PROJECT IP-3

IMPROVED CASSAVA FOR THE DEVELOPING WORLD

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IP-3: Improved Cassava for the Developing World - Project description

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)

IMPROVED CASSAVA FOR THE DEVELOPING WORLD

The crop

Cassava (*Manihot esculenta* Crantz) is a starchy root crop that has been cultivated in tropical America for more than 5,000 years. It was introduced to Africa and Asia by Portuguese explorers and traders during the 16 century. Cassava represents the alimentary basis for over 500 million people in the tropics, and it is grown in over 90 countries. Most of the crop is produced by small-scale poor farmers in marginal regions using traditional farming methods. The crop is used both as food and feed, and it represents one of the few linkages for farmers in those regions to dynamic markets.

Cassava is grown over 16 million hectares, with 50% in Africa; 30% in Asia and 20% in Latin America. Total root production is over 150 million; the five major producing countries being: Brazil (24 million tons, Mt), Nigeria (21 Mt), Zaire (20 Mt), Thailand (19 Mt) and Indonesia (15 Mt). The greatest consumption of cassava is in Africa, with an average 88 kg per capita (highest in Zaire with 387 kg per capita). Of the total world production, 80% is used domestically (61% food; 26% feed; 2% industrial uses and 11% waste). Cassava for feed is exported as chips, pellets or starch to developed countries. Cassava is mainly processed on a small scale in rural areas, generating considerable employment, and improving the economic status of socially depressed areas in the tropics.

The cassava root contains between 30 and 40% dry matter (mostly carbohydrates); it is rich in vitamin C, Ca and K, and poor in proteins. In contrast, the leaves contain high levels of protein (8%-10% of fresh weight). Cassava roots are eaten in different ways: boiled, baked, fried, as meal, flour, etc. Starch produced from cassava roots is also used to make a variety of sweet and savory foods such as crackers, tapioca pearls, noodles, or cheese breads. In some parts of the world, cassava leaves are consumed as a vegetable.

Cassava is known to produce well despite marginal conditions of soil and climate, due to its extensive fibrous root system, the sensitivity of stomata to drier climates, its association with soil mychorrhizae and the capacity to recover foliage once it is lost. Cassava can be grown in environments that receive less than 600 mm to more than 3,000 mm/year of rain. Although cassava is typically a tropical lowland crop, it can be found up to 2000 masl. It does not tolerate frost or flooding well. The crop can be harvested from 7 months to 2 years after planting. It stores relatively well underground, and once it is harvested it has a very short shelf-life (3-7 days), and must be consumed or processed immediately.

Cassava is vegetatively propagated through stem cuttings; which allows to fix any gene combination that suits the farmer or the breeder. The most important source of genetic variability is through sexual recombination. Male and female flowers are separated in the same inflorescence (monoic), being a protogenic species. Each pollinated flower has the potential to produce 3 mature seeds. Natural pollination is done by bees.

Although most of the genetic variability used in breeding programs comes from the cultivated cassava, there are more than 100 species within the genus Manihot, that can cross to cassava with different degrees of difficulties and contribute genes of interest to breeders.

CIAT has a collection of close to 6000 cassava accessions formed by landraces from Latin America and Asia, elite clones selected by CIAT and IITA, and 29 wild Manihot species. This collection is maintained in the field and in vitro, and has been characterized using morphological, biochemical and molecular descriptors.

Achievements from CIAT's cassava research

Sources of resistance or tolerance to major pests, diseases and abiotic stresses:

- Genotypes combining high levels of resistance to bacterial blight and super elongation disease, with good agronomic performance selected in Eastern Colombia.
- Complementary sources of resistance to different bacterial blight pathotypes selected.
- Genotypes with high levels of resistance to different pathogens causing root rots have been selected, and are being used in crosses to pyramid those genes and for molecular mapping.
- Highly heritable resistance to whiteflies has been detected and is being combined with desirable agronomic traits.
- Reduced levels of whitefly oviposition is one of the resistance components consistently transferred to the progenies.
- A RAPD marker has been associated to whitefly resistance, and will aid in future breeding.
- Sources of resistance to green mites, which are stable across evaluation sites have been found.

Sources of desirable root quality characteristics:

- Cassava roots and leaves have been characterized as sources of micro-nutrients for marginal regions of the tropics. There is good potential for vitamins A and C in the roots and minerals in the leaves.
- Genotypes with prolongued storability have been incorporated in crosses for future breeding and molecular mapping.
- Cassava starch can be used in processes that require resistance to acid media and freezing. Cassava starch can compete well with maize starch in food and industrial processes.

Gene pools for lowland semi-arid, sub-humid, humid, mid-altitude, highland tropics and sub-tropics:

- Between 1996-98 a total of 458,027 recombinant seeds were produced; 253,148 were distributed to National Programs in Latin America and Asia and IITA, the rest was used in our breeding process, or kept in storage.
- An average superiority of 68 % of the best selected parents over check varieties was achieved across ecosystems during the last 3 years. Largest improvement obtained for the highland tropics ecosystem, followed by mid-altitude tropics and the acid soil savannas.
- The significant genetic improvement in cassava yielding ability at Rayong FCRC(Thailand) is due firstly to the enhanced biomass and secondly to the improved harvest index.

Improved breeding methodologies, including farmer participatory approaches:

- Gene tagging to facilitate future cassava breeding is on its way for the following traits: whitefly and root rot resistance, and reduced post harvest deterioration, using the molecular map developed at CIAT.
- Farmer participatory evaluation of advanced selection is an integral part of the cassava germplasm development schemes implemented in Northern Colombia and North-East Brazil.
- 60 technicians in Brazil and Colombia have been trained in participatory breeding.
- A software for the analysis of farmer participatory breeding data has been developed and made available to National Programs.

Networks and trained national personnel for effective dissemination of genetic material:

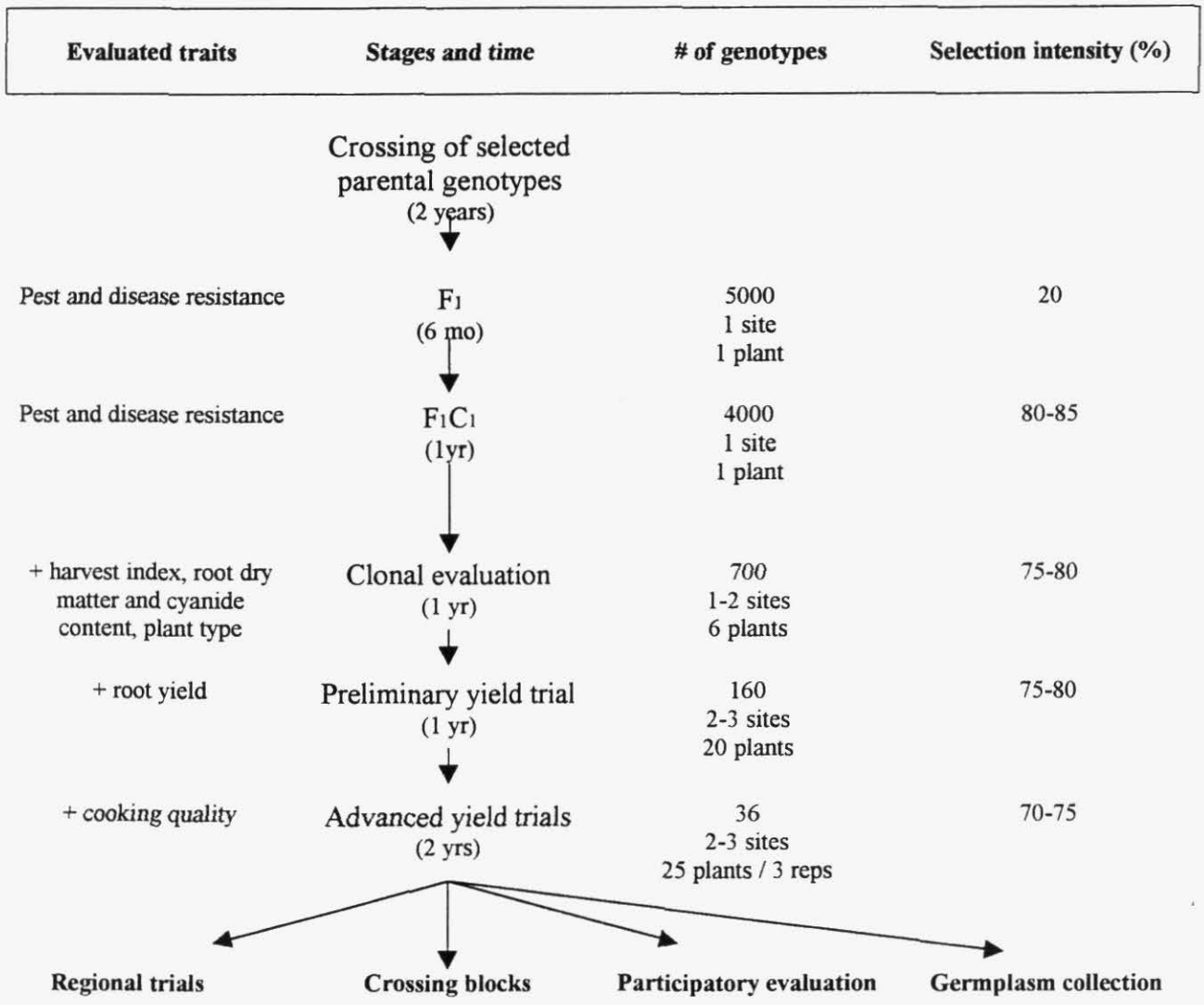
- Latin American and Asian networks of scientists have been supported through the organization of workshops, local training and supply of improved germplasm.
- 14 new varieties released within the Latin American and Asian network, during 1995-98.
- Improved varieties developed from CIAT's germplasm cover about 1,000,000 has in Latin America and Asia.
- Benefits derived from improved CIAT's germplasm have accumulated to U$ 800 millions across continents, since the inception of our breeding program.

The research strategy

The major goal of our project is to contribute in increasing and stabilizing cassava production in diverse environments and for different markets, by developing improved gene pools in cooperation with national programs. The purpose of our project is to generate basic understanding, tools and improved cassava germplasm for sustainable enhancement of cassava production and the diversification of end-uses in relevant ecosystems. The most important ecosystems are: the semi-arid (below 800 mm/year, unimodal); the sub-humid (800- 1500 mm /year, bimodal rainfall distribution), the acid soil savannas (1500 – 3000 mm/year, short dry period, low pH). The humid tropical lowlands; the mid-altitude tropics; the high-altitude tropics and the subtropics represent ecosystems of secondary importance in terms of area and total production. The main selection activity is conducted in sites selected to represent the conditions of the target ecosystem. For each of the zones we conduct a recurrent selection program, with a progressive set of stages as described in **Figure 1**.

As the breeding stages progress, we give emphasis to traits of lower heritability, because we have more planting material for each genotype, and the evaluation can be conducted in bigger plots with replications. Certain selection criteria are of general importance across ecosystem (i.e. yield potential, dry matter content), while others are specific for each ecosystem (i.e. pest and diseases). Elite genotypes are used as parents to obtain recombinant seed that is used to initiate a new selection cycle, and also transferred to National Programs for their adaptive selection programs. Besides the selection of superior genotypes a major research priority is the development and use of research tools that will shorten the breeding cycle and increase its efficiency, such as molecular marker assisted selection, and farmer participatory evaluation at early stages of the breeding cycle. New sources of resistance to major biotic and abiotic constraints, and favorable alleles for root quality traits are constantly being incorporated through recombination and selection.

Figure 1. Basic cassava breeding scheme applied for each of the priority ecosystems.



Collaboration with National Programs: CIAT has been actively involved with CORPOICA and CNPMF/EMBRAPA in the development and implementation of methodologies for the evaluation and selection of cassava germplasm with the participation of end-users. Also with CNPMF/EMBRAPA, a program has been developed for the development of cassava germplasm with adaptation to semi-arid conditions, and potential to be transferred to homologous conditions in Africa and Asia. In Thailand, CIAT works with FCRI, on the development and diffusion of improved cultivars that have improved and diversified the genetic base for cassava production in the region. This work has had a tremendous impact on cassava production in Asia with wide dissemination of improved varieties. CIAT and IITA have actively collaborated in the development and introduction of germplasm into Africa, combining elite Latin American genotypes with sources of resistance to African Cassava Mosaic Disease. Recently, in Latin America, an active interaction with the private sector involved in starch and feed production has been initiated, to learn more about their demands and tap new sources of financial support.

In Asia and Latin America and the Caribbean, there are relatively few strong cassava breeding programs. Among them are EMBRAPA/CNPMF (Brazil), INIVIT (Cuba), CORPOICA (Colombia), FCRI (Thailand), and IAS (Vietnam).

Current activities and results

Our project has centered its activities around the consecution of the following three outputs:

1. Genetic base of cassava and Manihot species evaluated and available for genetic improvement.
2. Genetic stocks and improved gene pools developed and transferred to National Programs and IITA.
3. National Programs in tropical and sub-tropical Latin America and Asia supported in adaptive selection and deployment of improved cassava varieties.

The main activities developed during the last 3 years, along with the main results are:

1. Genetic base of cassava and Manihot species evaluated and available for genetic improvement.

Activities	Summary of results
1.1. Germplasm characterized for reaction to cassava bacterial blight (CBB); super-elongation disease (SED) and stem and root rot diseases (RR), resistance under field and greenhouse conditions	
• Evaluate cassava genotypes for CBB and SED reaction in Villavicencio and Matazul	1254 genotypes evaluated for CBB and SED reaction. 526 in Carimagua, 483 in Villavicencio and 245 in both sites. 62 clones found tolerant in Villavicencio and 71 in Carimagua; 37 clones were tolerant in both sites, 5 of with 5 cycles of evaluation.
• Evaluate cassava genotypes for RR reaction in the greenhouse	16 out of 430 genotypes selected as resistant to *Phytophthora drechsleri* by stem inoculation of young plantlets in the greenhouse. Ten of them also have resistance to *Phytophthora parasitica* and *Phytophthora cryptogea*. 30 genotypes resistant to *P. drechsleri* by evaluation of roots from a group of 150.
• Evaluate 60 genotypes with different pathotypes of CBB causal agent.	103 genotypes evaluated. 10 had intermediate reaction to 10-12 strains of *Xanthomonas axonopodis pv. manihotis*.
• Develop an efficient inoculation method to select for resistance to RR *Phytophthora* spp.	Two root and stem inoculation techniques under greenhouse conditions for several *Phytophthora* species were developed and with high correlation with field resistance of cultivars.
• On-farm evaluation of promising genotypes in regions of Colombia where RR are endemic (Mitú, Santander de Quilichao)	Mitú: 9 promising root rot resistant genotypes with different cyanide content were planted in 3 indigenous communities, to be compared with local varieties. 10 varieties were planted in two governmental farms at Mitú. Santander de Quilichao: 16 promising genotypes with resistance to RR planted in a naturally infested field with high incidence of *Phytophthora*. Local varieties were included as control.
• Evaluate parental material, segregating and mapping progenies from contrasting genotypes under greenhouse conditions.	Preliminary results indicate highly significant differences between TSM 30572 (MNGA 2) and CM 2177-2 by inoculation of the stems of young plantlets in the greenhouse with *P. drechsleri*.

Activities	Summary of results
1.2. Characterization of cassava germplasm for resistance/tolerance to major pests	
• Evaluation of 1600 segregating progenies and elite germplasm for whitefly resistance	297 genotypes showed low whitefly population and damage and will receive additional evaluation.
• Yield depression in genotypes selected for whitefly resistance	No significant depression observed for resistant genotypes. Up to 20% reduction due to whitefly incidence in susceptible ones.
• Evaluation of germplasm accessions, breeding lines and progenies for mites, stemborers and whitefly resistance at different breeding sites.	80% CIAT's germplasm collection evaluated for whitefly resistance at Palmira and Nataima; 110 genotypes were selected as resistant. Accessions Mper 335 and MEcu 74 selected as highly resistant to whiteflies. Progenies from MEcu 72 and Mbra 12 about to be released as new varieties in Colombia.
• Evaluation of selected germplasm for resistance to mites.	4495 accessions evaluated for mite resistance in Palmira and Pivijay, 133 genotypes selected as resistant.
• Evaluation of selected germplasm for resistance to stemborers	950 genotypes evaluated, 273 showed low damage (less than 1 perforation per stem)
• Resistance mechanisms in selected cassava germplasm evaluated for mites and whitefly	Oviposition by mites and whitflies is reduced by up to 60% in resistant cultivars
1.3 Germplasm evaluation for root quality traits	
• Evaluation of genetic diversity and heritability for vitamins and mineral content in cassava roots and foliage	Sources of high carotene and ascorbic acid content in the roots selected. Inheritance of carotene accumulation determined. Stability of carotene content after cooking and drying determined. Variability in mineral content in roots and leaves studied. Higher concentrations of vitamins and minerals in leaves justify its use as a food supplement.
• Screening of elite genotypes for physiological post-harvest deterioration	Genotypes with more than 10 day shelf-life selected; traits associated to PPD can be used as indirect selection criteria.
• Evaluation of starch content and granule morphology among elite germplasm and core collection entries.	Genotypes with enhanced resistance to acid media and freezing, and high Pi-starch were selected. Genotypes with abnormal starch granule shapes will be studied in detail.

2. Genetic stocks and improved gene pools developed and transferred to National Programs and IITA.

Activities	Summary of results
2.1 Production of recombinant seeds to re-initiate breeding cycle and support national programs	
• Selection of parental material based on previous cycle results, and the information obtained from the previous output (resistance/tolerance, quality traits.	We observed a superiority of 68 % of the best selected parents over check varieties. A group of 257 genotypes selected for recombination. Sources of resistance to pest and diseases as well as specific traits selected for the development of control crosses.
• Establishment of crossing blocks and production of recombinant seed from previously established blocks	458,027 recombinant seeds produced. Large proportion of our work shifted to specific traits, through the development of genetic stocks, and pre-breeding populations.
• Generation (in Thailand) and distribution of advanced breeding materials for Asian national programs	Unrestricted support and collaboration from the Thai breeding program. Distribution of segregating progenies of high value for Asian National Programs.

Activities	Summary of results
2.2. Selection of recombinant progenies for broad and specific adaptation within major agro-ecosystems (sub-humid; semi-arid; highland and acid soil savanna).	
• Evaluation and selection of breeding materials at different stages	Largest improvement in relation to the local check variety observed for the highland tropics ecosystem, followed by mid-altitude tropics and the acid soil savannas. 33 elite genotypes incorporated to the germplasm collection and available for interchange with National Programs. A network of breeding trials has been established and is continuously producing results.
• Multiplication of selected elite germplasm.	80 has have been dedicated to multiplication during the latest 3 crop cycles. Continuous supply of prime quality planting material to development projects throughout the country.
2.3. Distribution of improved germplasm to partners in Latin America and Asia, and to IITA.	Considerable improved genetic diversity transferred to National Programs and other institutions working on cassava. Increased efficiency of Latin American germplasm introduction into Africa, by the development and shipment of back cross seed.
2.4. Propagation of mapping progenies, inter-specific hybrids and genetic stocks.	Genotypes within target families multiplied for basic research projects. Integration with projects in the area of biotechnology.

3. National Programs in tropical and sub-tropical Latin America and Asia supported in adaptive selection and deployment of improved cassava varieties.

Activities	Summary of results
3.1 Work together with National Programs in Latin America for the selection, multiplication and dissemination of elite cassava germplasm	
• Support planning and execution of project for germplasm development for semi-arid NE Brazil	Participatory farmer evaluation of advanced genotypes as a routine procedure within the breeding scheme. A group of varieties preferred by farmers is under multiplication and proposed for formal release. Germplasm transferred to Sub-Sahelian Africa.
• Joint evaluation of cassava germplasm with CORPOICA in Northern Colombia	Genotypes selected with a 34% higher dry matter production potential than check varieties. A network of representative sites for testing genotypes in Northen Colombia has been established.
• Cassava germplasm development for Colombian highlands in partnership with NGO's	Potential of cassava to compete with more industrial crops has been determined. Thirteen genotypes have been selected as the basis for next-year on-farm trials.
• Search for financial support for integrated projects in Paraguay and Cuba, where improved germplasm plays a central role	Integrated research and development proposals developed and submitted to donors. Close interaction with the National Programs established.
• Integration of private sector in cassava germplasm development project	A network of companies involved in feed and food industry developed for testing and multiplication of cassava germplasm.
• Look for support to the Latin American Cassava Research Program	Contact made with institutions from the private sector (related to cassava processing). The idea is supported by public programs.
• Participate in the development of a cassava multiplication scheme in Northern Colombia.	A de-centralized seed multiplication program established in Northern Colombia. 1:800:000 high quality stakes produced for regional and experimental genotypes. Technicians involved with multiplication plans were trained.

Activities	Summary of results
• Participate in the release of new cassava varieties	7 new cassava varieties were released in Latin America. An estimated area of 200,000 has in Latin America is planted to varieties derived from the germplasm maintained at CIAT.
3.2 Support National Programs in Asia in adaptive selection, multiplication and diffusion of improved cassava germplasm	
• Breeding for maximum productivity and adaptation under semi-arid and sub-humid conditions in Thailand	The significant genetic improvement in cassava yielding ability at Rayong FCRC is due firstly to the enhanced biomass and secondly to the elevated root dry matter content. Although considerable improvement with the CIAT/Colombia materials has been made, the superiority of the Rayong materials has persisted. Five successful varieties have been released since 1985 in Thailand; a new variety (CMR33-57-81) will be released in 1998.
• Upgrading yield potential and adaptation of breeding populations together with NARs in Asia	A total of 112,500 hybrid seeds have been contributed from the Rayong program. The genetic variability transferred from the center of origin to Asia, exceeds by far the genetic variability introduced spontaneously to Asia in the past 3 centuries.
• Multiplication; release and diffusion of improved varieties	Three new clones (OMR33-17-5 and KM 95, SM 1157- 3 as KM 95-3 and SM 937-26) in Vietnam and 3 new clones (CMP62-15 as VC6, CMP21-15 as VC7 and CM 3422- 1 as Lakan 4) were officially released, making the total number of CIAT-related cultivars in Asia raise to 31 (Thailand 7, Indonesia 3, Philippines 10, Malaysia 2, China 4 and Vietnam 5).
• Adoption of cassava varieties and impact studies in selected countries.	Total area planted with CIAT-related new cultivars between 0.787 and 0.860 million ha in 5 countries (Thailand, Indonesia, Vietnam, Phillipines and China) in Asia. Total economic effects due to the superior yield and quality of new cultivars accumulated in the past 10 years is estimated to be U$ 693 million in Asia
• Local training of Asian cassava breeders	Emphasis has shifted to on-site training. 44 Asian scientists from 7 countries participated in a workshop at harvesting time in Thailand.
• Facilitate communication within the Asian cassava breeders network	V Asian Cassava Research Workshop was held in the Chinese Academy of Tropical Agricultural Sciences; attended by 58 cassava scientists from Asia and CIAT. Several Asian countries have strong programs in germplasm selection and dissemination. There is variability in the capacity of different institutions to progress in each of the stages that lead to the dissemination of successful cassava varieties (i.e. China and Indonesia).

Activities	Summary of results
3.3 Development and adaptation of end-user participatory germplasm evaluation and selection methodologies	
• Support farmer participatory germplasm evaluation in NE and Southern Brazil.	A network of 40 extension agents and scientist has been trained in the methodology and are actively working. Manuals have been developed.
• Work together with NGO's in Northern Cauca for the evaluation of improved cassava germplasm with farmers and processors	A group of 18 technicians from the public sector and NGO's trained on farmer participatory evaluation.
• Start project on farmer participatory evaluation of early breeding cycles in Northern Colombia	Financial support approved to start working in October 1998. Multiplication of genotypes to incorporate in early on-farm evaluation.
• Publish Cassava Participatory Breeding manual en English.	Translation in process. Data analysis package has been produced (diskette and manual are available).
• Prepared manuscripts for publication in journals	2 papers have been published in Brazil, and 2 more are in preparation for publication in international journals.

The way ahead

We will continue with the stream-line approach of: screening the available genetic base for useful genetic information, combine complementary sources into improved gene pools, and transfer those gene pools for adaptive selection with National Programs. We foresee a greater use of tools that will help us improved the efficiency of cassava germplasm development.

Techniques implemented and tools developed for the assessment and more efficient use of the genetic base of cassava

Finalize the molecular map: The actual molecular map of cassava was developed on a progeny of 90 individuals, work is on-going to complement the map through the extension to 150 recombinant progenies, necessary for studying quantitative traits. Back cross progenies from selected individuals in the mapping populations will be used to developed a B1C1 map by transfer of framework. The project is actively involved together with CIAT's project SB-2 in activities aimed at obtaining a highly saturated map, that will serve as the basis for tagging genes responsible for important processes, and implementing MM assisted selection.

Development and application of advanced tools for molecular characterization: An effective implementation of MMAS and gene tagging will depend on our ability to adapt and implement the most effective tools for molecular characterization, as well as probes related to biochemical process of prime importance in cassava. The major activities in the near future will be the selection and implementation of multiplex micro satellite analysis and the acquisition and preparation of genes for important metabolic processes (i.e post harvest deterioration). It is planned to develop additional micro satellites and DNA markers for cassava germplasm characterization, including probes from genes involved in important metabolic processes.

