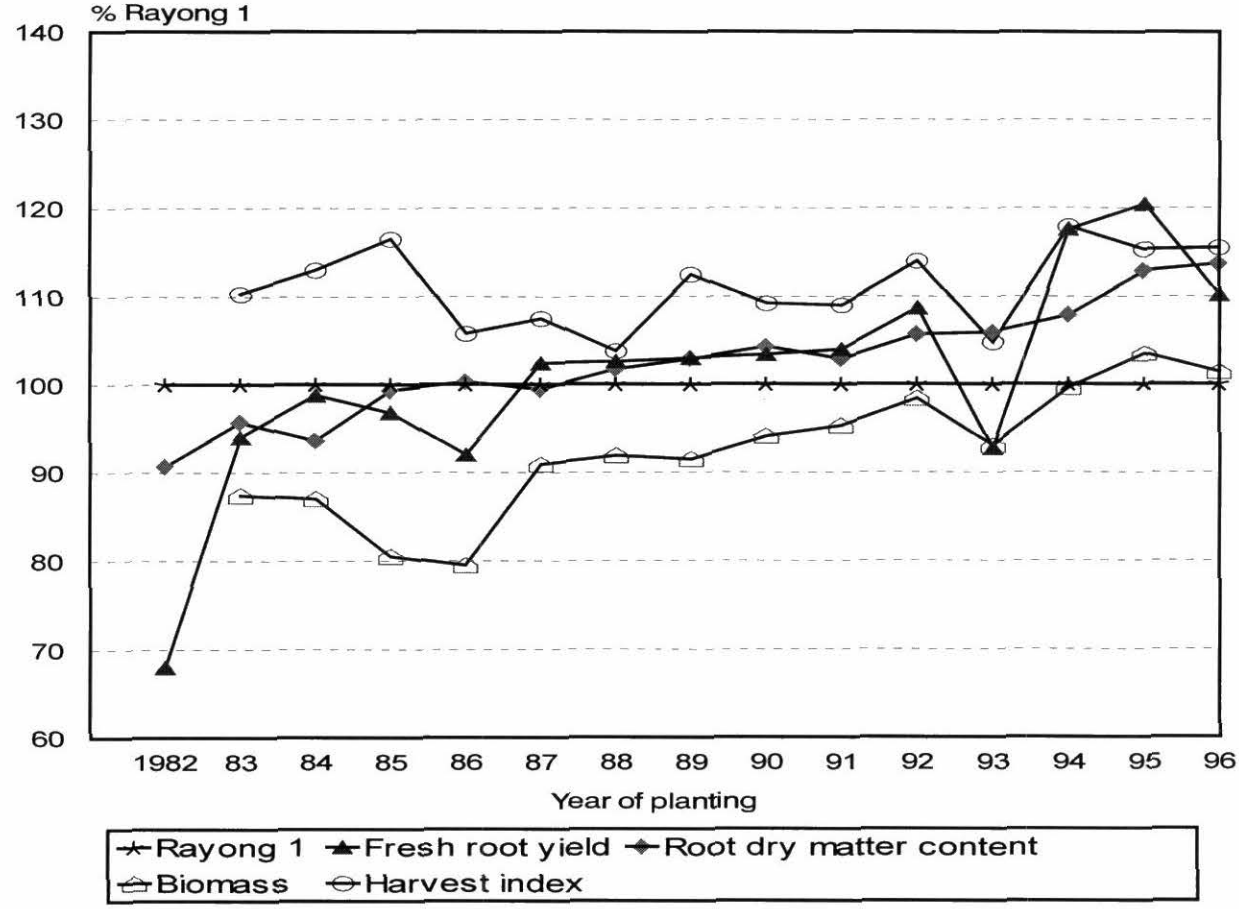

Figure 3.2. Change in the mean of breeding populations (all entry mean in yield trial) in fresh root yield, root dry matter %, biomass and harvest indes during the 1980/90s at Thai/CIAT collaborative cassava program in Rayong, Thailand.

the assimilated mass into economically utilizable product. Of the improvement in fresh root yield, a major part (25 to 30%) corresponds to the improvement in biomass, and only a minor part (5 to 10%) corresponds to the improvement in harvest index (**Fig. 3.2**). Genetic improvement in cassava yielding ability in the past 15 years at Rayong FCRC is due firstly to the enhanced biomass and secondly to the elevated root dry matter content. This is in a good contrast to the earlier population improvement at CIAT/Colombia during the 1970s where the elevated harvest index was the predominant factor.