Implement molecular marker assisted selection: One of the major objectives of adjusting molecular characterization techniques will be to incorporate them as one of the breeders' tools for more effective genetic enhancement. The obvious traits for which MMAS will be applied at the beginning are those for which we do not have the proper screening environment (i.e. ACMV resistance), and those for which there is a screening procedure, but it is subjected to environmental influences and variable pressure from biotic sources (i.e. whitefly resistance, root rot), or it is too costly and restricted to a small number of genotypes at a time (i.e. starch amylose/amylopectin). Once MMAS is proved effective within the developed genetic stocks and the proper parental material is identified, it should be incorporated into the progenies that are the basis for the recurrent selection program, and fully implement MMAS as a breeder tool.

Genetic base of cassava and Manihot species evaluated and available for cassava improvement

Identify and study sources and mechanisms of useful genetic variability in cassava and *Manihot* species: Priority will be given to screening the core collection, and wild species collection as sources of useful genetic diversity. Once desirable traits are identified, mechanisms and processes responsible for the higher levels of expression of those traits will be studied in order to comprehend and manipulate them in a more effective way. The active input from Pathologists and Entomologists is expected to continue. The main gaps to fill will be in the areas of Physiology and Root Quality. There will be a need to search for alternative ways of keeping competence in these areas.

Agronomic evaluation of mapping populations and genetic stocks: Interaction with other scientists will be crucial to set priority traits for gene tagging molecular assisted selection. A meaningful agronomic evaluation depends on the sites we can use for that purpose. The 3 main sites used for the recurrent selection program, may not be able to suit all the evaluation purposes in the best way. Field evaluation in additional sites is an expensive endeavor, therefore we should prioritize these activities in order to come up with the most effective way for testing. Molecular and phenotypic information will be integrated using the genetic map to localize important genes for each trait in preparation for MMAS.

Genetic stocks and improved gene pools developed and transferred to NARs and AROs

Development and maintenance of genetic stocks: Populations are developed by the recombination of contrasting genotypes for a particular trait (i.e. whytefly resistance) or sets of traits (physiological traits). The major purpose of these stocks is to provide the basic material for heritability studies, gene tagging and studying of mechanisms of resistance/tolerance, efficiency, etc.

Incorporation of wild germplasm into cassava: Although we have limited information on the potential of *Manihot* species as contributors of valuable genetic information, there are already a few well documented cases that will deserve our attention in terms of inter-specific crosses, and making that genetic information available to the breeding programs; escaping drought (*Manihot spp*, "manicobas"); leaf anatomical structure (*Manihot rubricaulis*); and waxy starch (*Manihot crassisepala*). Once we know more about the potential contribution of wild species for quantitative traits, a QTL breeding program can be initiated using a very broad base population.

Development of parental populations: The recombination of selected genotypes from the recurrent selection scheme, will not only provided initial material for the following selection cycle, but it will generate the populations that will be supplied to NARs. The recombination work should be expanded to incorporate a larger proportion of crosses between CIAT's selected genotypes and genotypes of interest to NARs (i.e. landraces from Asia, ACMV resistant genotypes from IITA, etc.).

Implementation of a recurrent selection program across ecosystems:

Improved germplasm continuous to be the core of the project activity, and the most important link to National Programs. Presently, improved gene pools are developed for 6 of the 7 previously defined ecosystems where cassava bears importance: Sub-humid lowland tropics, Semi-arid lowland tropics, Acid soil savannas, Mid-altitude and Highland tropics and Sub-tropics. In the 1998-2001 MTP reduced emphasis was assigned to breeding activities, with higher emphasis given to pre-breeding work. For this reason we propose to concentrate on the development of a low-land tropics improved populations through a recurrent selection process involving 3 sites: Santo Tomás (Sub-humid), Santander de Quilichao (Mid-altitude and acid soils); and Palmira (more fertile soils). The proposed scheme is based on a more systematic evaluation of a much reduced number of initial segregating progenies. Selected genotypes will be used to generate recombinant progenies to re-start the selection cycle, and they will also be crossed to sources of local adaptation (i.e. Asian landraces, ACMV resistant lines from IITA, etc.) to generate at least 50,000 seeds/year intended for distribution to IITA and NARs. A similar scheme will be put in place for the mid-altitude and highland tropics ecosystems combined. Germplasm development for the semi-arid is also considered in the special project financed by IFAD until 1998.

Distribution of improved populations and/or genetic stocks to NARs and AROs: This constitutes the nexus of our institution to other programs in the developing world. Currently we are producing more than 100,000 seeds/year for distribution. It is foreseen that the number will shrink to 50,000 in the future due to a reduction in our breeding activities. Population development and seed distribution will be rationalized, given the enhanced capacity of some National Programs to produce their own segregating material.

Relationship with National Programs in Latin America: This is the only outreach activity for Latin America, and it is based on a 3-year special project financed by IFAD. This project is conducted in close collaboration with our Brazilian counterparts, and includes germplasm evaluation, selection and recombination, as well as farmer participatory evaluation of advanced selections; and supply of segregating progenies to other programs in homologous environments (i.e. IITA for semi-arid Africa). There is considerable interest from the private sector (mainly processors) to support cassava research (particularly the development and diffusion of new varieties). CIAT is working to build a Latin American consortium for cassava research. This will not only contribute research funds, but also bring new opportunities for the participation of end users in designing and executing research.

INTRODUCTION

The major goal of our project is to contribute in increasing and stabilizing cassava production in diverse environments and for different markets, by developing improved gene pools in cooperation with national programs. The purpose of our project is to generate basic understanding, tools and improved cassava germplasm for sustainable enhancement of cassava production and the diversification of end-uses in relevant ecosystems. The most important ecosystems are: the semi-arid (below 800 mm/year, unimodal); the sub-humid (800- 1500 mm /year, bimodal rainfall distribution), the acid soil savannas (1500 – 3000 mm/year, short dry period, low pH). The humid tropical lowlands; the mid-altitude tropics; the high-altitude tropics and the subtropics represent ecosystems of secondary importance in terms of area and total production. The main selection activity is conducted in sites selected to represent the conditions of the target ecosystem. For each of the zones we conduct a recurrent selection program, with a progressive set of stages.

As the breeding stages progress, we give emphasis to traits of lower heritability, because we have more planting material for each genotype, and the evaluation can be conducted in bigger plots with replications. Certain selection criteria are of general importance across ecosystem (i.e. yield potential, dry matter content), while others are specific for each ecosystem (i.e. pest and diseases). Elite genotypes are used as parents to obtain recombinant seed that is used to initiate a new selection cycle, and also transferred to National Programs for their adaptive selection programs. Besides the selection of superior genotypes a major research priority is the development and use of research tools that will shorten the breeding cycle and increase its efficiency, such as molecular marker assisted selection, and farmer participatory evaluation at early stages of the breeding cycle. New sources of resistance to major biotic and abiotic constraints, and favorable alleles for root quality traits are constantly being incorporated through recombination and selection.

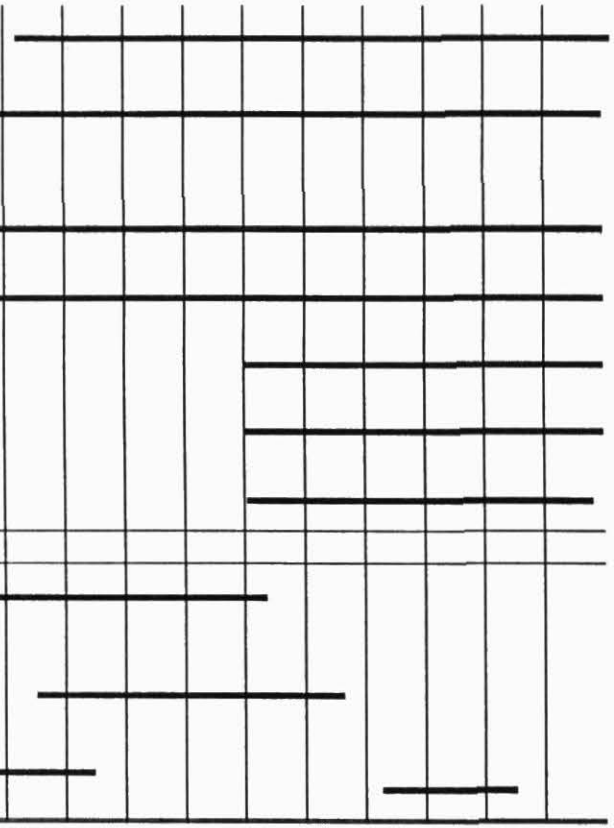
CIAT has been actively involved with CORPOICA and CNPMF/EMBRAPA in the development and implementation of methodologies for the evaluation and selection of cassava germplasm with the participation of end-users. Also with CNPMF/EMBRAPA, a project has been implemented for the development of cassava germplasm with adaptation to semi-arid conditions. In Thailand, CIAT works with FCRI, on the development and diffusion of improved cultivars that have diversified the genetic base for cassava production in the region. This work has had a tremendous impact on cassava production in Asia. CIAT and IITA have actively collaborated in the development and introduction of germplasm into Africa, combining elite Latin American genotypes with sources of resistance to African Cassava Mosaic Disease. Recently, in Latin America, an active interaction with the private sector involved in starch and feed production has been initiated. In Asia and Latin America and the Caribbean, there are relatively few strong cassava breeding programs. Among them are EMBRAPA/CNPMF (Brazil), INIVIT (Cuba), CORPOICA (Colombia), FCRI (Thailand), and IAS (Vietnam).

This report summarizes activities and results obtained during the last 3 years, with greater emphasis on the activities developed during the period 1997-98.

CIAT-PROJECT: IP-3 IMPROVED CASSAVA FOR THE DEVELOPING WORLD

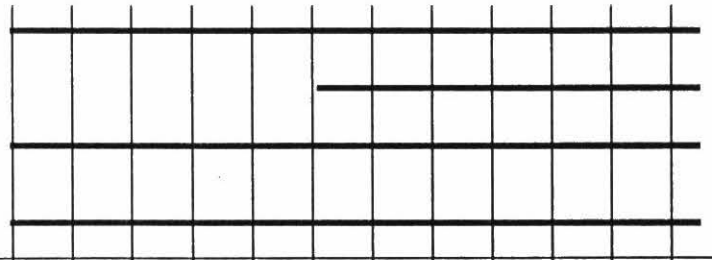
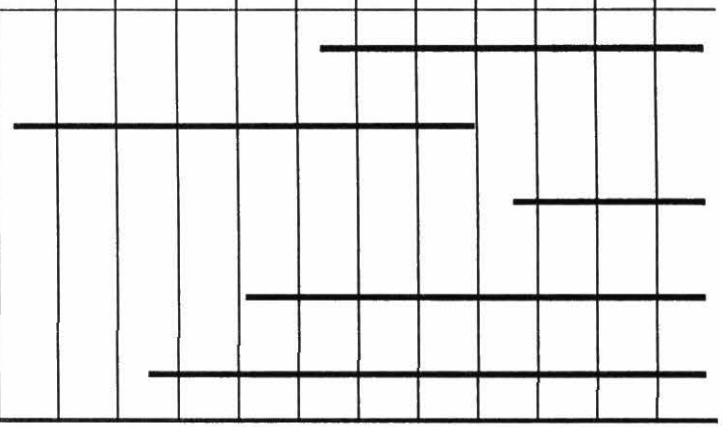
Narrative summary	Objectively verifiable indicators	Means of verification	Critical assumptions beyond the control of the project team
Program goal: To increase and stabilize cassava production in diverse environments and for different markets, by developing improved gene pools in cooperation with national programs	-Hectares under improved varieties. -Improvement in economic return by farmers growing improved varieties -Fluctuation in cassava yields over years	-Project report -Publications -Country and regional production statistics -Adoption and impact studies	-Starch and dry cassava markets continue with high dynamism -National programs are active and strong in most important countries -Private sector actively involved in the diffusion of improved germplasm
Project purpose: To generate basic understanding, tools and improved cassava germplasm for sustainable genetic improvement of cassava production and the diversification of end-uses	-Relative improvement in the most relevant traits -Preference by final users (farmers and processors) -Broad-base network involving public and private sector	-End-of-project report -Publications in referee journals -Proceedings from network meeting -Adoption and impact studies	-Proper financial support -Active collaboration with NARs -Active collaboration with advanced research organizations -Support from public and private sector -Availability of representative sites
Outputs:			
-Genetic base of cassava and Manihot species evaluated and available for genetic improvement	Genotypes inn different categories (tolerance/ resistance; quality, etc.) -Description of mechanisms -Genetic distances	-Project report -Publications in referee journals	-High heritability of traits -Sufficient genetic diversity towards desirable side -Adequate selection sites
-Genetic stocks and improved gene pools developed and transferred to national programs	-Number of recombinant seeds produced and transferred -Number of elite genotypes selected -Populations maintained -Field trials established	-CIAT's main data-base; files on seed production and shipment, and elite genotypes -Field visits -Reports and publications	--Adequate interaction with other disciplinary scientists -Crossability with wild species -Heritability of traits -Adequate lab-field integration
-National programs in tropical and sub-tropical Latin America and Asia supported in adaptive selection and deployment of improved cassava varieties	-Number of recombinant seeds transferred -Number of farmers participating -Number of varieties released -Area under released varieties	-Project report -Field day brochures -Publications -Country production reports	-Usefulness and relevance of new cultivars -Adequate strength of NARs -Proper dissemination channels
Inputs: Core Special Senior staffs: 259,140 Support personnel: 87,523 57,414 Operational resources: 41,516 86,786 Total: 388,179 144,200	Senior Staff: 2.20 Support staff: 4.35 Secretaries: 0.70 Field workers: 6.90	-Budget control spread-sheet -Project reports	-Stable core support -Capacity to attract non-traditional donors

Output/Activities	Resp.	Time (%)	Year 1998 J	F	M	A	M	J	J	A	S	O	N	D
1. Genetic base of cassava and Manihot species evaluated and available for cassava improvement														
1.1. Germplasm characterized for reaction to cassava bacterial blight (CBB); super-elongation disease (SED) and stem and root rot diseases (RR), resistance under field and greenhouse conditions	EA	50%												
• Evaluate 250 genotypes for CBB and SED reaction in Villavicencio and Matazul														
• Evaluate 480 genotypes for RR reaction in the greenhouse														
• Evaluate 60 genotypes with different pathotypes of *Xanthomonas axonopodis* pv. *manihotis* in the greenhouse														
• Rapid multiplication of promising genotypes for future experiments														
• Develop an efficient inoculation method to select for resistance to *Phytophthora* spp.														
• On-farm evaluation of promising genotypes in regions of Colombia where RR are endemic (Santander de Quilichao, Mitú)														
• Evaluate parental material and segregating progenies from contrasting genotypes under greenhouse conditions, including mapping progenies														
• Establish segregating progenies for field evaluation														
1.2. Characterization of cassava germplasm for resistance/tolerance to major pests	AB	50%												
• Evaluation 1600 clones Tolima and CIAT for whitefly resistance														
• Regional yield trials, whitefly resistant clones and hybrids. Huila and Tolima (with CORPOICA)														

• Yield depression promising clones for whitefly resistance. Tolima			
• Evaluation of cassava germplasm accessions, breeding lines and progeny for mites, stemborers (*Chilomima clarkei*), whiteflies and other at Meta (Villavicencio), Costa (Pivijay), Tolima and CIAT (with Breeding program) • Evaluation of selected germplasm (525 clones) for resistance to mites (Pivijay) • Evaluation of selected germplasm for resistance to stemborer *C. clarkei* • Planting of selected germplasm for pest resistance; increase materials • Resistance mechanisms in selected cassava germplasm evaluated for mites and whiteflies • Selected crosses between whitefly (MEcu 72 and mite (MVen 125) resistant clones			
1.3 Germplasm evaluation for root quality traits	CI	5%	
• Evaluation of genetic diversity and heritability for vitamins and mineral content in cassava roots and foliage • Screening of elite genotypes for physiological post-harvest deterioration • Evaluation of starch content and granule morphology among elite germplasm and core collection entries.			

Output/Activities	Resp.	Time (%)	Year 1998 J	F	M	A	M	J	J	A	S	O	N	D
2. Genetic stocks and improved gene pools developed and transferred to national programs	CI	15%												
2.1 Production of recombinant seeds to re-initiate breeding cycle and support national programs														
• Selection of parental material based on previous cycle results, and the information obtained from the previous output (resistance/tolerance, quality traits.				—	—	—					—	—		
• Establishment of crossing blocks and production of recombinant seed from previously established blocks			—	—	—	—	—	—	—	—	—	—	—	—
• Generation (in Thailand) and distribution of advanced breeding materials for Asian national programs			—	—	—	—	—	—	—	—	—	—	—	—
2.2. Selection of recombinant progenies for broad and specific adaptation within major agro-ecosystems (sub-humid; semi-arid; highland and acid soil savanna).														
• Evaluation and selection of breeding materials at different stages			—	—	—	—	—	—	—	—	—	—	—	—
• Multiplication of selected elite germplasm.						—	—	—	—	—	—	—	—	—
2.3. Distribution of improved germplasm to partners in Latin America and Asia, and to IITA.			—	—	—	—								
2.4. Propagation of mapping progenies, inter-specific hybrids and genetic stocks.			—	—	—	—	—	—	—	—	—	—	—	—

Output/Activities	Resp.	Time (%)	Year 1998 J	F	M	A	M	J	J	A	S	O	N	D
3. National programs in tropical and sub-tropical Latin America and Asia supported in adaptive selection and deployment of improved cassava varieties														
3.1 Work together with National Programs in Latin America for the selection, multiplication and dissemination of elite cassava germplasm	CI	20%												
• Support planning and execution of project for germplasm development for semi-arid NE Brazil			———	———	———	———	———	———	———	———	———	———	———	———
• Joint evaluation of cassava germplasm with CORPOICA in Northern Colombia							———	———	———	———	———	———	———	———
• Cassava germplasm development for Colombian highlands in partnership with NGO's			———	———	———	———	———	———	———	———	———	———	———	———
• Search for financial support for integrated projects in Paraguay and Cuba, where improved germplasm plays a central role						———	———	———	———	———				
• Integration of private sector in cassava germplasm development project			———	———	———	———	———	———	———	———	———	———	———	———
• Look for support to the Latin American Cassava Research Program						———	———	———	———	———	———			
• Participate in the development of a cassava multiplication scheme in Northen Colombia			———	———	———	———	———	———						
• Participate in the release of 3 new cassava varieties							———	———	———	———	———			
3.2 Support National Programs in Asia in adaptive selection, multiplication and diffusion of improved cassava germplasm	KK	80%												
• Breeding for maximum productivity and adaptation under semi-arid and sub-humid conditions in Thailand			———	———	———	———	———	———	———	———	———	———	———	———
• Upgrading yield potential and adaptation of breeding populations together with NARs in Asia			———	———	———	———	———	———	———	———	———	———	———	———

• Multiplication; release and diffusion of improved varieties • Adoption of cassava varieties and impact studies in selected countries. • Local training of Asian cassava breeders • Facilitate communication within the Asian cassava breeders network			
3.3 Development and adaptation of end-user participatory germplasm evaluation and selection methodologies	LAH	50%	
• Support farmer participatory germplasm evaluation in NE and Southern Brazil. • Work together with NGO's in Northern Cauca for the evaluation of improved cassava germplasm with farmers and processors • Start project on farmer participatory evaluation of early breeding cycles in Northern Colombia • Publish Cassava Participatory Breeding manual en English. • Prepared manuscripts for publication in journals			

Highlights

- Eighty one cultivars of cassava identified as resistant to mites (*Mononychellus tanajoa*) in two ecological zones.
- Six additional cultivars identified as resistant to whiteflies (*Aleurotrachelus socialis*).
- For cassava, new sources of resistance to cassava bacterial blight, superelongation disease, and *Phytophthora* root rots (RR) have been identified in the greenhouse and field.
- With the participation of indigenous women, evaluations of cassava genotypes for resistance to RR were implemented in the Department of Vaupés, southeastern Colombia.
- Evaluations by participating farmers of cassava genotypes for resistance to RR were implemented in the Department of Cauca (southwestern Colombia) and the State of Sergipe (Northeast Brazil).
- Twenty-eight local varieties from Vaupés were introduced to CIAT, and evaluated for RR tolerance in the greenhouse.
- A new method of rapid multiplication of cassava in an oasis substrate was developed to ensure rapid production of vigorous healthy planting material for experiments.
- The screening methodology was modified to permit the evaluation, in the greenhouse, of large numbers of cassava genotypes for resistance to pathogens causing RR.
- Recombinant progenies were obtained from crosses involving RR resistant and susceptible parental cassava materials. They were then evaluated for their reaction to high inoculum pressure, to map genetic factors responsible for resistance.

IMPROVED CASSAVA FOR THE DEVELOPING WORLD

OUTPUT 1: Genetic base of cassava and *Manihot* species evaluated and available for cassava improvement.

Sub-output 1.1. Characterization of Cassava Germplasm for Resistance to Cassava Bacterial Blight (CBB), Superelongation Disease (SED), and Stem and Root Rot Diseases (RR) under Both Field and Greenhouse Conditions.

Activity 1.1.1. *Characterization of 250 Genotypes for Their Reaction to CBB and SED in Carimagua and Villavicencio, Department of Meta, Colombia.*

At "La Libertad" (Villavicencio) and Carimagua, 158 and 219 cassava genotypes, respectively, were characterized for their reactions to CBB and SED under natural disease pressure formed by several pathotypes of each causal agent. These genotypes were evaluated for at least two crop cycles. Of all the genotypes, 7% were identified as resistant to both diseases (Table 1.1.1.1). From the group of 67 varieties evaluated during five crop cycles at Carimagua, four clones were resistant to both diseases. No varieties were resistant to both diseases in both evaluation sites, confirming the hypothesis that each pathogen is genetically diverse.

In April, 246 cassava clones were planted at Matazul (Puerto López, Meta), which replaced the Carimagua site. At Villavicencio, 198 clones were also planted.

Table 1.1.1.1 Cassava varieties, resistant to cassava bacterial blight and superelongation disease, were evaluated during two to five crop cycles at Carimagua and three cycles at Villavicencio, Department of Meta, Colombia.

Variety	Crop cycles (no.)	Root yield (t/ha)[a]	Variety	Crop cycles (no.)	Root yield (t/ha)[a]
Carimagua			Carimagua (continued)		
CG 1367-1	5	32.5	SM 1459-2	4	32.2
M BRA 703	4	14.0	SM 1468-5	4	37.5
M BRA 903	5	20.3	SM 1479-8	4	5.3
M BRA 917	4	24.9	SM 1558-18	3	34.0
M ECU 82	5	16.5	SM 1697-2	3	25.7
M ESC-FLA 006	3	18.1	SM 1821-7	2	47.4
M ESC-FLA 007	4	36.8	SM 1826-0	2	29.9
M ESC-FLA 021	3	24.4			
M ESC-FLA 039	3	23.9			
M ESC-FLA 075	3	34.7	Villavicencio		
SG 104-74	5	28.3	CM 2772-3	3	10.6
SM 1144-4	4	37.8	M COL 707	3	4.5
SM 1152-13	4	35.3	M COL 2387	3	38.5
SM 1159-6	4	17.1	M COL 2409	3	18.3
SM 1215-1	4	40.3	M COL 2538	3	5.2

a. Last crop cycle.

Activity 1.1.2. *Characterization of 480 Genotypes for Their Reaction to Phytophthora Root Rot Diseases in the Greenhouse.*

Field evaluation of cassava varieties for resistance to root and stem rots is costly, and a high, uniform, inoculum pressure difficult to maintain. Young cassava sprouts were therefore grown in the greenhouse and inoculated by wounding. The plants were then incubated at high relative humidity to stimulate symptom development and evaluated 7, 14, 21, and 28 days after inoculation. Disease progress for each variety was recorded by means of graphs and values obtained by estimating the areas below the curves. We carried out several experiments, using this technique.

We selected 420 genotypes and characterized them for their reaction to a highly pathogenic isolate (P12) obtained from Brazil. In contrast to most inoculated varieties, 59 genotypes had minimal lesion development and were thus considered tolerant (Table 1.1.1.2).

Table 1.1.1.2. Evaluation of 420 cassava genotypes for their reaction to the root rot pathogen, *Phytophthora drechsleri*, under greenhouse conditions.

Reaction	Genotypes	
	No.	%
Tolerant	59	14
Intermediately tolerant	114	27
Intermediate	116	28
Susceptible	100	24
Highly susceptible	31	7
Total	420	100

In a second trial, 60 genotypes were inoculated with five isolates from different *Phytophthora* species collected from important cassava-growing regions around Colombia: isolate P4, of the species *P. parasitica*; isolates 27 and 44 from Barcelona (Department of Quindío); isolate 66 from Palmira (Valle); isolate 69 from Buenaventura (Valle). These last four were *P. drechsleri*. As shown in Tables 1.1.1.3 and 1.1.1.4, only 13 varieties were intermediately tolerant or tolerant to most of these isolates, particularly M BRA 697, M BRA 781, M COL 306, and M COL 1780. Field evaluations in the Departments of Cauca and Vaupés (Colombia) were initiated to confirm tolerance under field conditions. These 13 varieties were also planted at ICA's Palmira Experiment Station for seed increase.

Table 1.1.1.3. Cassava genotypes selected for tolerance of different *Phytophthora* species in the greenhouse.