Five successful cultivars have been released in the past 13 years and another new cultivar (CMR33-57-81) may be released next year. The yield data of these cultivars from the regional yield trials in three years and the year of their release clearly testify the history of our yield breeding, and suggest a possibility of further improvement (**Table 3.8**).

The overall yield superiority of CMR33-57-81 is clear but its root dry matter content, though significantly higher than that of Rayong 1, is somewhat far from what we wish. Recent results from Standard Yield Trials, involving a breeding population three years later than CMR33 population, appeared to be promising in combining high fresh yield with high dry matter content beyond the level of Kasetsart 50 (**Table 3.9**).

It was clearly noticeable ten years ago that CIAT/Colombia hybrids did not offer the same selection opportunity as Rayong hybrids for the conditions in Thailand (**Table 3.10**). While some improvement with the CIAT/Colombia materials was made, the Rayong materials were also improved and the superiority of the Rayong materials persisted up to now. In the mean time, it became clear that the Rayong materials offered better selection opportunities in other national breeding programs in Asia as well. As a result, the percentage of selection within Rayong materials has been always significantly higher than that with CIAT/Colombia materials. Most Rayong hybrids come from cross parents selected locally from CIAT/Colombia hybrids; thus, the difference between CIAT/Colombia and Rayong hybrids is indebted to the effect of Rayong selection on cross parents.

Our fourteen years of observations on our multistage breeding program in Thailand yielded three M.S. thesis, one Ph.D thesis and one academic article in Crop Science (1998 Vol. 38(2)), and the following conclusion: 1. Broad-sense heritability and phenotypic correlations obtained at a given selection stage may lead to erroneous selection schemes. 2. Regression across evaluation stages gives the most useful information. 3. In early evaluation stages, eliminating inferior phenotypes is more beneficial than selecting superior phenotypes. 4. Selection of root dry matter content can be conducted without serious effects on other yield components. 5. Harvest index has consistently high heritability at each evaluation stage, while biomass and yield have low heritability. 6. Genotype x evaluation stage interaction of yield is greatest between single-row trial and plot trial, while that of harvest index is much smaller. Selection at single-row trial is most crucial to the final success of selection for higher yield. 7. Indirect selection for yield through harvest index is more effective than direct selection by yield itself especially in the early evaluation stages.

Table 3.8. Yield performance of six new cultivars and two traditional cultivars in regional trials in Thailand, harvested in three cropping seasons from 1994 to 1997 (Mean values from seven regional trials).

Clone	Parents	Year of release	Dry root yield (t/ha	Fress root yield (t/ha)	Root dry matter content (%)	Biomass (t/ha)	Harvest index
CMR33-57-81	R1 x R5	1998	13.0	38.7	33.7	62.0	0.63
Rayong 5	27-77-10 x R3	1995	11.5	33.4	34.3	58.4	0.58
Kasetsart 50	R1 x R9	1993	11.7	33.7	34.8	60.1	0.57
Rayong 90	CMC76 x V43	1991	11.2	31.8	35.4	53.0	0.60
Rayong 60	M Col 1684 x R1	1987	10.5	31.1	33.2	55.5	0.56
Rayong 3	M Mex 5 x M Ven 307	1984	9.3	26.1	35.5	45.0	0.58
Rayong 1	(Leading local cultivar until 1997)		9.4	29.6	31.7	58.0	0.51
Habatee	(Traditional table cultivar)		5.8	18.3	31.7	43.6	0.42

Table 3.9. Result of Standard Yield Trials (mean of three locations) in Thailand in 1996/97.