Genotype	Isolate[a]						Tolerance of isolates (%)
	P12	P4	44	66	27	69	
CM 523-7	MT	MT	MT	T	MT	MT	17
CM 5655-4	MT	MT	I	T	T	T	50
CM 6370-2	MT	MT	MT	MT	T	MT	17
CM 6740-7	T	MT	MT	MT	T	MT	33
CM 7951-5	MT	I	MT	T	T	MT	33
M ARG 13	I	MT	T	I	T	T	50
M BRA 73	S	S	T	T	T	T	67
M BRA 97	T	MT	T	T	T	T	67
M BRA 311	T	T	T	MT	T	MT	67
M BRA 383	MT	MT	T	T	T	T	67
M BRA 461	I	I	T	T	MT	MT	33
M BRA 697	T	T	T	T	MT	T	83
M BRA 781	MT	T	T	T	T	T	83
M BRA 819	T	S	MT	MT	T	MT	33
M BRA 894	S	MT	T	T	MT	T	50
M COL 72	T	MT	T	T	T	MT	67
M COL 306	T	MT	T	T	T	T	83
M COL 534A	T	I	MT	I	T	MT	33
M COL 764	MT	MT	T	T	MT	T	50
M COL 1468	MT	MT	MT	MT	T	MT	17
M COL 1505	MT	MT	MT	T	T	MT	33
M COL 1566	S	T	MT	I	T	MT	33
M COL 1684	MT	MT	T	T	T	I	50
M COL 1780	T	T	T	I	T	T	83
M COL 2025	I	MT	T	I	T	T	50
M COL 2550	MT	MT	T	T	T	MT	50
M COL 2733	MT	T	MT	MT	MT	I	17
M CR 45	MT	MT	T	T	T	T	67
M DOM 4	T	I	T	T	T	MT	67
M ECU 31	T	MT	MT	MT	T	MT	33
M PER 183	MT	MT	I	MT	T	I	17
M PER 184	MT	MT	T	MT	T	T	50
M PER 221	T	MT	MT	MT	T	MT	33
M PER 438	T	MT	MT	T	T	MT	50
M PER 496	T	MT	MT	T	MT	MT	33
M PER 542	T	MT	MT	T	MT	MT	33
M VEN 23	T	T	MT	T	T	MT	67
SM 526-3	T	T	T	T	MT	MT	67
SM 1210-4	I	MT	MT	MT	MT	I	0
SM 1219-9	MT	MT	MT	T	MT	I	17
Virulence (%)	43	20	50	63	73	35	

a. Origin of isolates: P12 (Brazil), P4 (Colombia); 27 and 44 (Quindío, Colombia); 66 and 69 (Valle, Colombia). Reaction to the disease: T = tolerant; MT = intermediately tolerant; I = intermediate; S = susceptible.

Table 1.1.1.4. Characteristics of the 13 cassava genotypes that most tolerated *Phytophthora* root rots.

Genotype	Origin	HCN content[a]	Root color	Root yield[b]	Reaction to other diseases[c]	
					CBB	SED
M BRA 73	Brazil	7	White	14.3	5	5
M BRA 97	Brazil	8	White	18.1	5	3
M BRA 311	Brazil	8	Yellow	12.0	3	4
M BRA 383	Brazil	7	White	17.8	3	4
M BRA 697	Brazil	7	White	13.5	1	1
M BRA 781	Brazil	7	White	16.2	3	2
M COL 72	Colombia	6	White	13.9	5	3
M COL 306	Colombia	6	White	6.7	2	2
M COL 1780	Colombia	5	White	1.5	2	1
M CR 45	Costa Rica	7	Yellow	17.0	2	3
M DOM 4	Dominican Republic	5	Cream	13.0	2	1
M VEN 23	Venezuela	9	White	14.0	4	5
SM 526-3	Colombia	7	Cream	19.8	3.5	-[d]

a. Cyanide content: 1 = low; 9 = very high.
b. Ton/ha.
c. Scale: 1 = tolerant; 2 = moderately tolerant; 3 = intermediate; 4 = susceptible; 5 = highly susceptible.
d. Not determined.

Activity 1.1.3. *Characterization of 69 Genotypes for their Reaction to Different CBB Pathotypes under Greenhouse Conditions.*

We characterized 69 cassava genotypes for their reaction to CBB under greenhouse conditions. Young cassava plants were grown in the greenhouse, inoculated by stem puncture with an aliquot of bacterial suspension at 1 X 10^5 cfu/ml. Disease severity was recorded 7, 14, and 21 days after inoculation. Each variety was inoculated with 12 pathotypes of *Xanthomonas axonopodis* pv. *manihotis*, the causal agent of CBB, from different edaphoclimatic zones in Colombia, Brazil, and Venezuela. All 12 isolates were highly virulent; the five most virulent being CIO 616, CIO 763, SantoTomás 1B, CIO 277, and CIO 10, which were isolated from Mitú (Vaupés), Puerto López (Meta), Santo Tomás (Atlántico), Boca del Pozo (Monagas, Venezuela), and Brasília (Goiás, Brazil), respectively. Seven cassava varieties were intermediately resistant to 7 or 8 of the pathotypes tested (Table 1.1.3.1), and seven were susceptible to all pathotypes.

Table 1.1.3.1. Disease reaction of cassava genotypes to 12 strains of *Xanthomonas axonopodis* pv. *manihotis*[a], the causal agent of cassava bacterial blight.

Clone	FR[b]		Isolates[c]												Total[d]			I + R (%)[e]
	V	C	V2	V132	V372	ST1A	ST1B	C241	C10	C261	C277	C285	C763	C616	R	I	S	
CG 165-7	*S*	-	I	S	S	S	S	S	S	S	S	S	S	S	0	1	11	8
CG 1355-2	*R*	*S*	S	S	I	I	S	I	S	S	S	S	S	S	0	3	9	25
CM 305-41	-	-	S	S	S	S	S	S	S	S	S	S	-	-	0	0	10	0
CM 1223-1	*R*	*I*	S	S	S	S	S	S	S	S	S	S	S	S	0	0	12	0
CM 3372-4	*R*	-	S	S	S	S	S	S	S	S	I	S	I	S	0	2	10	17
CM 4574-7	*R*	*R*	S	I	I	I	S	I	S	S	S	S	S	S	0	4	8	33
CM 4772-4	-	-	I	I	S	S	S	I	S	I	S	S	S	S	0	4	8	33
CM 5286-3	*R*	*R*	S	S	S	S	S	S	S	S	S	S	S	I	0	1	11	8
CM 5655-4	-	-	S	S	S	S	S	S	S	I	S	S	S	S	0	1	11	8
CM 6306-11	-	-	I	-	-	-	I	S	S	I	-	-	S	I	0	4	3	57
CM 6370-2	*I*	-	S	S	S	I	S	S	S	I	S	S	S	S	0	2	10	17
CM 6438-14	*R*	*R*	I	I	S	S	S	S	I	I	S	I	I	I	0	7	5	58
CM 6740-7	-	*S*	I	S	S	I	S	S	I	I	I	I	S	S	0	6	6	50
CM 6858-3	-	*I*	I	S	S	I	S	I	I	I	S	S	I	S	0	6	6	50
CM 6921-3	*R*	*I*	S	S	S	I	S	S	S	S	S	S	S	S	0	1	11	8
CM 7274-1	*R*	*I*	S	S	S	S	S	S	S	S	S	S	S	S	0	0	12	0
CM 7514-7	-	*R*	S	S	S	I	S	S	S	I	S	S	S	S	0	2	10	17
CM 7772-2	-	*S*	I	S	S	I	S	S	S	I	I	S	S	S	0	4	8	33
CM 7772-11	-	*S*	S	S	S	S	S	S	S	S	S	S	S	S	0	0	12	0
CM 7811-15	-	-	I	-	S	-	-	-	-	-	S	S	S	S	0	1	5	17
M ARG 6	*I*	*S*	S	I	S	S	S	S	I	S	I	S	S	S	0	3	9	25
M BRA 13	-	-	S	I	I	S	S	S	S	I	S	I	S	S	0	4	8	33
M BRA 71	*I*	-	S	S	S	I	S	S	S	S	S	S	S	S	0	1	11	8
M BRA 237	*I*	*S*	S	S	S	I	S	S	S	I	S	S	S	S	0	2	10	17
M BRA 311	*R*	-	S	S	S	I	S	S	S	S	S	S	S	S	0	1	11	8
M BRA 403	-	*S*	S	S	S	I	S	S	S	S	S	S	S	S	0	1	11	8
M BRA 404	*S*	*S*	I	I	S	I	S	S	S	I	I	I	S	I	0	7	5	58
M BRA 435	-	*S*	S	S	S	S	S	S	S	S	S	S	S	S	0	0	12	0
M BRA 466	-	-	I	S	S	I	S	S	I	S	S	S	S	S	0	3	9	25
M BRA 474	*I*	*I*	S	I	S	S	S	S	S	I	S	S	S	S	0	2	10	17
M BRA 489	-	-	S	I	I	I	I	I	I	I	S	S	S	I	0	8	4	67
M BRA 502	-	*I*	S	S	S	S	S	I	I	S	S	I	S	S	0	3	9	25
M BRA 532	-	-	I	I	S	I	S	S	S	I	I	S	S	S	0	5	7	42

M BRA 534	*R*	*I*	I	I	S	S	S	S	S	I	I	S	I	S	0	5	7	42
M BRA 589	*R*	*I*	S	S	I	S	S	S	S	I	I	S	S	S	0	3	9	25
M BRA 590	-	*I*	I	S	S	S	I	S	S	S	I	S	S	S	0	3	9	25
M BRA 699	*S*	*R*	I	S	I	I	I	S	I	I	S	R	S	S	1	6	5	58
M BRA 852	*R*	*R*	S	I	S	I	I	I	S	I	S	S	S	S	0	5	7	42
M BRA 881	*S*	-	I	I	S	I	S	S	I	I	I	I	I	S	0	8	4	67
M BRA 1044	-	-	I	S	I	S	S	I	S	I	S	S	S	S	0	4	8	33
M BRA 1045	-	-	S	S	S	I	S	S	S	S	S	I	I	S	0	3	9	25
M COL 72	*R*	-	S	S	S	I	S	I	S	I	S	S	S	S	0	3	9	25
M COL 1505	*S*	*S*	S	S	S	S	S	S	S	S	S	S	S	S	0	0	12	0
M COL 2216	*S*	-	S	S	S	I	S	S	S	R	I	S	S	I	1	3	8	33
M COL 2250	-	-	S	S	S	*I*	S	I	S	I	S	S	S	S	0	3	9	25
M COL 2253	-	-	I	S	I	S	S	I	S	*I*	S	S	S	S	0	4	8	33
M COL 2255	-	-	S	S	S	I	S	S	S	I	S	S	I	S	0	3	9	25
M COL 2265	-	-	S	S	S	I	S	S	S	S	S	S	S	S	0	1	11	8
M COL 2300	-	-	S	S	S	I	I	S	S	I	S	S	S	S	0	3	9	25
M CR 45	-	-	I	S	I	I	I	I	I	I	S	I	S	S	0	8	4	67
M CUB 5	-	*I*	S	S	S	S	S	I	S	S	S	S	S	S	0	1	11	8
M ECU 191	-	-	S	S	S	I	S	S	S	S	S	S	S	S	0	1	11	8
M VEN 25	*S*	*S*	S	I	S	I	S	S	S	S	S	S	I	I	0	4	8	33
SM 593-5	*R*	*S*	I	S	S	R	I	S	S	I	S	R	S	S	2	3	7	42
SM 627-5	*R*	*I*	S	S	S	I	S	S	S	S	I	S	S	S	0	2	10	17
SM 643-17	-	*S*	S	S	S	S	S	S	S	S	S	S	S	S	0	-	12	0
SM 653-14	-	-	S	S	S	I	S	S	S	S	S	S	S	S	0	1	11	8
SM 719-6	-	-	S	S	S	S	S	S	S	I	S	S	S	S	0	1	11	8
SM 909-25	-	-	S	S	I	I	S	S	S	I	S	S	I	S	0	4	8	33
SM 985-9	*R*	-	S	S	S	S	S	S	S	S	S	S	S	S	0	0	12	0
SM 1036-8	*R*	*I*	S	S	S	S	S	S	S	S	S	S	S	S	0	0	12	0
SM 1210-4	-	-	S	S	S	S	S	S	S	I	S	S	S	S	0	1	11	8
SM 1406-1	-	-	S	S	S	S	S	S	S	I	S	S	S	S	0	1	11	8
SM 1479-8	-	*R*	S	S	S	S	S	I	I	I	S	S	S	S	0	3	9	25
SM 1483-1	-	*I*	S	S	S	I	S	I	S	I	S	S	S	I	0	4	8	33
SM 1557-17	-	*S*	S	S	S	S	S	S	S	I	S	S	S	S	0	1	11	8
SM 1694-2	-	*R*	S	S	S	S	S	I	I	R	S	S	S	S	1	2	9	25
SM 1697-1	-	-	S	S	S	I	S	I	I	I	S	S	S	S	0	4	8	33
SM 7666-31	-	-	I	S	-	R	S	S	S	R	S	-	S	S	2	1	7	30

Totals														
Resistant	27	18	0	0	0	2	0	0	0	3	0	2	0	0
Intermediate	9	22	20	13	10	34	8	17	13	36	12	8	9	8
Susceptible	17	33	49	54	57	31	60	51	55	29	56	58	59	60
Virulence (%)			71	81	85	46	88	75	81	43	82	85	87	88

a. Disease reaction: R = resistant; I = intermediate; S = susceptible.
b. Field reaction at different crop cycles between 1980 and 1997 in Villavicencio (V) and Carimagua (C), respectively.
c. Isolates: Villavicencio 2; Villavicencio 132; Villavicencio 372; Santo Tomás 1A; Santo Tomás 1B; CIO 421; CIO 10; CIO 261; CIO 277; CIO 285; CIO 763; CIO 616; - = not determined.
d. Total of cassava genotypes that are resistant (R), intermediate (I), or susceptible (S).
e. Percentage of resistant (R) and intermediate (I) cassava genotypes.

We obtained a correlation of +0.17 between the reaction obtained by inoculating with the three isolates from Villavicencio in the greenhouse and the results of an evaluation of 14 varieties under natural disease pressure in the field, also at Villavicencio in 1997-1998. The correlation between the same isolates with 30 varieties at Carimagua was -0.01. The correlation between the isolate Villavicencio 32 in the greenhouse and the results in the field in 1997 and 1998 was +0.44. Analysis of data from 1996-1997 showed similar results. Observed disease severity in the greenhouse was always greater than in the field, which confirms the hypothesis of isolate escapes in the field during different crop cycles. Controlling the uniformity of disease pressure and the high variability of the pathogen's virulence is difficult in the field.

Activity 1.1.4. *Modified Inoculation Methods for Screening Cassava Genotypes for Resistance to Root Rots.*

Efforts were made to improve the methodology for screening cassava germplasm for resistance to root rots in the greenhouse. Modifications included multiplying plantlets by using short stakes, and modifiying both the inoculation technique and experimental design.

Two growth media, a sterile soil mixture (sand to clay loam at proportions of 1:3), and oasis substrate were compared for the best germination rates and development of plantlets. Plantlets were obtained from stakes carrying one, two, or three buds and cut from varieties M ARG 9, CM 2177-2, and CG 1-37. No differences were observed in germination rates. Stakes carrying two or three buds grew significantly better in oasis than did those growing in media, but, although similar, were somewhat retarded when compared with plantlets grown from 15-cm stakes planted in the soil mixture. This knowledge should help improve efficiency and plant quality in future greenhouse experiments.

Instead of covering the fungal plug with vaseline, we used parafilm, which prevented the inoculum from falling down.

Variability was considerably reduced by establishing experimental blocks containing plants of similar height and introducing covariance analysis for plant height.

Activity 1.1.5. *Evaluations of Promising Cassava Genotypes in Regions where Root Rots Are Endemic.*

Collection of Germplasm in the Departments of Cauca and Vaupés (Colombia) and Sergipe State (Brazil).

To evaluate cassava varieties for their tolerance of root and stem rot diseases and for their adaptation to local conditions, several on-farm trials were established in May and September 1998 at Mondomo (Santander de Quilichao, Department of Cauca), Buenos Aires (Cauca), and Mitú (Vaupés). Table 1.1.5.1 summarizes the genotypes planted.

Table 1.1.5.1. Cassava genotypes that were successfully established in regions where root rots are endemic, Colombia.

Genotype	Reaction to *Phytophthora* spp.[a]	Location [b]
CG 165-7	Intermediate tolerance	SCA, SCE, C, PP, M
CG 402-11	Intermediate tolerance	Santander de Quilichao, SCA, C, PP
CM 523-7	Intermediate tolerance	SCA, PP, M
CM 2177-2	Tolerant	M
CM 2772-3	Tolerant	SCE, C, M
M ARG 6	Susceptible	SCE, C, M
M ARG 9	Intermediate tolerance	Santander de Quilichao
M BRA 71	Intermediate tolerance	SCA, SCE, PP, M
M BRA 97	Tolerant	SCE, C, M
M BRA 311	Tolerant	Santander de Quilichao
M BRA 315	Tolerant	Santander de Quilichao
M BRA 383	Tolerant	Santander de Quilichao, Buenos Aires
M BRA 532	Intermediate tolerance	Santander de Quilichao, SCA, PP
M BRA 1044	Intermediate tolerance	Santander de Quilichao, SCA, SCE, C, PP, M
M BRA 1045	Tolerant	Santander de Quilichao
M COL 1522	Intermediate tolerance	Santander de Quilichao, Buenos Aires
M COL 2061	Tolerant	Santander de Quilichao
M COL 2300	Tolerant	Santander de Quilichao
MVEN 25	Tolerant	Santander de Quilichao, SCA, SCE, C, PP, M
Wasoco	Local variety	SCA
Wasaí	Local variety	SCA
Yuca de Abeja	Local variety	C
Yuca de Mirití	Local variety	C
Brava Blanca	Local variety	SCE
Dulce	Local variety	SCE, SCA
Abiyú	Local variety	PP
Yuca de Lapa	Local variety	PP
Santa Catalina	Local variety	C

a. According to greenhouse evaluations after inoculation of young plantlets.

b. Indigenous settlements near Mitú, Colombia; and SCA = Seima Cachivera; SCE = Seima Central; PP = Puerto Palomas; C = Cucura, in Brazil.
M = model farm belonging to the Secretaría de Agricultura del Vaupés, Colombia.

In collaboration with EMBRAPA (Cruz das Almas, Bahia, Brazil), 10 cassava genotypes were evaluated for resistance to root rots at several field locations in Brazil: Saco de Areira and Cachoeira de Potes, Aquidabá; and Bom Sucesso and Simón Díaz (Sergipe). Of these varieties, in no site did root rots affect 'Cedinha'. In contrast, 'Pretinha' was the most susceptible. From infected plants, several *Phytophthora* spp. and *Fusarium* spp. isolates were obtained. Pathogenicity was confirmed for *Phytophthora* isolates, but not for *Fusarium* isolates.

Twenty-eight local varieties from Vaupés (Colombia) were introduced to CIAT, and inoculated with five *Phytophthora* spp. and two *Fusarium* spp. isolates under greenhouse conditions (Tables 1.1.5.2 and 1.1.5.3). Disease reaction was not high in the susceptible variety M TAI 1. Stakes were scarce, and we could not inoculate all the varieties with all the isolates.

Table 1.1.5.2 List of cassava varieties collected in the Department of Vaupés, Colombia.

Variety	Local name	Root Color	Variety (continued)	Local name	Root color
Abiyú	Abiyú Ducú	Yellow	Nopará	Dupará	White
Bejuco	Mijsín Ducú	White	Pintadillo	Oreró Ducú	cream
Brava Blanca		White	Santa Catalina[a]	Santa Catalina	White
Busá	Busá Ducú	Yellow	Siringa	Wasá Ducú	White
Butisé[a]	Butisé Ducú	White	Totuma	Wajato Ducú	White
Carayurú	Troña Ducú	Yellow	Tucunaré	Buu	Yellow
Flores	Ori Ducú	Yellow	Wasaí	Mijpi Ducú	Yellow
Guaracú	Vojtéa Ducú	White	Wuasoco	Tañimi Ducú	White
Hoja de Plátano	Ojó puni Ducú	White	Yuca de Agua	Ojcó Ducú	White
Ibacabá (Seje)	Ñumú Ducú	White	Yuca de Gato	Pisana Ducú	Yellow
Inayá	Ijkii	White	Yuca de Mico	Ajqué Ducú	Yellow
Lapa Amarilla	Seme Ducú	Yellow	Yuca de Uva	Wsé Ducú	Yellow
Lapa Blanca	Seme Ducú	White	Yuca de Vara	Yucu Ducú	White
Mirití	Neé Ducú	Yellow	Zancudo	Muejtá Ducú	White

[a] With low cyanide content.

A greenhouse experiment was conducted to evaluate the effect of low and high fertility soils on the severity of symptoms arising from two *Phytophthora* isolates. Soil samples were taken from Mitú (low fertility) and the CIAT greenhouse mixture (high fertility). Isolates P12 and 66 were inoculated onto cassava varieties M BRA 383, M CR 81, and HMC 1, which, according to previous results, are tolerant, intermediate, and susceptible, respectively. No significant differences were found between disease progress in the plants with these soil types.

Table 1.1.5.3. Evaluation of local varieties from Vaupés, inoculated with *Phytophthora* spp. and *Fusarium* spp. isolates.

Variety	Isolate[a]						
	P12	66	TR 37	TR A9	TR 49	Mitú 9	TR A6
Santa Catalina	I	T	-	-	-	-	-
Yuca de Mico	I	MT	-	-	-	-	-
Wasaí	MT	T	-	-	-	-	-
Yuca de Vara	MT	MT	-	-	-	-	-
Mirití	S	MT	T	T	T	T	-
Busá	I	T	-	-	-	-	-
Zancudo	MT	MT	T	T	T	T	T
Yuca de Uva	I	I	T	T	T	T	T
Yuca de Gato	MT	MT	-	-	-	-	-
Pintadillo	MT	MT	-	T	T	T	T
Wuasoco	I	MT	T	T	HS	T	T
Flores	MT	MT	T	T	T	T	T
Inayá	I	MT	T	-	-	T	-
Siringa	MT	T	-	-	-	-	-
Tucunaré	MT	T	-	-	-	-	-
Yuca de Agua	T	T	T	-	-	T	-
Butisé	MT	T	-	-	-	-	-
Ibacabá	MT	T	T	-	-	T	-
Totuma	MT	T	T	-	-	T	-
Lapa Blanca	T	T	-	-	-	-	-
Carayurú	I	T	T	-	-	T	-
Guaracú	MT	MT	-	-	-	-	-
Hoja de Plátano	-	-	T	-	-	T	-
Bejuco	-	-	T	-	-	T	-

a. Isolates are *Phytophthora* spp. = P12 (Brazil); 66 (Palmira, Colombia); TR A9, TR 49, TR A6 (Mitú, Colombia). *Fusarium* spp. = TR 37, Mitú 9 (Mitú, Colombia). - = Not determined.
T = tolerant; MT = moderately tolerant; I = intermediate; S = susceptible; HS = highly susceptible.

Activity 1.1.6. *Characterization of Parents and Segregating Progenies for their Reaction to Different Pathogens of Root Rots under Greenhouse Conditions. Establishment of Segregating Progenies.*

To study the genetic structure of cassava varieties that tolerate root rots, inoculations were conducted in the greenhouse (plantlets) and laboratory (fragments of swollen roots). The two parents, CM 2177-2 and M NGA 2, the progeny of which is mapped by molecular markers, were evaluated after inoculating young plantlets with the following fungi: *Phytophthora* spp., *Fusarium* spp., and *Diplodia manihotis*. When the two parental genotypes were inoculated with *P. drechsleri*, significant differences in reaction were observed (Table 1.1.6.1). *Fusarium oxysporum* (isolates F1, F7, F8, F12, F14, and F22), *Fusarium* spp. (F34, F52, F56, and F58), and *Diplodia manihotis* (D1, D8, D45, D52, and D56) did not cause significant symptoms.

A selection of the progeny of the cross CM 2177-2 × M NGA 2 showed differences in resistance to *Phytophthora* isolates P12 and 43 (Table 1.1.6.2).

We also evaluated in the greenhouse, 31 genotypes for their reaction to five isolates of *Phytophthora* spp. Varieties M USA 2, M BRA 1045, CM 3372-4, and M COL 2025 proved tolerant of P12 and will be used to develop F_1 populations.

As soon as planting material becomes available, we will inoculate *Phytophthora* isolates onto progenies of crosses between contrasting varieties (M CR 81 × M BRA 1045 and CM 9600 × CM 95820), using about 40 individuals each progeny.

We evaluated 52 RAPD primers for DNA polymorphisms in two DNA bulks. One bulk was formed by M BRA 383, M BRA 697, and M COL 306, which tolerate six *Phytophthora* isolates, and the other bulk by M PER 359 and MBRA 894, which are susceptible to *Phytophthora* spp. We followed the methodology described Gómez et al. (1996)[1]. The polymorphisms found could lead to the identification of markers associated with resistance to root rots caused by *Phytophthora* spp. Evaluation of more primers is ongoing.

1. Gómez R; Angel F; Bonierbale M; Rodríguez F; Tohme J; Roca W. 1996. Inheritance of random amplified polymorphic DNA markers in cassava (*Manihot esculenta* Crantz). Genome 39:1039-1043.

Table 1.1.6.1 Reaction of two cassava genotypes to *Phytophthora* spp. isolates.