Clone	Parents	Dry root yield (t/ha)	Fresh root yield (t/ha)	RDMC (%)	Biomass (t/ha)	Harvest index
Selected clones						
CMR36-31-381	R5 x OMR29-20-118	13.4	36.8	36.3	54.8	0.68
CMR36-54- 40	CMR30-71-25 x CM3299-15	13.4	38.2	34.5	54.4	0.71
CMR36-30-329	R5 x KU50	13.3	35.4	37.2	58.4	0.61
CMR36-90- 2	KU50 x R5	13.0	35.5	36.0	54.7	0.65
CMR36-71- 33	CMR31-19-23 x KU50	12.9	36.6	34.8	51.5	0.72
CMR36-55 166	CMR30-71-25 x R5	12.6	36.6	34.3	48.4	0.76
Recommended cultivar						
Kasetsart 50	R1 x R90	12.5	34.4	36.3	51.9	0.67
Rayong 5	27-77-10 x R3	12.4	34.7	34.9	48.3	0.72
Control						
Rayong 1		10.0	30.1	32.3	51.5	0.59

Breeding material distribution

During the past 22 years, a total of 485,717 hybrid seeds have been distributed from CIAT/Colombia to national breeding programs in Asia, of which Thailand received the largest share of 177,331 hybrid seeds. More than 100,000 hybrids seeds have been contributed from the Rayong program to other national programs in Asia and CIAT/Colombia from 1985 to 1996 and another 10,415 hybrid seeds are to be distributed this year, making the total number 112,555 seeds in the past 13 years (**Table 3.1**).

Aside from maintaining a world cassava collection of more than 6,000 accessions at CIAT in Colombia, we have distributed more than half a million genotypes in the form of hybrid seeds produced with widely varied parental accessions, to Asian national cassava breeding programs over the past twenty years. The total amount of genetic variability thus transferred from the center of origin and diversification to Asia exceeds by far the genetic variability introduced spontaneously to Asia in the past three centuries. Much of this genetic variability is being actively utilized at many cassava research stations all over Asia. Furthermore, in releasing many new cultivars, we are actually increasing the diversity of cultivars in farmers' fields in many parts of Asia, contrary to the general belief that the dissemination of internationally developed new cultivars eliminate local genetic diversity. Genetic variability not in a utilizable form has a low potential of benefiting producers. Germplasm materials within easy reach of practicing breeders, whether they are institutional or spontaneous, provide the real potential. Our objective has been to enhance both the quantity and the quality of genetic variability utilizable to national breeding programs.

Table 3.10. Comparison between Rayong (Thai/CIAT) and CIAT/Colombia clones in Single-row Trial at Rayong, Thailand over 12 years.

	1986/87[1]		1991/92[1]		1995/96[2]		1996/97[2]	
Character	Rayong clones	CIAT clones (% Rayong clones)	Rayong clones	CIAT clones (% Rayong clones)	Rayong clones	CIAT clones (% Rayong clones)	Rayong clones	CIAT clones (% Rayong clones)
Dry root yield (Kg/plant)	1.10	0.80 (73)	0.84	0.68 (81)	1.18	1.08 (92)	0.77	0.70 (91)
Fresh root yield (Kg/plant)	3.21	2.44 (76)	2.53	2.19 (87)	3.62	3.44 (95)	2.55	2.39 (94)
Root dry matter content (%)	34.3	32.9 (96)	33.1	30.9 (93)	32.7	31.6 (97)	30.0	29.2 (97)
Biomass (t/ha)	5.71	4.81 (84)	4.20	4.08 (97)	5.82	5.97 (103)	3.92	3.79 (97)
Harvest index	0.56	0.51 (90)	0.60	0.54 (89)	0.62	0.58 (93)	0.65	0.63 (97)
Plant type rating[3]	3.42	2.87 (84)	3.99	3.35 (84)	4.23	3.56 (84)		
Germination/survival of planting stakes (%)[4]	72.6	45.3 (62)	83.4	75.3 (90)	91.5	82.8 (90)		

[1] Mean of all entries in Single-row Trial (1228 Rayong and 735 CIAT clones for 1986/87 and 1696 Rayong and 621 CIAT clones for 1991/92).
[2] Mean of primary selections in Single-row Trial (378 Rayong and 104 CIAT clones for 1995/96 and 309 Rayong and 66 CIAT clones for 1996/97).
[3] 1 = very poor, 5 = very favorable.
[4] Data from PYT of the following year.

Varietal release and dissemination

Three new clones (OMR33-17-5 as KM 95, SM1157-3 as KM 95-3, and SM937-26) in Vietnam and three new clones (CMP62-15 as VC6, CMP21-15 as VC7, and CM3422-1 as Lakan 4) were officially released, making the total number of officially release CIAT-related cultivars in Asia 31 (Thailand 7, Indonesia 3, Philippines 10, Malaysia 2, China 4, Vietnam 5).

According to latest statistics and estimations, the area planted with CIAT-related new cassava cultivars reached 0.622 million ha, or 64.4% of the total cassava area in the 1996/97 planting season in Thailand (**Fig. 3.3**; **Table 3.11**); 0.136 million ha in Lampung, Sumatra, Indonesia; and 21,300 ha in South Vietnam (Table 7). This and additional smaller areas in other countries gives the total area planted with CIAT-related new cassava cultivars 0.787 to 0.860 million ha in five countries (Thailand, Indonesia, Vietnam, Philippines, China) in Asia. As a consequence of these, we can now clearly see a significant increase of mean cassava yield at the country (Thailand, **Fig. 3.4**) and the provincial (Dong Nai, South Vietnam, **Fig. 3.5**) levels.

Economic effects of improved germplasm

Economic effects generated by new cassava cultivars, were based on the sales value of additional products directly attributable to the adoption of new cultivars. Value of sales includes production costs and net profits. For regular commercial operations, net profit rather than the value of sales may be more critical. However, in the national development context, value of sales may be more important indicator of the socio-economic benefits, as it represents employment, purchasing power and the availability of useful products.

Only two parameters were used to measure economic gain; additional (or reduced) field production of fresh cassava roots due to the higher (or lower) yield of new cultivars and additional factory starch (or chips) production due to the higher starch (or dry matter) content of new cultivars compared with the traditional cultivars.

For the yield and starch content advantage (or disadvantage) conferred by the adoption of new cultivars, the means of many on-farm trials were used (**Tables 3.11**, **3.12**). For on-farm price of fresh cassava roots and factory starch price, the low price in Thailand for 1996/97 was considered.

The additional economic effects caused by the higher starch content has been highly significant. Until recently, virtually all the economic benefits have been due to the higher starch content of new cultivars. The additional value due to the adoption of new cultivars is estimated to be 42.4 million US dollar in fresh root production and 87.6 million in starch production for the 1996/97 season in Thailand (**Table 3.11**).

In Indonesia, the additional fresh root yields in the fields and the additional starch production in the factories due to the adoption of new cultivars induced substantial economic

Table 3.11. Yield advantage of new cassava cultivars and monetary gain caused by their adoption in Thailand in 1996/97.

			Yield difference from the traditional cultivar, Rayong 1 in:		Monetary gain per unit area over Rayong 1, in:[3]			Total additional sale value due to adoption of new cultivar in	
Cultivar	Fresh root yield (t/ha)[1]	Root starch content (%)[2]	FRY (t/ha)	Starch content (%)	FRY ($/ha)	Starch ($/ha)	Area planted in 1996/97[4] (1000ha)	FRY ($ 1000)	Starch ($ 1000)
Rayong 1	16.5	16.1					344		
Rayong 3	14.5	22.0	-2.0	5.9	-60	188	4	-240	752
Rayong 60	17.7	17.0	1.2	0.9	36	35	201	7,236	7,035
Rayong 90	18.5	22.7	2.0	6.6	60	269	139	8,340	37,391
Kasetsart 50	19.7	19.8	3.2	3.7	96	160	149	14,304	23,840
Rayong 5	19.8	19.0	3.3	3.3	99	144	129	12,771	18,576
Total:								42,411	87,594

[1] Mean from on-farm yield trials conducted in 8 provinces in 1994/95 and 1995/96; Rayong 1 16.5 t/ha FRY and 16.1% starch content.
[2] Mean from Regional yield trials in 7 locations in 1994/95, determined by Reinmann scale.
[3] Based on the low 1997 price; $30/t for fresh roots and $220/t for starch.
[4] Data by Department of Agricultural Extension.