Isolate	Origin[a]	Inoculated plant tissue and cassava variety[b]			
		Stem		Root cylinder	
		CM 2177-2	M NGA 2	CM 2177-2	M NGA 2
P4	Colombia	I	MT	I	I
P7	Colombia	T	MT	I	I
P12	Brazil	T	I	S	S
2	V	T	T	MT	I
4	V	I	T	MT	I
10	V	MT	T	MT	I
15	Q	MT	MT	I	I
19	Q	MT	MT	I	I
25	Q	I	T	S	S
27	Q	T	T	T	I
28	Q	I	T	T	MT
29	Q	T	T	MT	I
35	Q	T	T	MT	S
37	V	MT	T	MT	I
39	Q	MT	T	I	S
40	V	I	I	I	I
44	Q	I	T	MT	I
50	Q	MT	T	AS	I
52	Q	T	T	MT	I
59	B	I	MT	MT	S
62	Q	T	MT	T	T
66	V	MT	MT	I	I
71	V	T	MT	MT	S
73	Q	I	T	I	I
75	C	T	T	MT	T
76	A	T	MT	S	S
77	A	I	MT	MT	I
78	A	MT	MT	AS	AS
79	A	MT	MT	T	AS
80	A	MT	T	T	T
97	C	MT	T	I	I
134	V	I	T	T	MT

a. V = Valle; Q = Quindío; B = Bolívar; A = Atlántico; C = Cauca (all departments of Colombia).

b. Reaction to the disease: T = tolerant; MT = moderately tolerant; I = intermediate; S = susceptible.

Table 1.1.6.2. Evaluation of the reaction of a progeny from a cross between the cassava varieties CM 2177-2 and M NGA 2 to *Phytophthora* isolates of different genetic groups.

Genotype	Isolate[a]					
	27	44	66	69	P4	P12
K 1	I	MT	T	MT	T	MT
K 6	MT	I	MT	I	T	T
K 7	T	MT	T	MT	MT	MT
K 15	T	T	T	MT	T	MT
K 28	MT	I	T	MT	MT	I
K 30	T	MT	T	MT	T	MT
K 32	T	S	T	I	T	S
K 33	T	T	T	T	T	T
K 34	T	T	T	T	T	MT
K 38	I	MT	MT	MT	T	I
K 40	S	T	I	I	T	I
K 41	T	T	I	MT	T	MT
K 43	MT	MT	T	T	T	MT
K 46	S	MT	MT	I	MT	I
K 47	T	T	I	I	T	MT
K 49	T	T	T	T	T	T
K 53	I	T	I	T	T	I
K 56	I	I	T	T	MT	T
K 58	T	MT	T	T	T	T
K 59	T	T	I	I	T	I
K 61	T	T	T	I	T	I
K 62	I	I	T	MT	T	MT
K 63	T	T	T	T	T	MT
K 66	T	MT	T	T	T	MT
K 69	MT	MT	T	T	T	MT
K 70	T	MT	T	MT	T	MT
K 71	T	MT	T	T	T	MT
K 72	T	T	T	MT	MT	I
K 74	T	MT	T	MT	T	MT
K 75	I	T	T	MT	T	MT
K 77	T	MT	T	MT	T	T
K 78	S	MT	I	I	T	MT
K 79	T	MT	MT	MT	MT	MT
K 82	MT	T	S	S	T	I
K 84	T	T	MT	MT	T	T
K 88	HS	MT	T	I	MT	I
K 89	T	S	T	I	T	S
K 91	S	I	S	MT	T	I
K 92	T	MT	T	MT	T	MT
K 95	T	T	T	MT	MT	MT
K 96	T	T	MT	MT	MT	I

K 98	T	T	T	T	T	MT
K 99	MT	MT	T	MT	T	MT
K 100	MT	S	MT	MT	MT	I
K 108	MT	HS	T	S	MT	I
K 110	MT	I	MT	I	MT	I
K 118	T	T	T	MT	T	MT
K 119	MT	MT	T	MT	MT	MT
K 120	T	MT	T	MT	T	MT
K 121	I	MT	T	MT	MT	MT
K 122	T	MT	T	MT	MT	MT
K 124	T	T	S	HS	MT	I
K 129	T	T	T	MT	T	T
K 130	MT	T	T	MT	T	T
K 132	T	T	T	T	MT	MT
K 136	T	T	MT	T	T	S
K 139	T	T	T	MT	MT	T
K 140	I	T	I	I	MT	S
K 141	T	MT	T	MT	T	MT
K 142	T	I	MT	T	T	S
K 143	T	MT	T	MT	T	MT
K 145	T	MT	T	T	T	MT
K 148	MT	MT	T	MT	MT	I
K 150	MT	MT	T	T	MT	T

a. Reaction to the disease: T = tolerant; MT = moderately tolerant; I = intermediate;
S = susceptible; HS = highly susceptible.
Isolates: P12 = Brazil; P4 = Colombia; 27 and 44 = Quindío (Colombia); 66 and 69 = Valle (Colombia).

PUBLICATIONS IN 1998

1. Papers Submitted to Refereed Journals (in alphabetical order of author)

Alvarez E; Cadena SF; Llano G. Evaluación de genotipos de yuca (*Manihot esculenta* Crantz) por su resistencia a diferentes cepas de *Xantomonas axonopodis* pv. *manihotis*. Fitopatología Brasilera.

Alvarez E; Iglesias C; Barragán MI. Avances en la identificación de fuentes de resistencia a la pudrición radical causada por *Phytophthora* spp. en yuca (*Manihot esculenta* Crantz) Fitopatología Brasileira.

Barragán MI; Alvarez E. Evaluación de la tolerancia a la pudrición radical causada por *Phytophthora* spp. en variedades de yuca (*Manihot esculenta* Crantz), bajo condiciones de invernadero. ASCOLFI Informa.

Barragán MI; Alvarez E. Identificación de fuentes de resistencia a la pudrición radical de yuca (*Manihot esculenta* Crantz). ASCOLFI Informa.

2. Presentations for conferences and proceedings

Alvarez E. Molecular breeding for resistance to *Phytophthora* spp. in Cassava. Paper presented to a conference held at the Universidad Nacional de Colombia, Palmira, May 7.

Barragán MI; Alvarez E. Evaluación de la tolerancia a la pudrición radical causada por *Phytophthora* spp. en variedades de yuca *Manihot esculenta* Crantz, bajo condiciones de invernadero. ASCOLFI, Pasto, Colombia, May 29. (Abstract.)

Barragán MI; Alvarez E. Identificación de fuentes de resistencia a la pudrición radical de yuca *Manihot esculenta* Crantz. ASCOLFI, Pasto, Colombia, May 29. (Abstract.)

II. THESES IN PROGRESS IN 1998

Cadena SF. Estudio de virulencia de 12 cepas de *Xanthomonas campestris* pv. *manihotis* en diferentes genotipos de yuca (*Manihot esculenta* Crantz). Universidad Nacional de Colombia—Palmira.

Llano G. Identificación de genes de resistencia a *Phytophthora* spp. en yuca, mediante el uso de sondas heterólogas. Universidad Nacional de Colombia—Palmira.

Loke JB. Identifying and isolating major genes conferring resistance to causal agents of the root rots *Phytophthora drechsleri*, *P. nicotianae*, and *P. cryptogea* in a segregating population of cassava (*Manihot esculenta* Crantz). Universidad Nacional de Colombia—Palmira.

Restrepo JA. Dinámica de las propiedades químicas del suelo y su relación con la resistencia de yuca (*Manihot esculenta* Crantz) a *Phytophthora* spp. mediante investigación participativa en comunidades indígenas de Mitú, Vaupés. Universidad Nacional de Colombia—Palmira.

III. LINKAGES WITH OTHER CIAT PROJECTS AND WITH CIAT'S PARTNER INSTITUTIONS

- CIAT Projects PE-1, SB-1, and SB-2
- EMBRAPA, Cruz das Almas (Bahia, Brazil)
- Universidad Nacional de Colombia—Palmira (Valle, Colombia)
- Secretaría de Agricultura, Mitú (Vaupés, Colombia)
- FIDAR, Cali, Colombia
- UMATAs from Mitú, Santander de Quilichao, Buenos Aires (Colombia)

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OUTPUT 1: Genetic base of cassava and *Manihot* species evaluated and available for cassava improvement.

Sub-output 1.2. Characterization of cassava germplasm for resistance/tolerance to major pests

In traditional production systems, few options are available to resource-limited farmers for controlling pests. The CIAT cassava germplasm bank is nearly 6000 accessions and locally selected cultivars (land races) collected primarily in the neotropics. These traditional cultivars represent centuries of cassava cultivation in diverse habitats, having been selected by farmers over a long period in the presence of a high diversity of herbivores. These land races often possess traits that confer low to moderate levels of resistance to multiple pests. This germplasm bank is constantly being evaluated for resistance to several arthropod pests that can cause yield losses in cassava. Evaluations are often done in more than one ecosystem. More recently emphasis is being given to whiteflies, mites and stemborers.

Activity 1.2.1. *Whiteflies: Germplasm Evaluation at CIAT-HQ and CORPOICA, Nataima.*

Cassava clones were evaluated at CIAT and Nataima, Tolima for resistance to the whitefly *Aleurothrachellus socialis*. Whitefly populations at CIAT were moderate to high for the fourth consecutive year. Evaluations at CIAT during 1998 concentrated on cultivars that had been selected as promising for resistance during previous years at ICA/Nataima.

Thirty two clones sown in 50 plant plots were evaluated using a 1 (low damage or low whitefly population level) to 6 (severe damage and high whitefly population) scale. Whitefly population scales are based on counts of eggs, pupae and adults. The 32 clones evaluated consisted of landrace varieties, hybrids and backcrosses and had previously shown good levels of resistance in screening trials in Tolima. Also included were five regional or farmer varieties from the Tolima area.

Results show that 9 cultivars or 26.5% presented very low damage levels (1.0 to 1.5) and 3 cultivars had damage levels between 1.6 to 2.5. The remaining 22 cultivars had damage levels between 2.6 and 5. The regional cultivars from Tolima, Azucena, Ceiba Blanca, Almidona, Llanera Precoz, and Cuero de Marrano had damage and population ratings between 4 and 4.5, indicating that farmer varieties in the regions are susceptible to whiteflies and probably experiencing significant yield losses.

The nine best cultivars were MEcu 64, MPer 335, MEcu 72 (all landrace varieties), CM 8424-6, CM 8424-33, CM 8424-4, CG 489-34 and CG 489-4 (all hybrids). All had damage ratings of 1.0, except MPer 415 and CG 489-34 with ratings of 1.5. MEcu 72 and CG 489-34 have consistently, over several years, maintained low damage ratings. The varieties MEcu 64 and MPer 335 have excellent growth habits as well as low damage ratings and low whitefly populations. These two varieties will continue to be evaluated at CIAT and Tolima and should inter into breeding schemes for improve whitefly resistant clones.

From 1994 through 1996 whitefly (*A. socialis)* populations at Nataima, Tolima were lower than normal. Low whitefly populations provide inadequate selection pressure to insure reliable resistance evaluation. All evaluations done at Nataima are with natural field populations of whiteflies.

During 1997-1998, whitefly populations have increased significantly allowing for more accurate germplasm evaluation. During the past year 1651 cassava clones, in observational fields, were planted and 1418 were evaluated. These clones were the F1 progeny from crosses of cassava clones previously selected for their resistance to whiteflies, with clones with desirable agronomic characteristics. These crosses resulted in 17 families **(Table 1.2.1.1).** Four field evaluations were done over a period of several months, using a whitefly damage and populations scale, as previously described.

Results indicate that whitefly populations were high and there was good selection pressure. Of the 1418 clones evaluated, 938 (66.1%) had damage ratings above 3.6 and were eliminated as susceptible **(Figure 1.2.1.1);** 308 (22%) clones had an intermediate damage evaluation (2.6 to 3.5). The remaining 172 (12.1%) clones had damage ratings below 2.6 and are considered as promising for resistance. 56 (3.9%) clones had damage ratings of 1 to 1.5, indicating possible high levels of resistance. However one cycle (year) of field evaluation is not adequate to confidently identify resistance and these clones will continue to be evaluated for at least 3 cycles (years). A 1.0 to 1.5 ratting signifies no damage symptoms and low whitefly population levels. The Families that most frequently occurred in this group was CM 8984 with 9 selections, and CM 8893 with 6 selections. In both of these families the resistant parent was CG 489-34, indicating that this clone may good heritable resistant traits.

Table 1.2.1.1. Families of cassava clones formed from crosses of whitefly (*A. socialis*) resistant and susceptible cultivars.

Family	Crosses		Observation
	Female	Male	
CM 3317	MBra 12 (T)	MCol 1468 (S)	MCol 1468 = CMC-40
CM 5438	MBra 12 (T)	MCol 1505 (S)	
CM 7559	MNGua-2	MBra 12 (T)	
CM 8884	CG 489-4 (R)	MCol 1468 (S)	CG 489-4 = MEcu 72 x MBra 12
CM 8885	CG489-4 (R)	MCol 1505 (S)	CG 489-4 = MEcu 72 x MBra 12
CM 8887	CG489-4 (R)	MCol 2256	CG 489-4 = MEcu 72 x MBra 12
CM 8889	CG 489-23 (R)	MCol 1468 (S)	CG489-23 = MEcu 72 x MBra 12
CM 8891	MCol 1468 (S)	CG 489-34 (R)	CG 489-34 = MEcu 72 x MBra 12
CM 8892	MCol 2246	GC 489-34 (R)	CG 489-34 = MEcu 72 x MBra 12
CM 8893	MCol 2256	CG 489-34 (R)	CG 489-34 = MEcu 72 x MBra 12
CM 8960	MCol 2246	MBra 12 (T)	
CM 8961	MCol 2256	MBra 12 (T)	
CM 8984	MCol 1505 (S)	CG 489-34 (R)	CG 489-34 = MEcu 72 x MBra 12
CM 8990	MCol 2026	CG 489-34 (R)	CG 489-34 = MEcu 72 x MBra 12
CM 8991	MCol 2026	MBra 12 (T)	
CM 8995	MEcu 72 (R)	MCol 1468 (S)	
CM 8996	MEcu 72 (R)	MCol 2246	

R = whitefly resistant cultivar
T = whitefly tolerant cultivar
S = whitefly susceptible cultivar

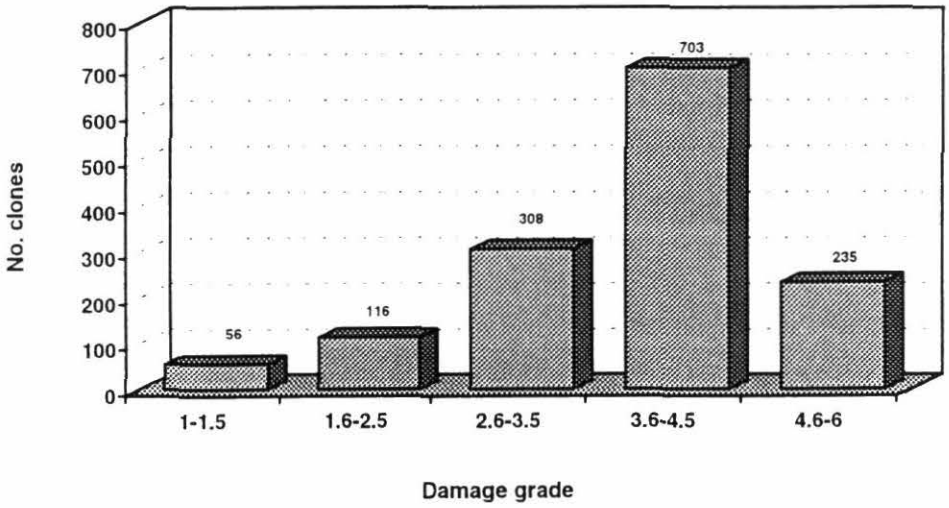

Figure 1.2.1.1. Evaluations of F1 cassava clones from crosses of whitefly (*A. socialis*) resistant and susceptible cultivars at CORPOICA, Nataima, Tolima (1997-1998).

Activity 1.2.2. *Evaluation of selected genotypes at regional trial level in CORPOICA, Nataima.*

Prior research has established that the cassava clones MEcu 72 is highly resistant to the whitefly, *A. socialis*, and the clone MBra 12 is "field resistant" or tolerant. Four progeny from a cross between these two clones were selected for resistance to whiteflies and good agronomic/culinary characteristics. CORPOICA/Natima is presently evaluating these clones in a series of regional trials. This trial consists of 8 clones, the two parents MEcu 72 and MBra 12, four progeny CG 489-34, CG 489-31, CG 489-23 and GC 489-4, the regional farmers cultivar (Aroma) and CMC-40, a susceptible check. The trial was planted with two treatments, with and without pesticide (Dimethorate, 2-3cc/Lt. water), and 3 replications per treatment of each cultivar. This is the first of a series of trials and was harvested during 1998.

The results from this trial, presented in Table 2, indicate that all of the whitefly resistant cultivars will yield greater than the farmers regional variety, Aroma. It can also be observed that the treated plots did not outyield the non-treated plots, with the exception of the regional variety. To a certain degree this was expected; previous trials with the resistant cultivars have given similar results. Resistance to whiteflies in these clones is high and whitefly populations seldom reach a high enough level to cause yield reduction. In this trial, on on-treated plots, whitefly populations for MEcu 72 remained below 1.8, CG 489-34 = < 2.7, CG 489-31 = < 1.8, CG 489-4 = < 2.6 and CG 489-23 = < 2.7; for CMC-40 populations rose to 4.5 and the regional cultivar, Aroma, to 4.1. Average damage ratings over 9 evaluations, on non-protected plots for MEcu 72 = 1.0, GC 489-34 = 1.3, CG 489-31 = 1.0, CG 489-23 = 1.7, and CG 482-4 = 1.5; for MBra 12 = 2.7, CMC-40 = 4.0 and Aroma = 3.7. CMC-40 and Aroma reached high damage ratings of 5.5 and 5.2 respectively.

These data indicate that whitefly populations and damage levels during the trial were high enough to cause yield reduction. The fact that no yield losses occurred on MEcu 72, CG 4879-23, CG 489-4, CG 489-31 and CG 489-34, can be explained by the high levels of whitefly resistance in these clones. MBra 12 is a clone with good agronomic qualities and tolerance to several arthropod pests (whiteflies, mites, thrips); it can usually yield well in-spite of high pest populations. CMC-40 is a whitefly susceptible clone, that in previous trials has often suffered considerable yield reduction. However, it is also a very vigorous cultivar that will yield well under favorable environmental condition, especially if there is ample rainfall. It was expected that CMC-40 would suffer greater yield losses in this trial. As can be seen from the results the regional, farmers cultivar, Aroma, yielded lowest of all the cultivars evaluated, indicating that it is susceptible to whitefly attack and will suffer yield losses.

Dry matter content of the cultivars was not affected by whitefly feeding, although, in general, dry matter was low (**Table 1.2.2.1**).

Table 1.2.2.1. Regional trial, CORPOICA/Nataima. Evaluation of cassava cultivars resistant to whiteflies (*A. socialis*), with and without pesticide treatment.

	Total Weight T/ha			
Clone	**Treated**	**Non treated**	**% Difference**	**% Dry matter**
MEcu 72	30.7 A	31.1 A	- 13	26.3 A
MBra 12	20.3 AB	22.1 AB	- 8.1	26.8 A
CG 489- 23	24.5 AB	26.54 AB	- 7.5	26.4 A
CG 489–31	25.8 AB	28.1 AB	- 8.2	26.3 A
CG 489–34	28.6 AB	32.5 A	- 12.0	27.8 A
CG 489–4	22.8 AB	28.9 AB	- 21.1	27.4 A
CMC-40	18.5 AB	27.7 AB	- 33.2	28.3 A
Regional *	14.6 B	9.5 B	34.9	27.7 A

* Variety Aroma

\- Differences in favor of Non-Treated

Whitefly populations in the treated plots were higher than expected, and in some cases as high or higher than the non-treated plots. Nine evaluations of whitefly populations were made by CORPOICA throughout the course of the trial and the average whitefly population on the treated plots was 2.0 and on the non-treated plots it was 2.03. This can help explain why there were not significant differences between the treated and non-treated plots. Possible explanation for high populations in the treated plots may be due to whitefly resistance to the pesticide or migration of whiteflies from neighboring field where no control was exercised.

Activity 1.2.3. *Identification Of Genomic Regions Responsible For The Determination Of Whitefly Resistance In Cassava.*

Whitefly (*Aleurotrachelus socialis*) is one of the most damaging pest and vector that affects the agricultural production in the world. There are almost 1200 species with a wide range of hostages like legumes, fruit trees and ornamentals where this insect causes big economic losses.

In cassava (*Manihot esculenta* Crantz), the principal symptoms in the plant are: total chlorosis, the apical leaves turn curly, the basal leaves turn yellow and dry, and it stops the developing of the plant. The adult insects are found preferentially in the apical zones of the plant, where they extracting large quantities the sap of the conductive vessels, causing a considerable damage by loss of vigour, with low yield in the production. The honeydew which excrete, as a result of the copious sap intake, serves as a substrate for sooty mold fungui, which can also damage hosts by blocking photosynthesis.

One of the strategies implemented to control this pest, in addition to biological control and chemical control is the searching of genetic resistance. Thus, studies have been done to detect

resistant and susceptible plants to whiteflie's attack whit the final goal to design a breeding program.

It has been reported (CIAT, 1995) the existence of different sources of resistance to Whitefly. The most important genotypes are: Mbra-12 and Ecu-72, those were used as parentals in the generation of new genotypes. The CG489-34 has shown the best resistant behavior. Also were selected the more susceptible genotypes: MCol 2026, MCol-1505.

The goal of this project is to study and to screen plants with resistance to withefly in cassava with molecular technics.

Different breeding populations have been obtained from the resistant and susceptible genotypes as parentals:

CG489-34 X Mcol-2026 = 131 individuals
CG489-34 X Mcol-1505 = 108 individuals
MBra-12 X Mcol-2026 = 135 individuals

We selected the more contrasting individuals (resistant and susceptible ones) in the field for each family. DNA was extracted from the different individuals and each group with the parental was mixed in a bulk.

We are using molecular screening (RFLPs and RAPDs) intended to find markers associated to resistance and later we intended to isolate the responsible genes.

We intend to screen the parental lines and the bulk with AFLP markers.

Parentals from each family were evaluated with RFLP markers from the cassava map (Fregene et al. 1997). Seventy two polymorphic probes were obtained.

Sixty two RAPDs markers have been screened with the bulks of the same families, the primer OP.P3 showed a clear polymorphism between the susceptible and resistant group. This marker is being evaluated with the whole population of each cross, to confirm its association with the resistance.

We pretend to isolate and sequence the polymorphic bands and generate a Scar. It could be used to make diagnosis of resistant materials to discriminate the most promising ones to the breeding programs and the farmers.

With the sequence of the genes of resistance we could establish homologies with the reported ones to other crops, to understand its expression patterns.

The RFLP, RAPD, Microsatellites and AFLP markers will be used to generate a framework map and for the QTL analysis.

Activity 1.2.4. *Whitefly Feeding Behavior.*

Cassava genotypes with resistance to whiteflies have been identified at CIAT. Resistant clone MEcu 72 shows high mortality for both adult and immature whiteflies, which may suggest less feeding on this genotype under natural conditions. It is necessary to identify whitefly feeding behavior on susceptible genotypes and to make comparisons with MEcu 72 in order to better understand the mechanisms of resistance.

Electronic monitoring of insect feeding (EMIF) is a technique that permits the identification and quantification of the feeding behaviors of hemipteran insects. By passing an electrical signal to a test plant, and tethering an insect with a fine gold wire, modifications caused by stylet movements and feeding behaviors can be observed as waveforms. EMIF has extensively been used for the study of mechanisms of plant resistance to insects. CIAT presently owns two AC-Electronic feeding monitors, and has access to a DC version of the system (EPG). The AC systems have been used with leafhoppers (*E. kraemeri*) on beans, and the DC systems with cassava mealybugs. Preliminary observations with both systems suggested that an easy protocol could be developed for monitoring the whitefly. In addition, CIAT technicians needed to be trained in wiring techniques, operation of the system, computer display and data acquisition.

Electronic Monitoring Methodology. The methodology devised for electronic monitoring of whitefly feeding behavior includes two major steps: a wiring technique to attach the thin wire to the mesonotum of an adult whitefly, and the proper settings (ground voltages, signal frequency) of the electronic monitoring system.

The "normal" gold wire used with leafhoppers (12.7 um) is too thick and stiff for the small whitefly adults. A thinner wire needed to be obtained. Since purchase of a thinner wire was very difficult in the short period of time allowed for this project, thinning of the existing gold wire was necessary. To do this a 10-20 cm piece of the thick wire is placed for 45 min in a solution of 3 mol Nitric acid and 9 mol Chlorhydric acid. This is a potent oxidizer that dissolves away part of the gold leaving a thinner wire while conserving its electricity conducting properties. Pieces of this thin gold wire are attached with silver paint to a copper stub.

Female whiteflies from a greenhouse colony are placed by mouth aspirator on a vacuum stand and held in place by a very gentle vacuum. Several individuals can be placed simultaneously. With the help of the copper stub, the thin gold wire is placed on the mesonotum of a female, and a very small drop of electrically conducting silver paint is used to attach the wire to the insect. Care needs to be taken for not getting silver paint on the whitefly's eyes or wings. This affects their behaviors even more than the tethered condition. New insects need to be used should silver paint get on their wings or eyes.