Table 3.12. Yield advantage of new cassava cultivars and monetary gain caused by their adoption in four Asian countries outside Thailand in 1996/97.

Region/country	Cultivar	Fresh root yield (t/ha) [1]	Root starch content (%) [2]	Yield difference from traditional cultivar in: FRY (t/ha)	Starch (%)	Monetary gain per unit area over traditional cultivar in[3] FRY ($/ha)	Starch ($/ha)	Area planted in 1996/97 (1000 ha) [4]	Total additional sale value due to adoption of new cultivar in: FRY ($ 1000)	Starch ($ 1000)
Sumatra/ Indonesia	Traditional	20.2	18.1							
	Adira 4	28.2	23.4	8.0	5.3	240	329	136	32.,640	44,744
South Vietnam	Traditional	12.0	20.0							
	KM 60	20.0	23.0	8.0	3.0	240	132	16.5	3,960	2,178
	KM 94	22.0	23.0	10.0	3.0	300	145	4.8	1,440	696
North Vietnam	Traditional	14.3	27.9							
	KM 60	19.4	29.6	5.1	1.7	153	73	0.27	41	20
	KM 94	19.9	30.7	5.6	2.8	168	122	0.08	13	10
Mindanao/ Philippines	Traditional	10.0	19.0							
	VC 5	16.0	19.0	6.0	0	180	0	5.5	990	0
Bohor/ Philippines	Traditional	10.0	19.0							
	Lakan	15.0	22.0	5.0	3.0	150	99	1.5	225	149
Guangxi/ China	Traditional	17.4	25.6							
	New cultivars	20.0	29.7	2.6	4.1	78	180	0.06	5	11
Total									39,314	47,808

[1] Means from large plot yield trials in Indonesia. Means from On-farm yield trials in Vietnam, Philippines and China.
[2] Means from regional yield trials. Determined by Reinmann scale.
[3] Based on the low 1997 Thai price; $30/t for fresh roots and $220/t for starch.
[4] Data for Indonesia given as 115% of the 1995/96 figure given by UJF, by Hung Loc Ag. Res. Center in South Vietnam, by BTAFRC and RCRC in North Vietnam, by PRCRTC in the Philippines, and by GSCRI in China.

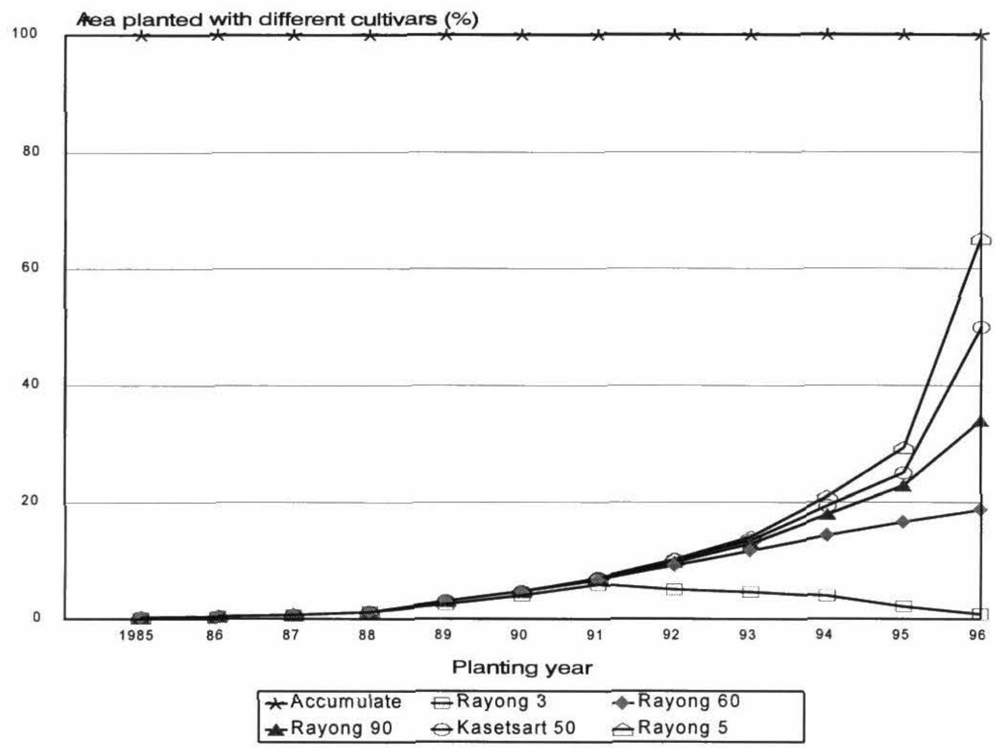

Figure 3.3. Change in area planted with different cassava cultivars in the latest 12 years in Thailand (Dptm. Of Agric. Extension, Thailand.

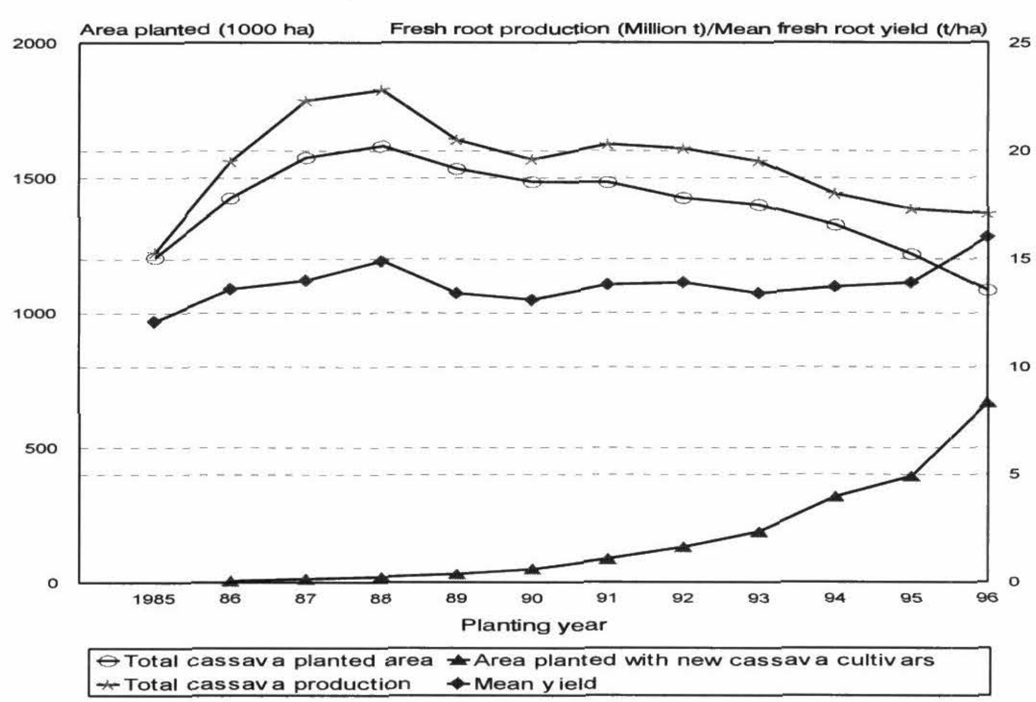

Figure 3.4. Changes in total cassava planted area, area planted with new cultivars, mean yield and total production in the past 12 years in Thailand.

gains, 32.6 and 44.7 million US dollars, respectively (**Table 3.12**). In Vietnam, more money has been made by the sales of planting stakes of new cultivars than fresh root harvests and higher starch content in the previous years, although the benefits caused by the additional fresh root production and the additional starch production would outstrip the stake sale from the 1996/97 season.

Throughout all these processes, the advantage of higher starch content was highly significant. It is the higher starch content rather than the higher fresh yield of new cultivars that accelerated the adoption of new cultivars. The total economic effects due to the superior yield and quality of new cultivars accumulated in the past 10 years is estimated to be 693 million US dollars in Asia.