Tethered whiteflies can be acclimated to the wire by placing them on a cassava leaf for 1 h. Before the electronic monitoring session begins, whiteflies are starved for 30 min. The copper stub holding the tethered whitefly is attached to the alligator clip on one of the input electrodes of the electronic monitor.

A constant signal, 250 mV at 250 Hz was established as the best setting for *Aleurotrachellus socialis*. This signal is transmitted via an electrode inserted in the substrate of a potted plant (4-8 weeks old). Detached leaves placed on a container filled with water and sealed with the output electrode of the electronic monitor also worked and showed better conductivity than the potted plants. However, the effects of detached leaves vs. whole plants on whitefly feeding behavior needs to be evaluated further.

Feeding Behavior. During probing stylet movements and other feeding behaviors induce changes to the constant signal. These modifications, known as waveforms, are captured in a computer using an analog to digital converter board, displayed on the screen on a time scale, and stored for post-acquisition measurement and analysis. Once waveforms have been correlated with specific behaviors, quantification can be made on the frequency and duration of these behaviors.

Waveforms produced by probing *A. socialis* on CMC-40 are shown in **Figure 1.2.4.1**. Due to time limitations it is impossible to correlate waveforms with specific behaviors for this whitefly species. However, Walker (1998) reports that several species of whiteflies share very much stereotypical styles of feeding and that waveforms patterns are very similar among them. Since waveforms shown are similar in appearance to the waveforms reported in the literature, we will describe these. All probes observed started with salivation waveforms corresponding to the intercellular path that the stylets follow in their way to the phloem. These waveforms are shown in figs 1a and 1c as "intercellular stylet path". They have also been correlated with the deposition of a salivary sheath. In some instances the stylets come across treachery elements in the xylem and the whitefly ingests from them (Fig. 1.2.4.1c). This particular waveform has not been completely correlated with, but there is evidence of ingestion. After reaching the phloem, normally whiteflies go into continued ingestion, producing a flat waveform whose beginning is illustrated toward the end of the trace in Figs. 1.2.4.1b and 1.2.4.1c.

A new waveform that has not previously been identified or associated with any behavior is shown in fig. 1d. It would be expected that as more electronic monitoring of whitefly feeding more patterns would be identified and more correlational work would be needed. Now that a methodology exists for the study of whitefly feeding behavior at CIAT, comparisons can be made among resistant and susceptible genotypes.

Training. Two research assistants spent about 10 h per week training in electronic monitoring of insect feeding. They developed skills for whitefly wiring and for data display and acquisition. They also received extensive lecturing in the principles and applications of the technique, and in the basics of homopteran feeding behavior.

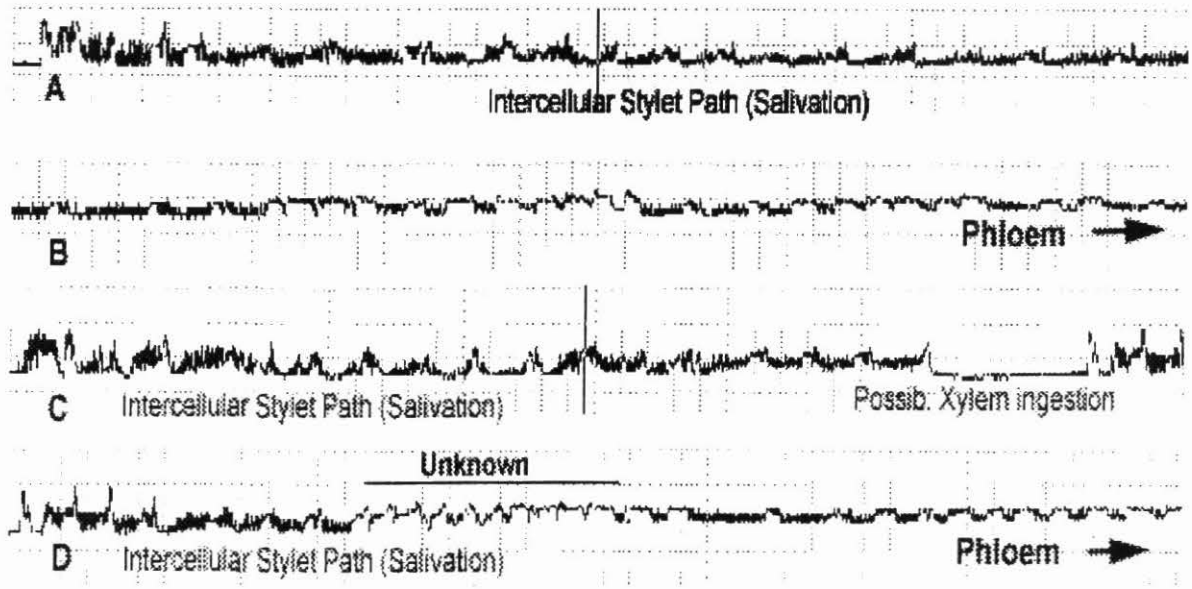

Figure 1.2.4.1. Waveforms produced by probing *Aleurotrachellus socialis* on Cassava cv. CMC-40. A. and B. Single probe (stylet penetration). B and C. Single probe forms a second whitefly. Note waveform identified as possible xylem ingestion and an unknown waveform that has yet to be correlated with a feeding behavior.

Activity 1.2.5. *Screening cassava germplasm for resistance to mites.*

More than 5000 clones from the CIAT cassava germplasm bank have been evaluated for resistance to mites, especially the cassava green mite (CGM) *Mononychellus tanajoa*. In recent years evaluations are being done both at CIAT and Pivijay, where mite populations are usually high due to the long dry season and poor soils.

During 1998, fifty two new hybrids were introduced into the CIAT germplasm bank and these were evaluated for mite damage. Most clones displayed very high damage levels and only three had low to moderate mite attacks (2.0 to 3.0 on a 1 to 6 damage scale). The 3 clones SM 616-22, SM 1181-3 and CM 6173-8 will be evaluated in another cycle.

More than 600 clones that have been selected as promising for resistance in past evaluations were evaluated at both Pivijay and CIAT. 388 of these maintained a damage level between 2.0 and 3.0. This represents about 7.8% of the germplasm evaluated. These 388 clones were also evaluated during the past year at Pivijay and 81 or 1.6% maintained moderate levels of resistance at both CIAT and Pivijay (**Table 1.2.5.1**). All 81 have damage ratings between 2.0 and 3.0 at both evaluation sites and at least two evaluations at each site. These clones will be further evaluated in another cycle.

Table 1.2.5.1. Cassava clones that show low mite damage when evaluated in two ecosystems. CIAT, Palmira and Pivijay, Magdalena.

MBra 64	MCol 1373	MPer 611
MBra 69	MCol 1432	MEcu 48
MBra 110	MCol 1439	MEcu 58
MBra 137	MCol 1856	MEcu 64
MBra 173	MCol 1926	MEcu 72
MBra 225	MCol 1951	MEcu 87
MBra 235	MCol 2019	MEcu 97A
MBra 245	MCol 2058	MGua 7
MBra 276	MCol 2179	Mgua 86
MBra 292	MCol 2477	MMex 59
MBra 391	MCR 6	MVen 54
MBra 404	MCR 20	MVen 125
MBra 420	MPer 181	MVen 146
MCol 52A	MPer 266	MVen 216
MCol 217	MPer 320	MVen 276
MCol 226B	MPer 365	MVen 291
MCol 282	MPer 366	CG 5-99
MCol 336	MPer 394	CG 406-5
MCol 344	MPer 415	CG 489-31
MCol 510	MPer 435	CG 489-57
MCol 548	MPer 461	CG 502-1
MCol 549	MPer 463	CG 1141-1
MCol 576	MPer 464	SG 350-23
MCol 593	MPer 523	CG 698-3
MCol 826	MPer 560	CM 3380-7
MCol 1219	MPer 562	CM 4574-7
MCol 1254	MPer 564	CM 6173-8

Activity 1.2.6. *Evaluation of Cassava Germplasm for Resistance to the Stemborer Chilomina clarkei.*

Numerous arthropod species have been reported to feed on and damage stems and branches of cassava. Although many species are world wide in distribution, literature reports indicate that they are more important in the neotropics. They are generally reported as causing sporadic or localized damage. However in recent years, the lepidopteran stemborer, *Chilomina clarkei*, has caused considerable crop damage in several areas of Colombia, with > 7000 ha under attack and this is increasing. Borers not only reduce yields by 45-62%, they also reduce the quantity and quality of stem cuttings for planting material. Adult stemborers are very mobile and difficult to kill and since the larvae mostly feed within the stems, pesticide is both impractical and costly. CORPOICA, because of pressure from farmers, has become increasingly concerned about this pest and requests CIAT's assistance. Funding restriction has limited our ability to study this pest to the extent needed.

In recent years we have responded to this problem by trying to identify cassava germplasm that might have some resistance to the borer. We have taken advantage of plantings by the cassava germplasm project (Improved Cassava for the Developing World IP3) to evaluate a large number of cassava clones at several sites where *C. clarkei* populations are high.

During 1996-1997, 455 cassava cultivars were evaluated at Pivijay, Magdalena. This region, for the past 3 to 4 years has had consistently high *C. clarkei* field populations. Evaluations are done by counting the number of stemborer holes and tunnels in cassava stems. The result of this evaluation is indicative of the level and extent of damage being caused by this pest. One hundred percent of the cultivars evaluated had stemborer damage (holes and tunnels) (**Figure 1.2.6.1**). Only 11 cultivars had an average of one or less larval holes per plant. This could indicate a level of resistance but more than one evaluation cycle will be required. One hundred and one cultivars (22.2%) had between 1 and 2.5 larval holes or low levels of damage which would probably not result in yield losses nor excessive damage to planting material.

The largest number of clones 189 (41.5%) had from 2.6 to 5 holes; a small group of 11 clones (2.4%) had more than 10 larval holes per plant. Sixty nine cultivars died; this was probably due to a combination of *C. clarkei* attack and environmental factors. Those cultivars with very low (< 2.5) holes per plant will be evaluated in subsequent planting cycles.

In two separate trial at Pivijay during 1997-98 (both were yield trials with 3 reaplications) a total of 98 cultivars were evaluated. All cultivars showed stemborer damage. Seventeen cultivars had up to one larval hole per plant and no cultivar had more than 5, indicating that *C. clarkei* populations were not as high as in previous evaluations.

Media Luna Evaluations: During 1997-98, 494 cassava cultivars were evaluated in germplasm evaluation trials at Media Luna (Magdalena). Three cultivars, CM4402-4, MCol 1237, MCR 117, were undamaged and 16 additional clones had less than 1 larval hole per stem (**Figure 1.2.6.2**). One-half, 247 clones (50%) had between 2.6 to 5 holes per stem and an additional 33% had more than 5 holes per plant.

In a separate trial of 21 clones, 7 had less than 2.5 holes/plant. A third trial of 24 clones, 14 clones had less than 2.5 holes/plant.

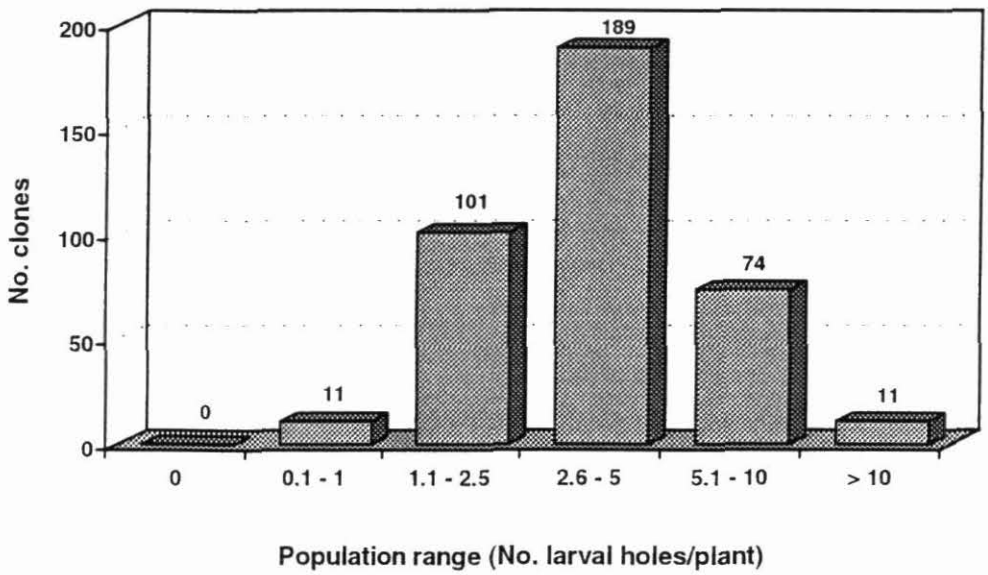

Figure 1.2.6.1. Populations of *Chilomina clarkei* (holes per plant) in 455 cassava clones evaluated at Pivijay, Magdalena (1996-97).

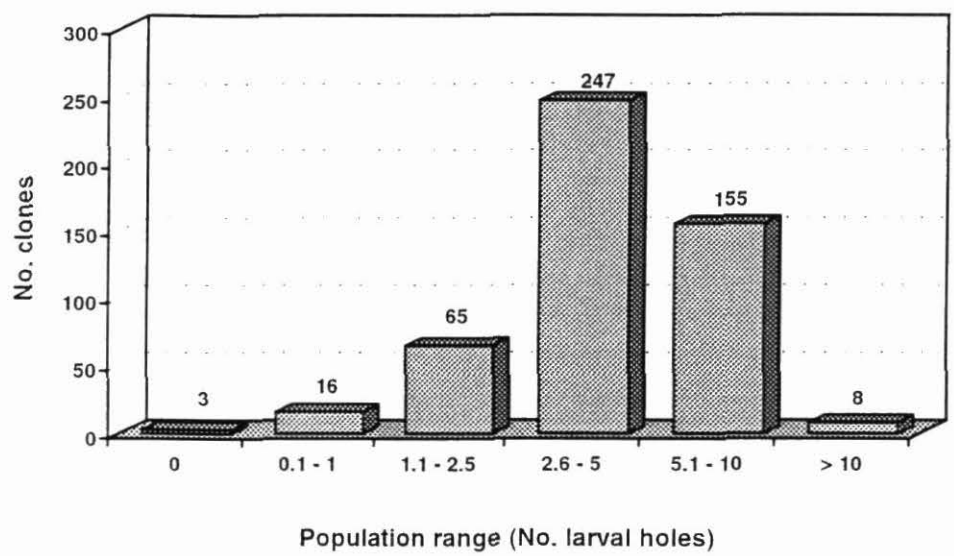

Figure 1.2.6.2. Evaluation of cassava cultivars for damage caused by the stemborer *Chilomina clarkei*, in Media Luna (Magdalena) (1997-98).

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IMPROVED CASSAVA FOR THE DEVELOPING WORLD

OUTPUT 1: Genetic base of cassava and *Manihot* species evaluated and available for cassava improvement.

Sub-output 1.3. Germplasm evaluation for root quality traits

Activity 1.3.1. *Evaluation of genetic diversity and heritability for vitamins and mineral content in cassava roots and foliage.*

Rationale: Most of the emphasis in relation to cassava breeding has been centered around increasing root production and concentration of starch. Since cassava is a staple in regions where there are severe deficiencies of micro-nutrients; we could use the crop as a vehicle to deliver vitamins and minerals in higher concentrations. The objectives of this project are: a) to screen 600 cassava landraces from CIAT's germplasm collection for B-carotene content in roots; b) to correlate B-carotene content with root color; c) to study the genetics of B-carotene accumulation in cassava roots d) to determine B-carotene losses and degradation in processed products; e) to determine the effects of environmental variation on B-carotene content in selected genotypes; and f) to evaluate the potential of cassava leaves as a source of minerals and vitamins for human nutrition. The work has been developed between 1995 and 1998, with the financial support of DANIDA.

Methods: The extraction procedure outlined by Safo-Katanga et al. (1984) was adjusted by extracting root parenchyma with petroleum ether. A sample of 10 g was taken out of the central part of one root, taken at random from a plant 10 to 11 months after planting. A sub-set of 632 accessions from the cassava germplasm collection was evaluated to study the range of genetic variability. Thrity-nine individuals from a cross between a yellow-root (CM 2772-3) and a white-root genotype (CG 1372-6) were sampled together with the parental material for the inheritance study. The work on carotene stability in response to different processing methods was conducted on 28 yellow-root genotypes from the germplasm collection, grown with 2 replications. The treatments were: a) fresh, unprocessed root parenchyma as a control (FR); b) root parenchyma cooked for up to 30 minutes (CR); c) flour obtained by oven drying cassava chips and milling (CFO); and d) flour obtained by sun drying cassava chips and milling (CFS). B-carotene stability across 3 different environments (Palmira, Villavicencio and Media Luna) was studied on 14 high-carotene genotypes.

Dry and grinned 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 (grinned or whole sample). A group of 20 genotypes was evaluated for mineral concentration both in roots and leaves, following recommendations from the sampling study.

Results: **B-carotene.** Although there is a close relationship between the quantitative levels of carotene and the color of root parenchyma, the variability observed among genotypes with similar parenchymal color resulted in an overlap between white and cream roots, and between cream and yellow roots. **Table 1.3.1.1** presents the mean values and standard deviations for groups of accessions classified according to root parenchymal color. Even those deep-yellow and orange roots showed a broad range of concentrations, from 0.6 to 2.4 mg carotenes/100 g fresh root. Although it seems feasible to improve β-carotene levels through visual selection for root color, there is a need to rely on quantitative screening in order to increase the efficiency of the process.

Table 1.3.1.1. Average carotene concentration in cassava roots classified according to root color.

Root color	Numerical scale	Carotene (mg/100g)	Standard deviation
White	1	0.13	0.48
Cream	2	0.39	0.28
Yellow	3	0.58	0.28
Deep yellow	4	0.85	0.17
Orange	5	1.26	0.11

It seems possible to select genotypes with 2 mg/g of carotene out of the available genetic variability, which sets a considerably higher upper limit than previous reports (Jos et al., 1990; Moorthy et al., 1990). Given that the average daily requirements of vitamin A is around 3 mg (WHO, 1995); the consumption of 150 g of roots from genotypes with such high concentration can supply this requirement, provided that the carotene is 100% available to the human organism.

The 5 genotypes having the highest β-carotene concentration were collected in the Amazonian region of Brazil and Colombia, where yellow parenchyma cultivars are preferred by farmers.

Across a total of 632 samples, a significant correlation (r=0.82) between root color and carotene content, was determined. Calculating r^2, we have that 67% of the total variability in carotene content can be explained by the variability in root color. Therefore, it is possible to improve carotene content by visual selection for color intensity, but there is still some scope to improve selection efficiency by quantitative evaluation of carotene content.

A previous report by Hershey and Ocampo (1989) established that root color (white/cream/yellow) was determined by a partially dominant gene. The hypothesis of two genes with epistatic effects controlling root color, was studied from a cross between a white-root and a yellow-root genotype. These genes were nominated as Y_1 with complete dominance, allowing for the transport of carotene at high levels to the roots; and Y_2 with partial dominance allowing for the accumulation of carotene in the roots. The genotype of the white-root parent was assumed to be $y_1y_1Y_2y_2$, and the yellow-root parent as $Y_1y_1Y_2Y_2$, according to the observed segregation in the F_1. The expected segregation from those genotypes was 50% white ($y_1y_1Y_2\_$), 25% cream ($Y_1y_1Y_2y_2$), and 25% yellow ($Y_1y_1Y_2Y_2$). According to the Chi square test, the observed segregation has a probability between 80 and 90% of supporting the original hypothesis. The parent/progeny performance for root color and carotene content is presented in **Table 1.3.1.2**. Although major genes dominate the transport

and accumulation of carotene in the roots, the quantitative variability observed within root color classes suggested that a number of genes with smaller effects are involved in the accumulation process. Therefore, there is good scope to achieve maximum levels of expression by a process of recurrent selection (Jos et al., 1990).

Table 1.3.1.2. Segregation for root color and carotene concentration (fresh weight basis) in a cross between contrasting parents.

Genotypes	Number of individuals (Observed)	Number of individuals (Expected)	Carotene (mg/100 g)
CM 2772-3 (yellow)			0.42
CG 1372-6 (white)			0.08
White	20	19.50	0.09
Cream	10	9.75	0.28
Yellow	9	9.75	0.38

The effects of different processing methodologies [FR (control), CR, CFO, and CFS] were studied in a group of 28 genotypes. On average, boiling (CR) reduced carotene content the least (34%), followed by oven dried flour (CFO) with a 44% reduction. Sun dried flour (CFS) reduced the carotene concentration to the lowest level (73% reduction), which seems to imply that carotenes are photo-labile. Although the correlation among different processing methods across genotypes was significant (**Table 1.3.1.3**), the relative magnitude of the effects (r^2), indicates that the genotypes with the highest carotene concentration in the fresh root controls are not the ones with the highest concentration after processing. Therefore, after routine screening for high β-carotene in fresh roots, a test of stability after different processing methods should also be routinely carried out.

Considerable amounts of carotenes were conserved after processing, particularly when oven drying was carried out. These results are supportive of the findings of McDowell and Oduro (1981), that gari obtained from yellow-root cultivars, presented concentrations of carotene of up to 1.13 mg/100 g. In relation to the nutritional value of processed cassava foods, it is also important to study how much carotene left after processing is available to the human body, once the cassava product is consumed.

With regard to stability in different environments, there were significant differences ($P<0.001$) among evaluation sites. Average carotene concentration for all the evaluated genotypes in the sub-humid ecosystem was double (1.63 mg/100g of roots) the one observed in the more fertile mid-altitude site (0.82 mg/100g); with the acid-soil savanna ecosystem falling in-between (1.35 mg/100g). Although there were significant interactions with the site of evaluation, testing in the site with the greatest expression for the trait (sub-humid ecosystem) will result in a more precise screening, a broader expression range and a higher heritability than in the other environments. Sub-humid tropics is the most important ecosystem for cassava production in Africa and Latin-America.

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.

Table 1.3.1.3. Correlation (r) among processing methodologies for carotene concentration within a group of 28 yellow-root genotypes [control (FR), cooked parenchyma (CR), oven dried flour (CFO) and sun dried fluor (CFS)].

	FR	CR	CFO
CR	0.80**		
CFO	0.62*	0.70**	
CFS	0.59*	0.76**	0.79**

*, **: significant at 5% and 1% probability, respectively

Minerals. Results showed that experimental error 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 (Data not shown). 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 (var) 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 in them. The limited variability observed in Fe concentration, will require to study a broader spectrum of genotypes including other *Manihot* species.

Achievements: - Sources of high carotene and ascorbic acid content in the roots selected.

- Inheritance of carotene accumulation determined
- Stability of carotene content after cooking and drying determined
- Variability in mineral content in roots and leaves studied
- Higher concentrations of vitamins and minerals in leaves justify its use as a food supplement.

References

Hershey, C. H. and Ocampo, C. 1989. Description of new genetic markers in cassava. Cassava Newsletter 13:1-5.

Jos, J., S.; Nair, S. G., Moorthy, S. N. and Nair, R. B. 1990. Carotene enhancement in cassava. J. Root Crops. 16:5-11.

Mc Dowell, I. and Oduro, K. A. 1981. Investigation of the beta-carotene content of yellow varieties of cassava. Journal of Plant Foods 5:169-171.

Moorthy, S. N., Jos, J. S., Nair, R. B. and Sreekumari, M. T. 1990. Variability of B-carotene content in cassava germplasm. Food Chemistry 36:233-236.

Safo-Katanga, O., Aboagye, P., Amartey, S. A. and Olaham, J. H. 1984. Studies on the content of yellow-pigmented cassava. In: Terry, E. R. et al. (eds). Tropical Root Crops Production and Uses in Africa. IDRC, Ottawa, Canada. pp. 103-104.

W.H.O. 1995. Global prevalence of vitamin A deficiency. MDIS Working Paper #2. W.H.O., Geneva, Switzerland.

Papers produced

Iglesias C; Mayer J; Chavez L; & Calle F 1997 Genetic potential and stability of carotene content in cassava roots. Euphytica 94:367-373.

Activity 1.3.2. *Screening of elite genotypes for physiological post-harvest deterioration.*

Rationale: The short post-harvest storage life of cassava roots is an intrinsic characteristic that affects the marketability of the product. Roots have to be consumed or processed shortly after harvest. Post-harvest physiological deterioration (PPD) begins as early as 24 hours of harvest, resulting in root production and quality losses, high marketing margins and risks, and restricted management flexibility for farmers, traders and processors.

A limited amount of genetic variability for PPD is available in cassava germplasm, providing quantitative genotypic differences in the shelf-life of cassava between very few days to one or possibly two weeks. However, selection for reduced PPD from existing genetic variants in breeding programs is seriously hampered by environmental effects and the complex inheritance of several traits under simultaneous improvement. Commonly cultivated cassava varieties have shelf lives of only a few days. Although results from early research showed a close positive association between PPD and root dry matter content, recent results from studies on a wider genetic range, failed to find a significant association between those traits.

The process of PPD in cassava resembles wound-healing responses found in other plant systems. Such defensive responses are eventually inhibited by successful wound repair in the majority of

the systems studied. However, this repair process is not successful in the harvested cassava storage root (except under certain storage conditions as described below), leading to the *hypothesis that unrestrained* cascades of wound responses ultimately result in root deterioration.

The objective of the present work is to associate PPD resistance/susceptibility reactions to other root traits of accumulation of metabolites in the roots, in order to facilitate germplasm screening, gene identification and tagging, as well as increasing the efficiency of the breeding work.