Poverty alleviation in relation to varietal adoption

Virtually all the cassava production takes place in small farmers' fields and all the harvests are sold to the processors in Thailand. In Vietnam also, all the cassava is produced by small farmers, and in South Vietnam those advanced cassava farmers who have adopted the new cultivars sell virtually all the harvests to the processors. In Indoensia and the Philippines, some field productions are handled by large plantations; yet, the majority of production takes place in small farmers' fields. Thus, we can assume that virtually all the additional economic effects gernerated by the higher fresh root yield of new cultivars are entering directly to the pockets of small farmers.

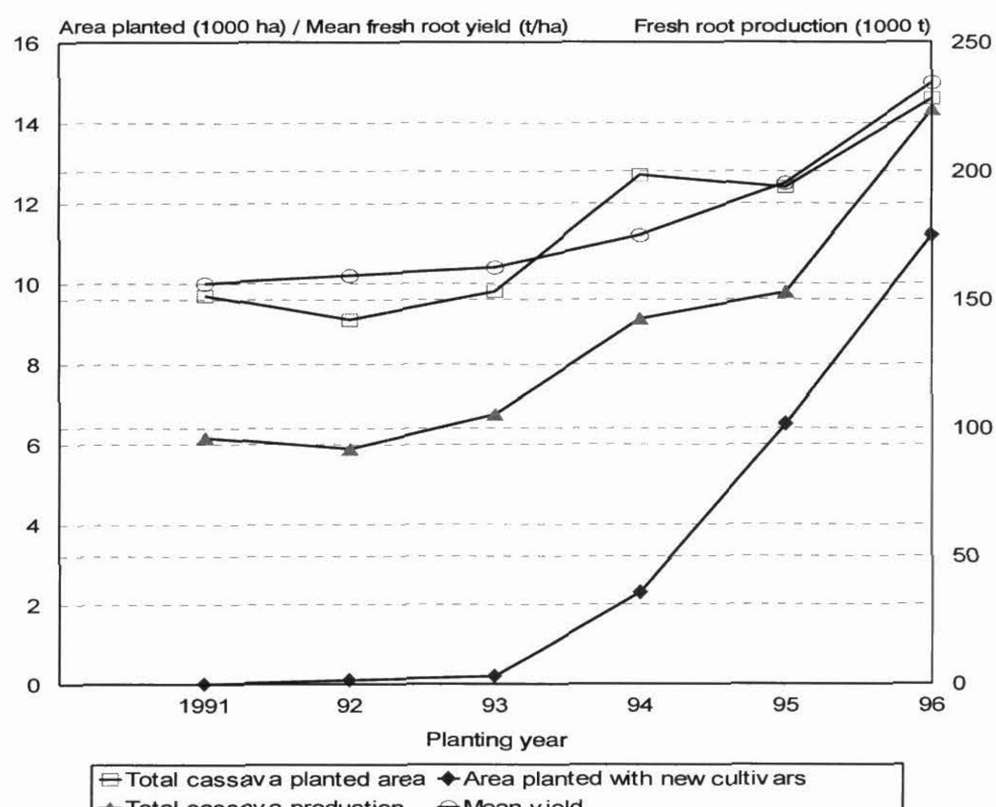

Figure 3.5. Change in cassava planted area, area planted with new cultivars, mean yield and production in Dong Nai province, Vietnam.

On the other hand, how much of the additional profit generated by the higher starch content of new cultivars is shared by the farmers depends on what differential prices starch factories (or chipping plants) pay to the farmers. If factory pays the same price for roots of different starch content (in other words, does not honor or recognize the breeders' and farmers' efforts to produce higher quality products), all the additional profit would be absorbed by the factory.

Most large factories are returning 55 to 100 % of the value of additional starch production caused by higher starch content of the raw material to the farmers. We can safely assume that a substantial portion, more than a half, of 693 million US dollars so far generated by the adoption of new cultivars has entered the household income of small farmers.

The recent varietal dissemination in North Vietnam revealed that thousands of small farmers are adopting new cassava cultivars in their small plots (360-5000 m^2). Virtually all of them use the additional cassava yield for pig feeding which results in 50-600 kg additional sale (US$45-545) per family per year to the market. A new technology component (improved varieties) is spreading thin and wide very democratically creating economic opportunities for bettering their farm lives, representing the most equitable contribution of crop breeding.

<u>Natural resource management and cassava breeding</u>

Cassava is often quoted as a crop conducive to soil degradation. Much efforts are directed to identify soil management methods to lessen soil erosion or mineral nutrient exhaution. While individual methods are important and indispensable components of soil management, a more fundamental requirement is to first upgrade the economic situation of farmers so that the farmers can consider the long term future of their farming and start adopting better soil management practices. Here, to cut the vicious cycle of poverty and environmental mismanagement is the most crucial factor. Among many technical components that constitute good farm management, improved cultivars may be the most readily adoptable component to induce good resource management. The following comment by Dr. Tran Ngoc Ngoan, Deputy Director of Agro-Forestry Research and Development Center of Thai Nguyen University, tells all about this; "A good variety is a prerequisite for implementing any soil management practice, primarily to interest farmers and secondly to improve their economic conditions".

Facilitate communication among cassava scientists

The project on cassava germplasm development remains as 100% cassava research activity within CIAT. After the dissolution of the Cassava Program (Dec. 31, 1996), our project took the lead to maintain the communication and coherence in the area of cassava research at CIAT. For that purpose a group denominated the Cassava Committee was formed, and has met at least once a month, to deal with aspects that cut across projects, and to foster the interaction among projects. There are several issues that were handled by the Leader's office before, mainly relating to inter-institutional relationships, which should be attended on the light of our standing global mandate in cassava. All our partners and collaborators were communicated about the transition from a Cassava Program to research in cassava organized through projects, and the way they can communicate with us, depending on the area of interest. The Committee has prioritized areas of research that will promote integration of scientists across projects, such as proposals related to novel plant type and genetic modification of cassava starch.

The second phase of the IFAD-funded project for cassava germplasm development, crop management and processing in the semi-arid of Brazil and Africa, started in January 1997. Although a planning meeting was to be held, we articulated to develop a joint work plan through electronic mail, involving CIAT, CNPMF (Brazil) and IITA. Money saved from that planning meeting will be invested in trips to experimental sites during the first year. After the official closing down of the IITA-CIAT liaison scientist position (March 1996), the interaction with IITA has been reduced, with the exception of the Inter-Center Committee on Root and Tuber Crop Research. We expect to re-gain momentum through the IFAD-funded project during the following 3 years.

A joint planning meeting with EMBRAPA took place in August. In the area of cassava germplasm development, and based on the success we have had in the semi-arid through the IFAD-funded project, we plan to replicate such experience in other ecosystems of importance for EMBRAPA and CIAT (i.e. humid tropics, acid soil savannas, sub-tropics). It will constitute one more step towards strengthening our position in Brazil, and being able to continue our contribution to the global mandate through the work developed in Brazil, at a time of diminishing resources for work developed at CIAT's Head Quarters.

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1. Alvarez, E., Loke, J.B., Sánchez, J., Chacón, M.I. and G. Llano. 1997. Molecular characterization of Phytophthora species from Cassava (*Manihot esculenta*) in Colombia. Plant Disease. In preparation.

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7. Yeoh HH; Sanchez T; & Iglesias C. 1997 Cyanogenesis in cassava: Genetic variability in cyanogenic potential of cassava and possible more of inheritance. (Submitted to J. Agric. Sci.).

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9. Yeoh HH; Sanchez T; & Iglesias C. 1997 Enzyme-based dip-stick: An easy-to-use alternative for estimation of cyanogen level in cassava roots. (To be presented at the XI ISTRC meeting in Trinidad & Tobago, will appear in the Proceedings)

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2 Alvarez, E. and M. L. Molina. 1997 . Caracterización Morfológica y Molecular de Aislamientos de *Sphaceloma manihoticola* (Bitancourt & Jenkins) en Colombia. ASCOLFI - 1de Agosto.

3 Alvarez, E.; Sánchez. J.; Chacón, M. I. and J.B. Loke. 1997. Pudrición de raices en Colombia: Avances en la caracterización de aislamientos de *Phytophthora* spp. de yuca. ASCOLFI - 1 de Agosto.

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