Methods: The work was developed at CIAT (Palmira) during the period September 1995 – March 1998. Two screening trials were established with 16 and 63 elite genotypes with 3 replications in plots of 25 plants. A random sample of 5 roots from each genotype was harvested and evaluated according to the procedure described by Wheatley (1982). Distal and proximal extremes of each root were cut in order to obtain a 15-cm piece. The distal part of the root was covered with a plastic film and secured with a rubber band. Roots were stored in a cool shaded place and were evaluated at 5, 10 and 15 days after harvest. Each root was cut into seven 2-cm slices, and each slice was scored for PPD. Related root traits such as dry matter content (%) and cyanide were recorded in both trials, and starch and sugar content was measured in the first trial.

Results: In the screening of 16 genotypes run during the crop cycles 1995-96, PPD at 10 and 15 days was correlated with starch cooking facility (FCC), starch instability (INE) and the ratio of total sugars (AZ) to starch concentration (AL) (**Table 1.3.2.1**). Principal component analysis considering those traits as independent variables revealed that the ratio AZ/AL had the largest positive relationship with PPD. The second largest component, but having a negative effect on PPD was starch cooking facility, which represents an intrinsic characteristic of cassava starch. The evaluation of the same genotypes during the crop cycle *1996-97 resulted in a* significant difference among genotypes at 5 and 10 DAH, but no difference was observed at 15 DAH. From this trial, 3 genotypes with less than 20% PPD at 15 days were selected to be used in crosses for building up

Table 1.3.2.1. PPD reaction of elite germplasm and related root and starch characteristics.

	1995-96							1996-97
Genotypes	% DM	HCN total ppm	FCC	INE	AZ/AL	PPD15	PPD15 + Microb	PPD5
CM 5665- 1	38.9	94	5.8	249	7.5	32	54	12
CM 6119- 5	38.4	149	6.5	320	10.8	45	63	48
CM 7086-17	37.8	248	8.7	290	9.1	59	59	40
CM 7463- 2	35.3	102	8.2	205	6.9	25	59	40
SM 690- 6	38.3	188	5.7	289	6.7	23	23	29
SM 1068- 4	38.4	75	8.2	232	5.0	9	24	10
SM 1088- 1	38.1	103	7.5	257	6.6	17	28	32
SM 1111- 8	35.2	183	7.8	219	6.9	28	51	20
SM 1280- 2	37.2	180	7.5	244	7.6	30	35	76
SM 1116- 3	37.5	57	8.2	240	6.0	14	15	22
SM 1363- 3	36.5	91	9.1	262	6.2	62	65	74
SM 1477-19	37.6	198	8.2	263	6.4	20	42	10
SM 1565- 8	37.7	238	8.1	240	8.6	31	63	47

SM 1588- 1	35.2	317	8.5	298	10.0	36	47	10
SM 1600- 4	35.8	120	8.2	270	6.1	23	33	51
MDOM 5	38.0	109	10.5	205	7.3	21	62	8
Average	37.0	153	7.9	255	7.4	30	45	33

genetic stocks. Genotypes SM 1280-2 is interesting, because it combines resistance to PPD and microbial deterioration. Correlations among PPD for each of the evaluation dates was not significant, although the correlation between 15 DAH in first crop cycle and 5 DAH second cycle was significant. These results show that PPD reaction is highly affected by the environment and that conditions for screening should be standardized in order to allow for a better detection of favorable alleles.

More recently the screening of a broader range of genotypes (63) revealed a considerable range of diversity (**Table 1.3.2.2**), but for certain genotypes PPD was masked by root rot symptoms. It is important to combine resistance to both PPD and root rot, in order to extend the shelf life of cassava roots, and have a stable performance across years. In this study, we observed a significant positive correlation between PPD and % root dry matter (r= 0.55**), and a significant negative correlation between PPD and cyanide content (r= -0.43**). This is the first time that a significant relationship with cyanide content is reported.

Table 1.3.2.2. Genotypes with extreme PPD reaction in evaluations after 1 and 2 week storage (1997).

	Initial sample		**After 1 week storage**			**After 2 weeks storage**		
Genotype	% DM	Total HCN	% DM	Total HCN	**% PPD**	% DM	Total HCN	**% PPD**
High PPD								
CM 6786- 4	37.2	112	39.7	119	**65.7**	39.4	104	**72.7**
CM 8224- 2	41.4	146	43.9	97	**65.7**	44.9	71	**84.3**
SM 909-25	45.1	80	42.7	129	**71.7**	42.4	84	**74.7**
Low PPD								
SM 1602-13	37.5	180	39.3	187	**20.0**	39.6	161	**15.7**
M BRA 12	35.8	205	36.6	233	**19.3**	36.4	211	**15.0**
MCOL 1468	32.5	163	32.6	165	**9.7**	34.3	238	**15.3**
Std. Dev. 5%	2.3	38	1.4	55	10.3	3.1	48	11.8

We have recently started a joint research project with the University of Bath which has the following 3 components: 1) cDNA clones for a range of genes known to be involved in wound-responses in other plant systems will be isolated from cassava, based on DNA homology among functionally conserved genes. These genes will then be assayed for their expression in contrasting cassava genotypes and controlled environments affecting PPD. Simultaneously, the cDNA clones will be included in the genetic map of cassava and monitored as candidate genes affecting PPD, through quantitative trait analysis under representative field conditions.

Achievements: - Genotypes with more than 10 day shelf-life selected

- The ratio of total sugars to starch concentration was positively correlated with the level of post-harvest deterioration.
- No correlation was found with dry matter content as previously reported.

References

Wheatley C 1982 Studies on cassava (Manihot esculenta Crantz) root post-harvest physiological deterioration. PhD thesis. University of London. London. 246 p.

Publications produced

Iglesias C. J Bedoya. N Morante & F. Calle (1996) Genetic diversity for physiological deterioration in cassava roots. In Kurup GT et al. Tropical Tuber Crops: Problems. prospects and future strategies. Science Publishers Inc.. Lebanon. NH. USA. pp 73-81.

Activity 1.3.3. *Evaluation of starch content, quality and granule morphology among elite germplasm and core collection entries.*

Rationale: Cassava represents an excellent source of starch in the tropics. due to its production efficiency. and the intrinsic characteristics of the starch produced. CIAT has given emphasis to the selection for higher starch content within cassava gene pools during the last 15 years. As a result of that. a series of elite genotypes with high concentration of starch are currently available at National Program level. Not so much emphasis has been given to study and develop alternative sources for starch quality. which can open new avenues to boost the demand for cassava. and create new markets for farmers growing the crop in marginal regions. During the last 3 years we have centered our efforts in 3 areas: a) increasing starch content; b) characterizing starch quality within the existing range of genetic diversity for cassava; and c) create new variants through genetic transformation. We will be reporting on the analysis of starch resistance to different treatments in a range of genotypes. and the variability in starch granule structure found in the cassava germplasm collection.

Methods: *a) Resistance to acid media and freezing.* Starch from 9 genotypes was used in this study. Those genotypes were selected out of a larger group. based on the range of amylose content (Wheatley et al.(1992). 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 25C 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. Prior to evaluate viscosity, gel samples from the acidity trial were left at ambient temperature, while those from the freezing study were left for 1 hour in a hot bath (30°C). Viscosity was measured in a Brookfield viscometer, with a speed of 10 rpm at 25°C. The Brabender viscoamylograph was used to evaluate reological properties of the gels. Amylose was evaluated with the cholorimetric method 6647 of I.S.O (1987).

b) Starch granule shape. A total of 4420 genotypes from the global cassava germplasm collection were screened under microscope, after staining with a 0.2% solution of lugol (ICl). Those genotypes presenting abnormal granule structure or associations among granules, were separated for further studies.

c) Starch phosphorilation. Forty cassava genotypes were analyzed for their content of Glucose-6-P, at the Royal University of Denmark (KVL).

Results: *a) Resistance.* **Table 1.3.3.1** shows the functional properties of the starches evaluated. There were significant differences among genotypes in relation to amylose content, with MMEX 59 having the lowest concentration (10.45%) and MVEN 77(12.50%), CG 165-7 (12.30%) and MVEN 25 (12.20%) having the largest values. Gels were clear and showed low resistance to cooking. Gelatinization temperatures ranged between 63.2 and 69.4 C. Maximum viscosity varied between 440 and 610 UB.

Table 1.3.3.1. Physico-chemical properties of cassava starch

Gentoype	Amylose %	T gelatinization(°C)	V maximum(UB)
MCOL 1684	11.09 (±0.10)	64.3	510
CM 3306-4	10.87 (±0.14)	65.2	515
MBRA 162	11.90 (±0.25)	63.6	520
MMEX 59	10.52 (±0.24)	63.6	590
CG 915-1	11.43 (±0.09)	66.3	552
MVEN 77	12.52 (±0.14)	67.8	490
MPER 196	11.37 (±0.20)	69.4	440
MCOL 2485	11.52 (±0.05)	64.3	610
MVEN 25	12.25 (±0.05)	64.8	545
CG 165-7	12.35 (±0.10)	66.3	518

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 (**Figure 1.3.3.1**). Gels did not show changes in their structure, and no liquid was released (syneresis) during the different periods of storage.

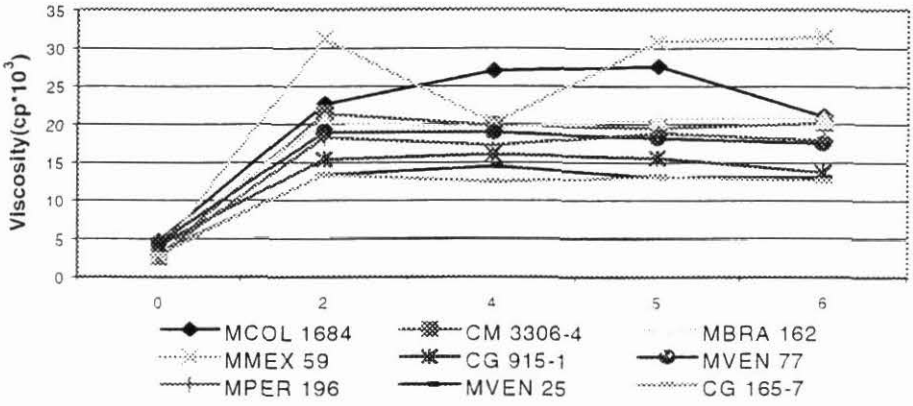


Figure 1.3.3.1. Cassava starch gel viscosity during storage in acid medium.

In **Figure 1.3.3.2.** 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.

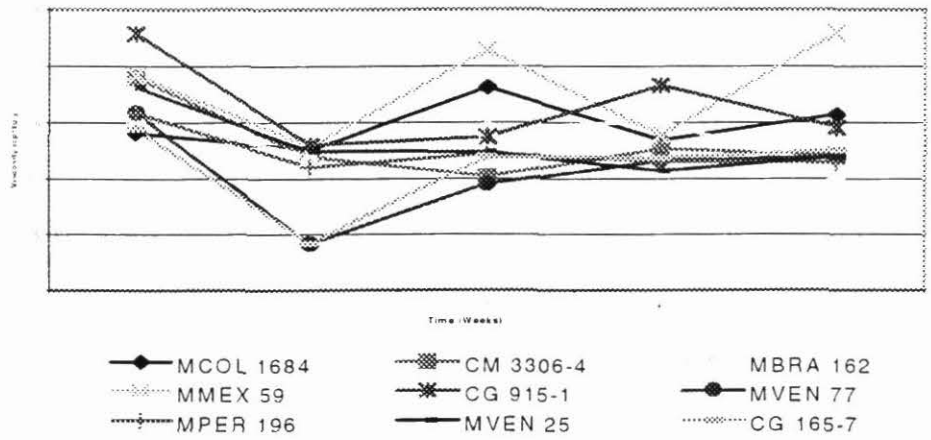


Figure 1.3.3.2. Cassava starch gel viscosity during freezing at –20°C.

b) Granule shape. A total of 20 genotypes were detected with abnormalities in starch granule shape or in strange associations among granules: CG 26-12; MCoi 31; MCol 1489; MCol 1700; MCol 2197; MEcu 51; MEcu 74; MEcu 191; MInd 11; MMex 77; MPar 79; MPar 12; MPar 137; MPer 279; MPer 401; MPer 540; MVen 21 and MVen 327. This abnormality can result from different causes; among them mutations in the ratio of amylose/amylopectin, differential re-growth due to defoliation or lodging, etc. The genotypes will be multiplied this year for further studies of starch functional and chemical properties.

c) Starch phosphorilation. Root and tubers usually have higher levels of starch phosphorilation than cereals. The range found in cassava (0.61 to 3.60 nmol Glc6P/mg starch) is very interesting to start an improvement process through selection and recombination (**Figure 1.3.3.3**). However, it is considerably lower than the range already reported for potato starch (5.0 to 30.0 nmol Glc6P/mg starch). It is interesting to notice that the 2 genotypes with the highest Pi level (SM 853-7 and CM 7438-1) are from the highlands. Starch synthesized in the highland ecosystem has particular quality traits due to the lower average temperature under which it is accumulated. We are going to use these 2 genotypes as parent lines to generate recombinant progenies and seek for transgressive segregation for Pi-starch concentration. KVL has developed a screening methodology for breeders to incorporate Pi-starch as a selection criteria.

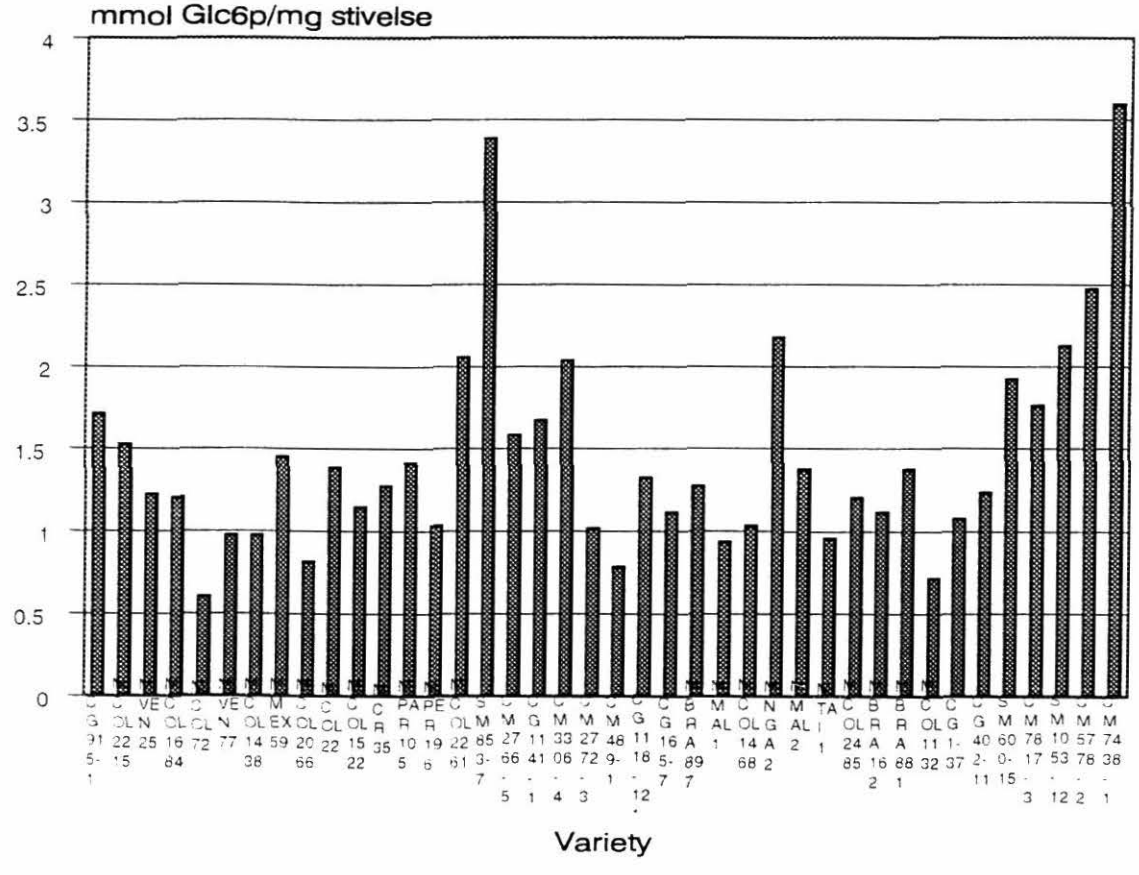


Figure 1.3.3.3. Starch phosphorilation in different cassava genotypes.

Achievements:

- Genotypes with enhanced resistance to acid media and freezing conditions have been selected.
- Cassava germplasm base has been screened for starch granule abnormalities. Genotypes with abnormal shapes and conglomerated structure will be studied in detail.
- Parental material was selected to develop recombinant progenies for the selection of high Pi-starch concentration in cassava.

OUTPUT 2: Genetic stocks and improved gene pools developed and transferred to national programs.

Sub-output 2.1. Production of recombinant seeds to re-initiate breeding cycles and support national programs.

Activity 2.1.1. *Selection of parental material based on previous cycle results, and the information obtained from the previous output (resistance/tolerance, quality traits).*

Rationale: The selection of parents to build populations for future breeding work represents the core of our improvement efforts, since it will determine the genetic progress we will achieve in the future. There are two types of populations developed: open pollinated and control crosses. We usually used open pollination (polycrosses) to develop populations for target ecosystems. We have consistently developed polycrosses for the sub-humid tropics, acid soil savannas, semi-arid tropics, mid-altitude and highland tropics, and sub-tropics. In the case of controlled crosses, we used them to develop progenies for specific traits, special studies or the combination of elite experimental material with local landraces that need to be improved.

Methods: Genotypes that have been selected over 2 consecutive years in advanced yield trials are only selected to participate as parents for the following generation. Among those genotypes, we select those with outstanding performance for the most important agronomic traits. After the analysis of variance is conducted with data across 2 years, those genotypes exceeding at least one standard deviation from the overall mean are considered as parents for the next generation. Sometimes we also include landraces or already released cultivars that can contribute special features to the progenies generated.

The information provided by Pathologists, Entomologists and Quality Specialists in relation to sources of resistance or special traits is used to select genotypes for control crosses. These control crosses are developed upon specific requests from National Programs that want their main landrace or released variety crossed to genotypes with specific traits; or requests from CIAT's scientists that want to pyramid genes, or develop segregating progenies for gene tagging.

Results: **Table 2.1.1.1.** presents the most important parents selected for the development of gene pools targeted to specific ecosystems, and their performance in relation to check local or released varieties. That difference multiplied by the heritability of the traits represents the genetic progress for next generation. We can see that we have been very successful in selecting

Table 2.1.1.1. Agronomic performance of best parental material selected for each of the ecosystems we work in Colombia (1995-97).

Variety	Root yield t/ha	% from check	% dry matter	% from check	Dry matter yield t/ha	% from check
Sub-humid						
CM 7514- 8	21.05	152.43	34.54	99.60	7.27	151.81
CM 8027- 3	21.86	158.29	34.19	98.59	7.47	156.05
SM 1411- 5	23.09	167.20	34.13	98.41	7.88	164.55
SM 1433- 4	21.80	157.86	34.83	100.43	7.59	158.54
SM 1438- 2	21.31	154.31	35.78	103.17	7.62	159.20
CG 1141- 1	13.81	100.00	34.68	100.00	4.79	100.00
Acid soil savannas						
CM 6740- 7	22.17	137.53	36.20	99.42	8.03	136.74
CM 7073- 7	20.88	129.53	36.18	99.37	7.55	128.71
SM 1438- 1	21.50	133.37	35.23	96.76	7.57	129.05
SM 1697- 1	26.10	161.91	35.00	96.13	9.14	155.64
MCOL 2298	21.70	134.62	35.60	97.78	7.73	131.62
CM 523- 7	16.12	100.00	36.41	100.00	5.87	100.00
Mid-altitude tropics						
CM 5655- 4	34.72	161.26	38.10	121.03	13.23	195.18
CM 6740- 7	29.28	136.00	36.68	116.52	10.74	158.46
CM 7514- 7	30.38	141.11	42.12	133.80	12.80	188.80
SM 1565- 17	37.33	173.39	35.65	113.25	13.31	196.35
SM 1741- 1	32.40	150.49	38.93	123.67	12.61	186.10
MCOL 1468	21.53	100.00	31.48	100.00	6.78	100.00
Highland tropics						
CM 7438- 1	27.65	207.43	34.03	107.59	9.41	223.17
SM 600- 19	18.13	136.01	36.08	114.07	6.54	155.14
SM 616- 22	25.13	188.52	33.55	106.07	8.43	199.97
SM 707-17	25.30	189.80	32.42	102.49	8.20	194.37
SM 853- 7	22.55	169.17	34.20	108.13	7.71	182.91
COL 1522	13.33	100.00	31.63	100.00	4.22	100.00

outstanding genotypes for all the ecosystems but in particular for the highland and mid-altitude tropics.

In relation to the selection of parents for specific traits, during the last 3 years we have incorporated genotypes that excel for their: resistance to green mites, bacterial blight, whitefly and root rots, high concentration of carotenes and root dry matter, low concentration of cyanide, short stature, excellent cooking quality, and broad adaptation. A total of 343 genotypes selected

for their performance in specific traits have taken part of our control crosses during the last 3 years. This group represent a broad and selected genetic base to re-start our selection process for specific traits, incorporate genes for specific traits into popular varieties in different countries, and diversify the genetic base for resistance and other traits.

Achievements:

- An average 68 % genetic advantage of the best selected parents over check varieties.
- A group of 257 genotypes selected to participate in the generation of recombinant progenies that will serve as the basis for future selection cycles at CIAT and National Program level.
- Sources of resistance to pest and diseases as well as specific traits selected for the development of control crosses.

Activity 2.1.2. *Establishment of crossing blocks and production of recombinant seed from previously established blocks.*

Rationale: Populations developed for specific ecosystems 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 constructed by the recombination of contrasting genotypes (i.e. cyanide inheritance). Often times 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.

Methods: For polycrosses we use the design developed by Wright 1965 for polycrosses in forage species. For this type of design there is a need to have a number of clones equal to a prime number minus one (i.e. 12, 16, 18, etc.). The design allows for each genotype to have the same probability of being surrounded by any other genotype of the selected group. Knowledge on flowering capacity is important in order to select a group of materials with synchronized flowering. When there are considerable differences we have to implement delayed planting and/or pruning of the most earlier flowering genotypes. At harvest the seed from different plants of the same genotype are combined together and named as a half-sib family (SM).

For control crosses, we plant 10 to 20 plants depending on the flowering capacity of the genotype in question. Each flower has the potential to produce 3 seeds, but in average we obtain no more than 1 seed per cross, due to the sensitivity of the stigma to the manipulation during pollination. Seeds from the same cross are mixed together and name as a full-sib family (CM)

Results: A total of 458,027 recombinant seeds were produced during the period 1996-98 (**Table 2.1.2.1**). Parental populations aimed at specific ecosystems of continents represented 77% of the total seed produced. Genetic stocks are being built for traits of high priority in our project. In the case of Africa and ACMV resistance, we are developing "backcross" populations between F1 crosses (African x Latin American), and a different African parent. The strategy is to have progenies with 75% African background. Stocks for root quality traits represent a large

Table 2.1.2.1. Recombinant seed produced within the project (Oct 1995 – Oct. 1998).

Parental population	Controlled crosses	Poly-crosses	Total
Broad adaptation	10,758	26,601	33,359
Africa	11,039	90,474	102,143
Asia	8,630		8,630
Dwarf plant type	1,484	516	2,000
Resistance to:			
Bact. Blight	3,699		3,699
White flies	4,677		4,677
Root rot	390		390
Post harvest deterioration	2,007		2,007
Cooking quality	2,203	7,385	9,588
Cyanide content	2,406		2,406
High carotene content	4,444		4,444
Root yield potential	1,067		1,067
Crosses to wild species	4,054		4,054
Mol. map population	3,368		3,368
Adaptation to acid soils	2,301		2,301
Tetraploid cassava	609		609
Sub-humid tropics	260	32,411	32,671
Acid soil savannas	1,025	52,256	53,181
Mid-altitude tropics	11,156	38,178	49,334
Highland tropics	3350	73,506	76,956
Sub-tropics		18,276	18,276
Semi-arid tropics	847	41,920	42,867
Total:	**79,774**	**381,523**	**458,027**

proportion of our efforts. In the case of cooking quality, phosphorilated starch and carotene content, we have crossed genotypes with the highest performance, with the purpose of selecting transgressive segregants within the progenies. For cyanide, white flies, post harvest deterioration and bacterial blight we have crossed genotypes representing the extremes in performance in order to map and tag the genetic factors responsible for the inheritance of those traits. In the case of dwarf genotypes we are developing a population with combining genetic factors determining short plant type, in order to start breeding for other agronomic traits with that population.

Achievements:

- Considerable amount of recombinant seeds produced.
- Large proportion of our work shifted to specific traits, through the development of genetic stocks, and pre-breeding populations.
- More targeted crosses with landraces build during this period, upon request from National Programs.

Activity 2.1.3. *Generation (in Thailand) and distribution of advanced breeding materials for Asian National Programs.*

Rationale: Breeding for Asia has mainly centered around the issue of increased productivity of dry matter per hectare. Yield and root dry matter concentration have been the primary traits for selection, with almost none emphasis given to pests and diseases, or cooking quality. The work developed in Asia for 15 years, has revealed the possibility to select for broader adaptation of genotypes. We have the case of Rayong 60 and Kasetsart 50 with good performance in a range of Asian countries. In order to exploit those two facts plus the need to explore those genotypes in the pipe-line of the Thai breeding program, a considerable importance has been given to the production of recombinant seed in Thailand, and the transfer of recombinant families to other countries in Asia.

Methods: The same approaches as the ones implemented at CIAT-HQ (polycrosses and controlled crosses) have been implemented in Thailand, but a greater proportion of segregating progenies from controlled crosses is usually produced.

Results: Close to 100,000 were produced during the last 3 years of activities. Thirty percent of that seed was transferred to 4 National Programs in the region and to CIAT/HQ (**Table 2.1.3.1**). The retirement of our cassava breeder stationed in Thailand, may restrict in the future, this type of collaboration, from the Thai program. Although it will take longer for other National Programs to receive materials from Thailand, in the future we foresee that the flux of improved germplasm between CIAT-HQ and the Thai breeding program will continue, and it will be through us that other National Programs will receive progenies involving the latest selections in Thailand.

Achievements:

- Unrestricted support and collaboration from the Thai breeding program.
- Use of the most elite genotypes in crosses
- Distribution of segregating progenies of high value for Asian National Programs.

Table 2.1.3.1. Cassava F1 hybrid seeds from CIAT/Thailand, distributed to Asian programs (1995-97).

Country	1995	1996	1997	Total
Indonesia	2,805	1,718	2,300	6,823
China	2,330	2,292	1,500	6,122
Vietnam	2,740	3,309	2,940	8,989
Philippines	1,190	1,350	1,100	3,640
CIAT/Colombia	2,158		2,575	4,733
Total	**11,223**	**8,669**	**10,415**	**30,307**

Sub-output 2.2. **Selection of recombinant progenies for broad and specific adaptation within major agro-ecosystems (sub-humid; semi-arid; highland and acid soil savanna).**

Activity 2.2.1. *Evaluation and selection of breeding materials at different stages.*

Rationale: Our strategy for cassava germplasm development is centered on the development of improved gene pools for specific edapho-climatic zones with importance for cassava production, as defined in **Table 2.2.1.1**. The most relevant ecosystems are the semi-arid and sub-humid tropics, for which we devote the majority of our efforts. The main selection activity is conducted in sites selected to represent the conditions of the target ecosystem. For every genotype that is tested in those sites we keep a copy at CIAT. CIAT-HQ is considered to be free of bacterial blight and some important viruses, and we want to maintain that condition. In case we do not keep a copy of each genotype, we would have to pass each of them through quarantine, which usually takes more than a year.

Methods: For each of the zones we conduct a recurrent selection program, with a progressive set of stages as described in **Figure 2.2.1.1.**. As the stages progress, we give more emphasis to traits of lower heritability, because we have more planting material for each genotype, and the evaluation can be conducted in bigger plots with replications. Certain selection criteria are of general importance across ecosystem (i.e. yield potential, dry matter content), while others are specific for each ecosystem (i.e. pest and diseases).

Progenies generated from the crossing blocks (F1) are planted in screen houses and transplanted to the field after 2 months at CIAT. At 6 months after planting, 2 stakes are harvested from each plant and given a consecutive number according to the plant. One of the stakes is planted at CIAT, the other one is planted at the main selection site (F1C1). Selection is conducted at harvest on individual plants at the main selection site. Planting material taken from the selected genotypes, at CIAT, is used to establish a non replicated 6-plant plot both at CIAT and at the main selection site (Clonal evaluation stage). Evaluation is done using the central 3 plants.

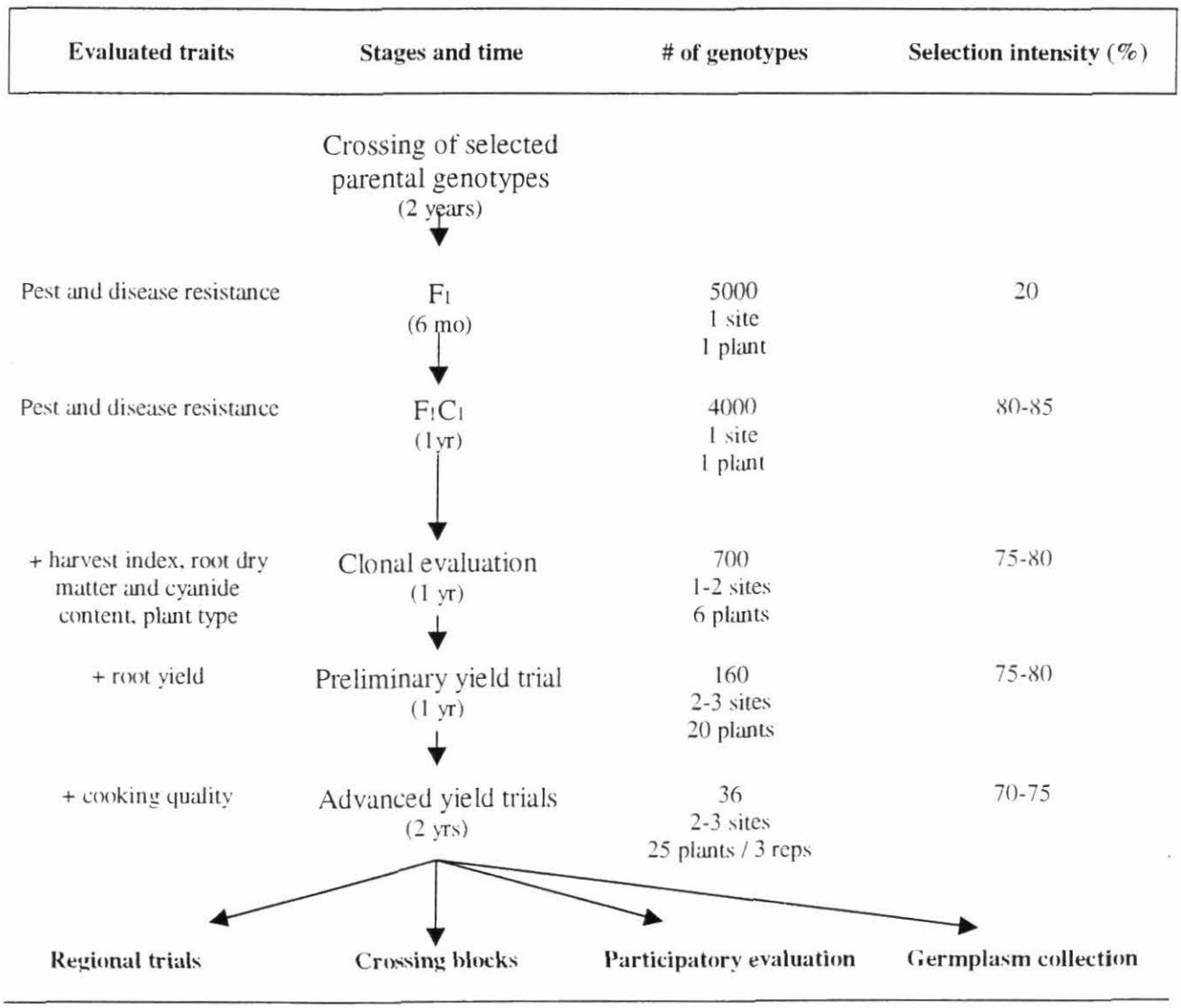
Selections are transferred to the following stage (preliminary yield trial) and planted in non replicated 20-plant plots. Evaluation is done in the central 6 plants, and selections are passed to the advanced yield trials at 1 or 2 sites, with 3 replications of 25-plant plots. Genotypes selected over 2 consecutive years at the advanced yield trial level are consider as "elite genotypes" and incorporated in the germplasm collection and the crossing blocks. Since each year we initiate a new breeding cycle, we have all the stages simultaneously being conducted in each site.

Table 2.2.1.1. Main ecosystems for cassava production, representative production regions and main breeding sites.

Description	Representative Countries/Regions	Main Sites for Breeding Work
Sub-humid tropics (800-1500 mm /year, bimodal rainfall distribution)	Colombia (Atlantic Coast & Santanderes); NE Brazil; NE Thailand; Domin. Rep.; N. Venezuela; Mexico (Yucatan Peninsula); subhumid belt of Africa;	*Media Luna* Santo Tomás; Betulia
Acid soil savannas (1500 – 3000 mm/year, short dry period, low pH)	Plains of Colombia & Venezuela; Brazil (Cerrado); Mexico (Tabasco); Cuba; W Africa savannas; Philippines; Panama (Ocu)	Villavicencio Matazul Sder de Quilichao
Humid tropical lowlands (above 3000 mm/year, no clear dry period)	Amazon basin (Brazil, Colombia, Peru); West Java & Sumatra; Malaysia; S. Vietnam; Equatorial West Africa	Villavicencio
Mid-altitude tropics (800-1400 masl)	Andean zone; central Brazilian highlands; mid-altitude areas of Nigeria, Cameroon, East Africa	Palmira Sder de Quilichao
High-altitude tropics (1400-2000 masl)	Andean zone; Rwanda; Burundi	Popayán Mondomo
Subtropics (latitudes higher than the tropics)	S Brazil; Argentina; China; N Vietnam; Cuba; Paraguay; S Africa	Sta Cat. (*Brazil*)
Semiarid (below 800 mm/year, unimodal)	NE Brazil; NE Colombia; (Guajira) semiarid belt of West Africa; Tanzania; Mozambique; Ecuador (Coast)	Guajira Sto Tomas NE Brazil

Results: In order to summarize results from the last 3 years of work, we present the 5 best selections from the clonal evaluation, preliminary and advanced yield trials, for the cycle 1997-98; the trial mean, mean of the check varieties and mean of all selections, for each of the ecosystems that we work in Colombia (**Tables 2.2.1.2, 2.2.1.3, 2.2.1.4**). More than 100 breeding trials were conducted during the 3 crop cycles from 1995 until 98. Comparing among breeding stages, we can observe that for the most important target trait (dry matter yield) the genetic progress (difference between mean of selections and trial mean) is greater as we advance in the

Figure 2.2.1.1. Basic cassava breeding scheme applied for each of the priority ecosystems.



breeding cycle. Dry matter yield is the resultant from a relatively low heritability trait (root yield) and an intermediate to high heritability trait (root dry matter %). The more we advance in the breeding cycle we have bigger plots, more repetitions within sites, and more sites of evaluation; therefore it is expected that the experimental error will be reduced, and the genetic progress enhanced.

The largest improvement in relation to the local check variety can be observed for the highland tropics ecosystem, followed by mid-altitude tropics and the acid soil savannas. The mid-altitude site represents better soil conditions compared to the others, that is reflected in a higher average performance for most of the breeding stages reported. On the other hand the response to selection depends more on the available genetic diversity and the possibility to combine traits that result in higher yield potential.

Table 2.2.1.2. Agronomic performance for the best 5 genotypes selected at the clonal evaluation stage in each of the ecosystems, along with the check variety mean and the trial mean.

Genotype	Parents		Root yield t/ha	% Root dry matter	Dry matter yield t/ha	Harvest index	HCN
	Female	Male					
Sub-humid tropics							
CM 7518- 8	MCOL 1505	CM 3299- 4	31.5	34.1	10.74	0.69	8
CM 8796-	MCOL 1734	SM 494- 2	33.9	37.4	12.65	0.59	9
CM 8803- 1	MBRA 108	CM 523- 7	37.8	34.2	12.93	0.60	6
CM 8803- 7	MBRA 108	CM 523- 7	32.0	35.7	11.44	0.57	8
SM 2277-14	SG 536- 1		31.3	39.5	12.35	0.60	3
CG 1141- 1			21.8	37.7	8.22	0.49	5
Trial mean			21.0	34.3	7.15	0.54	7.4
Mean of selections			21.3	35.2	7.48	0.55	7.3
Acid soil savannas							
SM 1652-21	CM 3372- 4		38.0	35.5	13.48	0.69	9
SM 1682-29	CM 3380- 7		36.7	30.7	11.26	0.55	9
SM 1812-83	SG 804- 5		31.5	33.0	10.40	0.52	7
SM 2211- 7	CM 5789- 1		35.7	32.8	11.70	0.58	7
SM 2288- 3	CM 7986-13		29.9	34.1	10.23	0.49	9
CM 523- 7			20.0	32.9	5.99	0.48	8
Trial mean			21.2	32.4	6.89	0.50	7.6
Mean of selections			22.8	33.9	7.71	0.51	7.6
Mid-altitude tropics							
CM 8777- 3	CM 6028- 1	SG 536- 1	35.4	40.2	14.24	0.51	9
CM 8787- 5	SG 105-11	SG 536- 1	40.6	35.0	14.22	0.66	9
SM 2275- 1	CM 6028- 1		42.5	37.7	16.01	0.54	9
SM 2276- 5	CT 5- 5		53.8	33.3	17.92	0.66	9
SM 2277- 6	SG 536- 1		38.5	36.6	14.12	0.54	7
MBRA 12			38.6	35.8	12.95	0.47	7
Trial mean			23.2	36.5	8.50	0.54	7.0
Mean of selections			25.3	37.7	9.50	0.56	7.0
Highland tropics							
CM 8654- 1	SG 638- 6	SM 424- 2	39.6	33.9	13.43	0.63	2
CM 8654- 6	SG 638- 6	SM 424- 2	32.5	33.2	10.78	0.56	2
SM 2123- 7	CG 402-11		32.3	36.0	11.61	0.71	6
SM 2136-17	MCOL 2016		31.2	35.1	10.94	0.57	2
SM 2232- 6	SM 523- 1		26.0	37.6	9.77	0.55	2
CG 402-11			19.4	32.4	6.28	0.57	6
Trial mean			19.1	33.1	6.37	0.53	3.8
Mean of selections			23.9	34.2	8.16	0.55	3.6

Table 2.2.1.3. Agronomic performance for the best 5 genotypes selected at the preliminary yield trial stage in each of the ecosystems, along with the check variety mean and the trial mean.

Genotype	Parents		Root yield t/ha	% Root dry matter	Dry matter yield t/ha	Harvest index	HCN
	Female	Male					
Sub-humid tropics							
SM 1516- 7	CG 1220- 2		31.5	32.2	10.13	0.62	9
SM 1517- 9	CG 1320-10		31.5	34.3	10.79	0.52	5
SM 2077- 1	CM 3992- 9		29.4	34.1	10.03	0.69	9
SM 2090- 7	CM 5577- 1		38.3	31.1	11.53	0.69	9
SM 2095-12	SG 787-10		33.3	33.5	11.16	0.61	9
CG 1141- 1			24.4	35.2	8.69	0.58	8
Trial mean			24.4	33.1	8.01	0.58	7.6
Mean of selections			25.6	33.9	8.61	0.57	7.7
Acid soil savannas							
SM 1438-18	CG 1005- 2		30.2	34.9	10.55	0.68	8
SM 1223-24	CM 2174-7		27.9	36.6	10.23	0.61	6
SM 1234-19	CM 2967- 8		34.8	31.8	11.05	0.75	8
SM 1363-11	SG 495-19		30.8	37.0	11.40	0.64	7
SM 2219-11	SM 494- 2		32.3	35.2	11.36	0.58	7
CM 523- 7			21.4	36.8	7.78	0.53	7
Trial mean			21.4	33.0	7.10	0.57	7.5
Mean of selections			25.5	34.2	8.68	0.59	7.8
Mid-altitude tropics							
SM 1509- 8	CG 910- 3		28.8	32.4	9.35	0.57	6
SM 1521- 7	CM 3299- 4		26.3	36.0	9.48	0.56	4
SM 1690-22	M BRA 5		23.3	33.0	7.69	0.48	8
SM 1789-51	MCOL 1505		31.0	31.1	9.63	0.47	6
SM 1855-15	CM 523- 7		23.5	35.5	8.35	0.48	7
MBRA 12			23.1	31.7	7.32	0.45	8
Trial mean			14.6	33.4	4.88	0.40	6.6
Mean of selections			16.5	34.6	5.65	0.44	6.5
Highland tropics							
SM 1712- 5	SG 427-64		15.8	37.0	5.86	0.55	3
SM 1847-32	MCOL 1522		15.0	32.8	4.91	0.47	4
SM 1935-14	CG 501- 2		28.6	30.5	8.73	0.55	8
SM 1937- 7	CG 1231- 3		22.6	34.9	7.87	0.50	8
SM 1991- 1	CM 4488- 4		17.8	29.7	5.30	0.61	9
CG 402-11			17.9	32.6	5.76	0.60	7
Trial mean			10.3	31.4	3.29	0.43	5.2
Mean of selections			14.5	33.6	4.82	0.47	5.0

Table 2.2.1.4. Agronomic performance for the best 5 genotypes selected at the advanced yield trial stage in each of the ecosystems, along with the check variety mean and the trial mean.

Genotype	Parents		Root yield t/ha	% Root dry matter	Dry matter yield t/ha	Harvest index	HCN
	Female	Male					
Sub-humid tropics							
CM 6182- 8	MCOL 2215	MCR 2	28.8	36.6	10.9		8.0
SM 1427- 1	CM 3997- 1		32.8	33.2	11.4		9.0
SM 1511- 6	CG 915- 1		34.5	35.8	12.3		8.5
SM 1565-17	MCOL 1505		36.9	30.3	11.4		7.0
SM 1657-12	CM 4209- 3		34.0	33.6	12.1		9.0
CG 1141- 1			19.9	36.0	7.5		7.5
Trial mean			24.6	34.0	8.4	0.64	7.3
Mean of selections			27.5	34.9	9.8	0.66	7.5
Acid soil savannas							
CM 7073- 7	CM 2777- 8	MVEN 77	21.4	35.3	8.18	0.54	6.0
SM 1812-56	SG 804- 5		21.6	34.4	8.27	0.56	9.0
SM 1859-26	CM 2766- 5		25.0	31.6	8.06	0.52	6.0
SM 1861-18	CM 2952- 1		25.8	34.8	8.39	0.66	7.5
SM 1862-25	CM 3372- 4		23.8	33.8	8.11	0.57	8.5
CM 523- 7			24.4	35.3	8.41	0.60	7.5
Trial mean			18.0	32.6	6.08	0.54	7.4
Mean of selections			20.2	34.5	7.23	0.55	7.5
Mid-altitude tropics							
SM 1557-17	CM 4729- 4		36.1	38.3	13.82	0.60	6.0
SM 1602-13	CM 489- 1		33.9	36.7	12.46	0.63	5.5
SM 1642-22	CG 996- 6		39.2	38.7	15.14	0.55	3.0
SM 1690-13	MBRA 5		33.9	37.5	12.75	0.58	4.5
SM 1741-1	MPAR 59		31.5	38.9	12.28	0.64	6.5
MBRA 12			14.7	37.3	5.52	0.35	8.0
Trial mean			21.4	36.6	7.88	0.50	5.8
Mean of selections			25.1	38.0	9.53	0.53	5.7
Highland tropics							
CM 6952- 1	CG 501- 2	CM 1090-52	24.6	36.7	9.00	0.47	5.0
SM 352- 1	MCOL 2016		25.6	34.2	8.82	0.41	3.0
SM 616-22	MCOL 1522		22.0	32.3	7.19	0.38	2.0
SM 707-17	CG 402-11		28.7	31.5	9.13	0.50	1.0
MCOL 2740			24.2	30.7	7.40	0.48	4.0
CG 402-11			28.3	30.6	8.67	0.46	1.0
Trial mean			13.5	32.3	4.53	0.38	2.5
Mean of selections			19.1	34.1	6.47	0.45	2.6

A list of 33 elite clones selected during this period is presented in **Table 2.2.1.5**. This elite clones has been incorporated to the germplasm collection to ensure their long-term maintenance. Most of them are taking part of crossing blocks to generate new sets of recombinant progenies. They are also being cultured in vitro, in order to have them available to National Programs that would like to test them under their local conditions.

Table 2.2.1.5. Elite genotypes incorporated into the cassava germplasm collection during 1996-98.

	Parents		Main adaptation	Secondary adap.
Genotype	Female	Male	zone	zone
CM 6698- 3	M BRA 12	CM 2772- 3	Mid-altitude	Sub-humid
CM 6952- 1	CG 501- 2	CM 1090- 2	Highlands	
CM 7514- 7	CM 3299- 4	C. 3306- 4	Mid-altitude	
CM 7686- 5	CM 3320- 4	CM 2174- 7	Mid-altitude	Sub-humid
CM 7951- 5	M BRA 12	CM 2766- 5	Mid-altitude	
CM 8024- 2	CM 3555- 6	M BRA 12	Mid-altitude	
CM 8027- 3	CM 3555- 6	M MAL 2	Sub-humid	
SM 853-21	CG 358- 3		Highland	
SM 856-11	CG 402-11		Highland	
SM 929- 3	CG 358- 3		Highland	
SM 909-25	CM 2087-101		Mid-altitude	Acid savannas
SM 1002- 1	M COL 1413		Highland	
SM 1219- 9	CG 1450- 4		Mid-altitude	Acid savannas
SM 1406- 1	CG 1-37		Mid-altitude	Sub-humid
SM 1407- 3	CG 489-34		Mid-altitude	
SM 1411- 5	CG 1141- 1		Sub-humid	
SM 1427- 1	CM 3997- 1		Sub-humid	
SM 1433- 4	M BRA 191		Sub-humid	
SM 1435- 1	M COL 1505		Sub-humid	
SM 1438- 2	M TAI 8		Sub-humid	
SM 1479- 8	M BRA 5		Mid-altitude	Acid savannas
SM 1483- 1	SG 104-264		Acid savannas	
SM 1511- 6	CG 915- 1		Sub-humid	
SM 1562-11	CM 5735- 3		Acid savannas	
SM 1619- 3	M BRA 222		Sub-humid	
SM 1624- 2	M BRA 255		Sub-humid	
SM 1627-16	M BRA 293		Sub-humid	
SM 1674- 1	CM 523- 7		Acid savannas	
SM 1697- 1	SG 106-59		Acid savannas	
M BRA 466			Acid savannas	
M BRA 489			Acid savannas	
M BRA 502			Acid savannas	
M COL 2329			Acid savannas	

Achievements:

- Considerable genetic progress realized in comparison with the mean of check varieties.

- 33 elite genotypes incorporated to the germplasm collection and available for interchange with National Programs
- A network of breeding trials has been established and is continuously producing results.
- An open ended recurrent selection scheme has been put in place in Colombia.

Activity 2.2.2. *Multiplication of selected elite germplasm.*

Rationale: The demand for elite germplasm is always high because it represents the basis for research in other disciplines, on-farm testing and regional trials in Colombia. Aside from maintaining all elite genotypes in the germplasm collection, a group of high priority genotypes is kept in plots of at least 50 plants. The ones with the highest demand are multiplied more extensively, reaching plots of up to 1 ha. Our project has been able to supply cuttings to other scientists at CIAT, and to institutions throughout Colombia.

Table __. Genotypes distributed to partner institutions in Colombia since October 1997.

Genotypes	# of stakes	Institution[1]
CG 1141- 1	9,500	Public / private
CM 507-37	2,500	Public
CM 523- 7	15,000	Public / private
CM 2177- 2	2,500	Public
CM 3306- 4	10,100	Public
CM 4365- 3	1,100	Public / private
CM 5655- 4	20,000	Private
CM 6370- 2	20,000	Private
CM 6740- 7	10,000	Private
CM 7514- 7	20,000	Private
SM 643-17	20,000	Private
SM 653-14	20,000	Private
SM 719- 6	20,000	Private
SM 909-25	20,000	Private
SM 1210- 4	20,000	Private
SM 1406- 1	20,000	Private
SM 1557-17	20,000	Private
MCOL 1505	9,100	Public / private
MCUB 74	2,500	Private
MPER 183	10,100	Public / private
Total:	245,000	

[1] Public=UMATA (municipal extension service); CORPOICA (national research institution); secretaries of agriculture in different Departments. Private = cooperatives; starch factories; feed industries.

Methods: Multiplication plots are established as blocks of 50 or more plants. They are given the best possible management in terms of crop, pest and disease management. The objective is to obtain planting material of prime quality. There are 2 ways to deliver the planting material: one is as 1 m pieces, which gives more security in case there is a dry period ahead and the material needs to be stored; and 20 cm pieces, ready to plant. We recover the production and shipment cost through a basic price.

Results: In **Table 2.2.2.1** we have a detail of the genotypes with the greatest volume produce and shipped to associated scientists and partner institutions during the later year. The most important purpose for the seed supplied has been to establish basic multiplication seed lots, followed by the establishment of regional trials and basic research experiments. Although we do not run this activity as a commercial one, it generates considerable resources both from the selling of planting material as well as from the selling of roots; allowing us to support part of the personnel we employ in research. This multiplication activity is essential for the diffusion of our best genotypes.

Achievements:

- An area of about 80 has have been dedicated to multiplication during the latest 3 crop cycles.
- Continuous supply of prime quality planting material to development projects throughout the country.
- Generation of funds that help us support research.

Sub-output 2.3. Distribution of improved germplasm to partners in Latin America, Asia and to IITA.

Rationale: This constitutes the main linkage to breeders in National Programs. Through the seed or in-vitro material we transfer the genetic progress obtained from our main breeding activity. As we will see later, there have been several new cassava varieties selected out of germplasm distributed by CIAT. In the case of Asia and Africa, cassava originated from a very restricted genetic base, originally introduced from Latin America. Our main purpose for the transference of improved germplasm is not only to enhance the productivity but also to increase the genetic diversity at the field level, in order to prevent major disasters associated to narrow genetic bases.

Our seed shipments are sent upon request, Previously, public institutions were the major recipient of our recombinant seeds. During the later years, requests from private sector have increase considerably, as well as request from advanced research organizations working on cassava biotechnology in Europe or North America.

Methods: The shipments are prepared according to the request and the infrastructure of the institutions receiving the seed. Most of the seed shipments are between 1,500 and 3,000 seeds, although programs such as the Brazilian and Thai, usually received between 5,000 and 10,000, while IITA, receives above 25,000 seeds. In the case of in-vitro shipments, we send 5 tubes per genotype, and the number of genotypes almost never exceed 25. We send information about the

families or genotypes that have been prepared; and request to have fee-back data on the performance of the germplasm introduced in order to plan better future shipments.

Results: A total of 253,148 seeds corresponding to 2115 families and 580 genotypes in-vitro were distributed during the period 1995-98 from CIAT-HQ to our partners in Latin America, Asia, IITA and advanced research organizations (**Table 2.3.1.1.**). The salient feature of the shipments has been the massive introduction of germplasm to Africa (IITA), representing 50.4 % of the total shipments. Previously we used to send F1 crosses between Latin American germplasm and elite genotypes from IITA selected mainly for their resistance to African Cassava Mosaic Virus (ACMV). The frequency of selections for resistant progenies was considerably low in the F1's, although it was higher than the frequency of selections 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's should be introduced. Our interest in increasing the frequency of resistant genotypes is to allow a more proper selection for other important traits that the Latin American germplasm can contribute to Africa (i.e. low cyanide, high dry matter content, good cooking quality, etc.). Susceptibility to ACMV has covered up all the potential genetic contribution of Latin American germplasm in the past.

Table 2.3.1.1. Germplasm distributed to different research programs in the world (September 1995 – Sept 1997).

Continents	Genotypes in-vitro	Crosses (families)	Plants (in-vitro)	Seeds in the shipment
Latin America				
In-vitro	375		1885	
Hybrid seed		434		39,600
Asia				
In-vitro	41		202	
Hybrid seed		1298		85,815
Africa				
Hybrid seed		379		127,533
Europe + USA				
In-vitro	150		980	
Hybrid seed		4		200
Total				
In-vitro	566		3067	
Hybrid seed		2115		253,148

Achievements:

- Considerable improved genetic diversity transferred to National Programs and other institutions working on cassava.
- Increased efficiency of Latin American germplasm introduction to Africa, through the development and shipment of back cross seed.

Sub-output 2.4. Propagation of mapping progenies, inter-specific hybrids and genetic stocks.

Rationale: Given the experience our group has in the management of seedling nurseries and multiplication of genotypes, we provide service to other projects in related to the development and use of the molecular map, gene tagging and introgression of wild germplasm. By doing so, we promote the integration of advanced tools into our breeding efforts.

Methods: After obtaining the recombinant seeds, we grow the F1 nursery for 1 year, in order to obtain well developed plants that can produce 10 short cuttings. Depending on the project we proceed to multiply each genotype in the progeny using all the cuttings, or we handle half of the cuttings to the scientist interested in evaluating the progeny, and maintain the other half for multiplication. After the first multiplication we usually give all the resulting material to the interested scientist.

Results: The molecular map was originally developed on a progeny of 90 genotypes from the family CM 7857, resulting from a cross between MNGA 2 (TMS 300572) and CM 2177-2 (ICA-Cebucán). This cross was designed within our project, taking into consideration the genetic distance between the parents, and the fact that both parents complemented each other for traits of importance (i.e. resistance to ACMV, bacterial blight, and major pests, cooking quality, etc.). 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, Santander de Quilichao and Villavicencio. Some of the traits for which we are evaluating the progeny include: reaction to bacterial blight, super-elongation, thrips, root rots, post harvest deterioration, root dry matter content, cooking quality, root yield, cyanide. We hope that for some of those traits we can detect specific regions of the genome in between molecular markers with a large effect upon the trait (QTL's), which can then be used within our breeding scheme to follow those genes.

Some of the genetic stocks we are multiplying at the moment include populations for: white fly; root rot and bacterial blight resistance, cooking quality, post-harvest deterioration, cyanide content and carotene content. All those genetic stocks were developed with the aim to tag specific regions of the genome directly involved in the genetic determination of those traits.

With respect to wild *Manihot* – cassava crosses, we are developing families with parental material selected out of a recent genetic diversity study using AFLP's and micro-satellites. Genotypes from the species *M. carthagenensis*, *M. brachyloba*, and *M. aesculifolia* are being crossed to selected cassava genotypes. The purpose of these crosses is to identify regions of the genome from wild species that can contribute to enhance root yield potential and quality. We are aiming at exploring the concept that wild species can contribute positive QTL's for traits that can not be assessed directly in the wild species per se.

Achievements:

- Genotypes within target families multiplied for basic research projects.
- Integration with projects in the area of biotechnology.

OUTPUT 3: National Programs in tropical and sub-tropical Latin America and Asia supported in adaptive selection and deployment of improved cassava varieties.

Sub-output 3.1. Work together with National Programs in Latin America for the selection, multiplication and dissemination of elite cassava germplasm

Activity 3.1.1. *Support planning and execution of project for germplasm development for semi-arid NE Brazil*

Rationale: Cassava production is one of the few alternatives to sustain the living of small farmers in semi-arid regions. That is a result of the capacity of the crop to survive and produce relatively well under severe water stress conditions, when other crops fail. During prolonged periods of drought in NE Brazil, cassava has been the only source of carbohydrates and proteins both for human and animal consumption. Sources of cassava germplasm with improved tolerance to drought, represent a very valuable resource for homologous regions in the world where human population is expanding into marginal areas for agriculture, particularly in semi-arid Sub-saharan areas.

Within the NE- region of Brazil, a very broad genetic base for adaptation to semi-arid conditions was detected among cassava germplasm accessions. The exploitation of such wide genetic diversity for the development of improved genotypes for production under homologous conditions represents an attractive approach to increase productivity and ameliorate quality of cassava in the region, because of its low adoption cost and low impact to the environment.

Cassava germplasm evaluation conducted during the period 1991-97 in four sites within the semi-arid ecosystem in NE Brazil, has resulted in the selection of genotypes with improved water use efficiency. That improvement is a consequence of a greater capacity to extract water stored in the soil, and the possibility of producing larger amounts of dry matter per unit of extracted water. Resistance to mites, also constituted a major selection criteria, given the importance of such biological constraint to cassava production. As a result of those activities, a genetic base for future improvement of the crop in semi-arid regions was established. At the same time, those genotypes combining all desirable agronomic traits have the potential to be used by farmers in the target region in the near future.

Starting in 1997, a second phase for the project was financed by IFAD. The main objectives of the project are: to maximize the production potential of selected genotypes through the optimization of cultural practices; to intensify the adoption and diffusion of improved genotypes with the active participation of farmers; and to generate new genotypes through the process of recombination among complementary parents and selection in segregating progenies.

The initial 5-year phase of this project was started in 1990 as a pure breeding project, and it has evolved through the years to become a more integrated, on-farm, participatory project for the development of the crop in semi-arid regions.

Methods: The original work started with the evaluation of 1008 accessions from the cassava germplasm collection held at CNPMF (Bahia – Brazil). Genotypes selected for their broad and specific adaptation took part of the on-farm evaluation. An average test will include 9 introduced genotypes and a local check variety. Also, selections from the original evaluated germplasm constituted the basis for recombination and generation of segregating progenies that served as the basis to build a breeding scheme for the semi-arid ecosystem.

Results: In 3 years (1994-97), participatory farmer evaluation became the core of the project, with experimental station breeding activities feeding into it. After analyzing information from 2-3 cycles of participatory evaluation there is a list of general farmer selection criteria (**Table 3.1.1.1.**), which may have some resemblance to what we breeders usually look in experimental station trials (i.e. productivity, although expressed in different terms), but refers more to specific concerns from the farmers. 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.

Table 3.1.1.1. Farmer selection criteria identified through the participatory research approach, and incorporated into the formal cassava breeding process.

Main selection criteria
1. Germination ability
2. Concentration starch and quality of "farinha"
3. Number of enlarged roots
4. Production of planting material
Complementary selection criteria
1. Harvesting facility
2. Peeling facility
3. Absence of root constrictions
4. Absence of root peduncle
5. External root color (white in Araripina)
6. Root parenchyma color (white)
7. Root HCN content
8. Erect plant type, with late branching, medium to low plant height
9. Number of stems per plant (2 a 3)
10. Foliage yield, good leaf retention (Quixadá)

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 (**Figure 3.1.1.1.**), is a practical way of visualizing how the materials are performing in a given area.

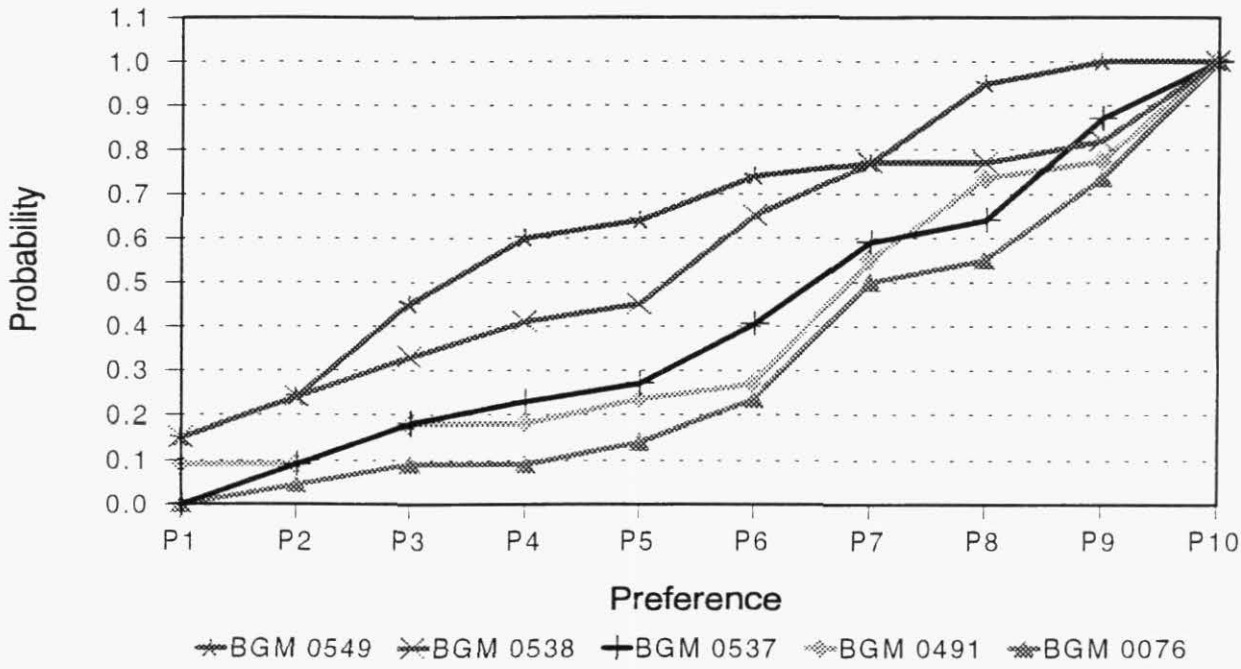


Figure 3.1.1.1. Farmer preference for broad-adaptation genotypes evaluated in semi-arid NE Brazil during 1994-97.

This year we explored a new avenue for farmer participatory evaluation. We invited a group of 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 3.1.1.2.**).

Table 3.1.1.2. Genotypes from regional yield trial selected by farmers at the Exp. Station in Quixadá-CE

Genotypes	Root yield (t/ha)	Foliage yield (t/ha)	Root dry matter content (%)
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

Some of them were selected for having good dry matter content according to their testing methodology (chewing; nail; cracking the roots, etc.). Our objective is to perfect this methodology in order to gain efficiency in our breeding efforts for the semi-arid.

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.

Our close interaction with other IFAD-funded project (PROSERTÃO) is based on farmer participatory evaluation of genetic materials generated within our project, and alternative crop management technologies generated at CNPMF. Partnerships such as this one, will broaden the scope of our project, and ensure that both the genetic material and the methodology generated within the project will diffuse and have the expected economic impact.

Breeding activities have been re-structured. Previously all breeding stages were conducted in the 4 experimental sites (Itaberaba, Araripina, Petrolina and Quixadá). Since 1997, 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. 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 at Araripina, for example, ranged from 25% to 100% depending on the year, when all selections are considered; although the top 5 white-root selections ranged from 44% in preliminary yield trial to 158% in clonal evaluation trial. One of the main objectives for the following year is to study the homology of those regions with others in NE Brazil with the use of GIS technology, in order to know the possibilities for further diffusion of those genotypes. (Probably good if we include scheme, plus a summary of results).

The transfer of close to 70,000 recombinant progenies represent the main linkage with Africa. Thanks to the IFAD-financed project, the genetic base for the genetic improvement of cassava in Africa has been considerably expanded.

Genotypes selected by farmers are already under active multiplication by farmers and by State institutions (like EPACE in Ceará). Those materials will be officially recommended and released in 1998.

Planting material multiplication is having a central role to play in the diffusion and adoption of varieties selected by farmers. The project is actively seeking partnership with other projects and institutional efforts to ensure that the selected material is rapidly propagated. Some of the genotypes under consideration have been selected under extremely dry conditions, and can have a tremendous contributions for regions that are periodically affected by weather phenomena such as "El Niño".

Achievements:

- 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.
- Improved 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 (like PROSERTÃO).
- Germplasm *transferred* to Sub-sahelian Africa.

Activity 3.1.2. *Joint evaluation of cassava germplasm with CORPOICA in Northern Colombia.*

Rationale: The objective of this project was to evaluate, select and diffuse cassava genotypes for industrial uses (starch or dry cassava production), with high dry matter yield potential under an optimized crop management.

Methods: For two consecutive crop cycles we evaluated 20 genotypes (16 experimental clones and 4 of the best check varieties) in 4 sites in the Northern part of Colombia: Media Luna and Caracolí (poor, sandy soils); Repelón (high fertility; clay/loam soils, with irrigation); and Betulia (intermediate fertility, sandy/loam soils). The majority of experimental clones included in this study had high cyanide and/or white roots, characteristics that made them unsuitable for the fresh market, and more favorable for industrial production.

Results: In spite of the difference in soil fertility and availability of water for the different sites, there was a considerable similarity in terms of production potential among sites (6.39 to 7.74 t/ha of dry matter). Four of the 16 experimental clones were independently selected in all sites across the 2 years; while 5 clones were selected in 3 of the 4 sites (**Table 3.1.2.1.**). Those 9 genotypes are the ones being actively multiplied for further field testing, and evaluation of end-product quality (starch or chips) with the industry sector. On average a genetic gain of 35 % was observed when comparing the 9 selected genotypes with the check varieties included in the evaluation. Improvement in root yield was the main responsible for that genetic gain, since dry matter concentration remained similar to the check varieties.

Achievements:

- Genotypes selected with a 34% higher dry matter production potential than check varieties.
- A network of representative sites for testing genotypes across Northern Colombia has been established.

Table 3.1.2.1. Average agronomic performance for cassava genotypes in 4 sites of Northern Colombia.

						Selected in:			
Genotype	Root yield t/ha	Harvest index	Dry matter yield t/ha	% Dry matter	Cyanide	Car.	Med. Luna	Rep.	Bet.
CM 4365- 3	21.4	0.56	7.12	34.9	7.0	1	1	1	
CM 6182- 8	20.6	0.58	7.41	36.1	7.4		1		1
CM 6754- 8	22.5	0.58	7.24	32.3	8.7	1	1		1
CM 6758- 3	32.6	0.53	6.38	32.1	6.8	1		1	
CM 7514- 8	23.2	0.54	8.17	35.1	6.7	1	1	1	1
CM 8027- 3	18.3	0.45	6.23	33.3	8.8	1	1		
CT 20- 2	17.4	0.47	5.81	32.2	6.5	1			
MBRA 384	23.6	0.53	8.10	33.4	5.1	1		1	1
SM 643-17	16.7	0.44	6.37	36.2	8.5			1	
SM 1201- 5	20.3	0.47	7.07	35.0	7.4	1	1		1
SM 1257- 7	14.3	0.41	5.09	35.7	5.2				
SM 1411- 5	26.3	0.54	9.00	34.3	8.8	1	1	1	1
SM 1427- 1	23.1	0.56	7.14	30.8	8.9	1			
SM 1431- 2	27.1	0.49	9.71	32.9	8.4	1		1	1
SM 1433- 4	20.9	0.49	7.39	34.5	6.2	1	1	1	1
SM 1438- 2	22.4	0.53	7.86	35.3	8.9	1	1	1	1
MCOL 1505	17.0	0.46	5.66	33.3	6.3				
MCOL 2215	15.0	0.41	5.59	34.8	4.7				
CG 1141- 1	19.2	0.49	6.65	34.4	6.5				
CM3306- 4	16.1	0.49	5.73	35.4	5.8				
Overall mean	20.9	0.50	6.99	34.1	7.1				
Check mean	16.8	0.46	5.91	34.5	5.8				
Selection mean (9)	23.1	0.52	7.96	34.2	7.5				
L.S.D. (0.05)	3.78	0.04	1.38	1.05	0.95				

Activity 3.1.3. *Cassava germplasm development for Colombian mid-altitude and highlands in partnership with NGO's and private sector.*

Most of our efforts in relation to cassava germplasm development have been concentrated on marginal ecosystems (i.e. semi-arid; low-fertility soils, etc.). Although cassava is considered a resilient crop in terms of adaptability to those marginal conditions, it is a species with an excellent capacity to respond to added inputs (water, fertilizer, etc.). In fact, under the most favorable conditions, cassava is only out-performed by sugar cane in terms of production of mega-calories per unit of area (ref.). Although we do not target our breeding to the favorable conditions in Palmira, all genotypes that are evaluated in sites representing the target ecosystems are maintained at CIAT, and get to be evaluated.

Methods: a) From evaluations in Palmira, we selected 16 genotypes with the greatest dry matter yield per hectare and evaluate them together with 4 check varieties for 2 years (1995-97) at 3 different sites in the Department of Valle del Cauca (Palmira, Buga and Ginebra). Plots consisted of 25 plants with 4 replications. Harvest was done at 11 months after planting. b) For

the mid-altitude evaluation we included 4 genotypes that have been declared elite for the region, based on several years of experimental evaluation. A total of 17 on-farm evaluation trials have been established, with non replicated 50-plant plots. The on-farm trials are still to be harvested. In order to select genotypes for future on-farm trials, an advanced yield trial was established in the region, including 29 of the most elite genotypes.

Results: a) As a result of that evaluation 9 genotypes were selected (**Table 3.1.3.1.**) and 7 were substituted for the 1997-98 evaluation. The average yield of the 9 selected genotypes across years was 10.64 t/ha of dry matter, which represents a 46.2 % greater production potential than the best selections in the Northern part of the country (see Section 3.1.2.). We concluded that it was possible to select cassava genotypes with production potential greater than 12 t/ha of dry matter, which represent around 13.5 t/ha of grains in one year. Under this conditions cassava can have a competitive margin with higher value crops such as sugar cane, particularly for the starch

Table 3.1.3.1. Average agronomic performance for cassava genotypes in 3 sites of Valle del Cauca Department (1995-97).

Genotype[1]	Root yield t/ha	Harvest index	Dry matter yield t/ha	% Dry matter	Cyanide
CM 5655- 4	31.6	0.66	11.56	36.6	6.8
CM 6370- 2	29.2	0.64	10.15	34.3	7.0
CM 6740- 7	27.3	0.56	10.27	36.7	5.1
CM 7514- 7	28.1	0.64	11.79	40.6	5.3
CM 7951- 5	27.4	0.67	11.16	37.3	7.2
SM 643-17	22.7	0.52	8.82	38.9	4.5
SM 653-14	26.8	0.56	9.94	38.9	4.6
SM 719- 6	25.1	0.56	9.36	37.4	2.5
SM 909-25	31.3	0.69	12.51	37.5	4.8
SM 1210- 4	27.5	0.61	10.95	39.6	5.5
SM 1219- 9	31.0	0.66	11.08	36.1	8.2
SM 1406- 1	23.3	0.54	8.80	37.0	5.3
SM 1407- 3	27.6	0.55	8.40	34.7	5.6
SM 1557-17	28.7	0.62	10.12	36.0	4.8
SM 1565-17	34.4	0.68	11.80	34.9	6.4
SM 1741- 1	33.0	0.69	13.62	37.9	6.1
CM 523- 7	25.5	0.56	8.90	38.1	6.0
MBRA 12	19.6	0.56	7.61	33.8	5.5
MCOL 1468	20.5	0.49	6.66	31.8	4.8
MCOL 1505	22.4	0.54	8.47	36.6	6.3
Overall mean	28.4	0.60	10.60	37.1	5.6
Check mean	22.0	0.54	7.91	35.1	5.7
Selection mean (9)	30.2	0.65	11.64	37.4	6.2

[1]Selected genotypes in bold

production market. Five hectares of multiplication for the 9 selected materials have been established. Based on the results from the following evaluation cycle a reduce group of genotypes will be recommended for the private sector interested in promoting them.

b) Also in the mid-altitude to highland ecosystems, we have established a network of farmer participatory evaluation of cassava varieties, including 17 sites. The financial support for this

Table 3.1.3.2. Average agronomic performance for cassava genotypes evaluated in Satander de Quilichao – Northern Cauca (1997-98).

Genotype[1]	Root yield t/ha	Harvest index	Dry matter yield t/ha	% Dry matter	Cyanide	Cooking quality
MBRA 383	38.0	0.46	12.7	33.5	2.0	1
CM 507-37	30.0	0.58	7.4	24.6	6.5	4
CM 849- 1	31.0	0.48	10.1	32.7	6.5	5
CM 2967- 8	16.9	0.36	5.7	33.9	2.0	3
CM 5655- 4	29.8	0.49	9.6	32.1	3.5	5
CM 6370- 2	25.2	0.52	7.1	28.2	2.5	3
CM 6740- 7	22.1	0.36	5.8	31.0	2.5	2
CM 7514- 7	25.0	0.44	9.4	37.6	2.5	5
CM 7951- 5	44.2	0.62	15.1	34.1	7.5	1
SM 643-17	15.2	0.26	5.5	36.1	5.5	5
SM 653-14	25.5	0.46	9.1	35.6	2.0	5
SM 719- 6	18.5	0.39	6.1	32.8	2.0	5
SM 909-25	27.7	0.49	9.5	34.3	2.0	2
SM 1210- 4	27.5	0.49	9.9	35.9	2.0	3
SM 1219- 9	39.0	0.53	12.6	32.3	4.5	1
SM 1406- 1	28.1	0.43	9.2	32.8	3.0	3
SM 1460- 1	31.8	0.49	10.2	32.2	5.0	3
SM 1468- 9	26.3	0.46	8.3	31.5	5.5	3
SM 1543-16	32.8	0.53	10.4	31.7	7.0	4
SM 1557-17	34.2	0.56	11.3	32.9	3.5	1
SM 1557-27	24.9	0.44	7.7	31.1	6.0	1
SM 1606-16	24.3	0.40	7.9	32.5	6.5	2
SM 1741- 1	39.6	0.59	13.5	34.2	3.5	1
MBRA 12	28.7	0.48	8.6	30.1	5.0	5
MCOL 1468	27.2	0.49	8.9	32.8	3.5	2
MCIL 1684	23.0	0.52	6.4	27.7	7.5	5
MCOL 1505	22.4	0.52	7.1	31.9	4.5	5
CM 523- 7	27.9	0.53	9.2	33.0	3.0	1
HMC 1	7.2	0.15	2.0	27.0	2.0	5
Overall mean	27.4	0.47	9.02	32.3	4.1	3.1
Check mean	22.7	0.45	7.24	30.4	4.3	3.8
Selection mean	32.9	0.51	11.30	33.9	3.9	2.8

activity is provided by the Ministry of Agriculture of Colombia. Our main partner is FIDAR, a well recognize NGO in the highland region. The evaluation included genotypes selected for their resistance to bacterial blight, and production potential under highland environment; along with the local check varieties. We have only harvested 1 experimental and one on-farm trial at the moment, since the crop cycle exceeds 12 months. Results from this evaluation will allow to collect information on farmer selection criteria in the region, main crop management practices, and to determine the range of adaptation of the pre-selected genotypes. We are also multiplying those genotypes in order to have enough planting material for further diffusion, once final selection by farmers is made.

Most of the genotypes evaluated at the experimental station level, coincided with those that took part on the selection trials for yield potential in high fertility soils. The soils in the experimental station were acid (pH 3.7) but with high concentration of organic matter (9.2%). Seven of the 13 selected genotypes coincided with selections made in the more fertile soils (**Table 3.1.3.2.**). It is therefore possible to select for broader adaptation genotypes for the Southern part of Colombia within the mid-altitude ecosystem.

Achievements:

- Nine genotypes selected for further multiplication and testing under favorable soil and climate conditions.
- Potential of cassava to compete with more industrial crops has been determined.
- A network of on-farm trials has been established in Northern Cauca.
- Thirteen genotypes have been selected as the basis for next-year on-farm trials.

Activity 3.1.4. *Search for financial support for integrated projects in Paraguay and Cuba, where improved germplasm plays a central role.*

During the course of 1997-98 projects involving cassava activities have been developed with Paraguay and Cuba. The projects are titled:

1. Sustainable development and valorization of cassava in Paraguay: Integration of user-oriented crop production, plant protection and post harvest processing.
2. Ecologically sustainable plant protection and post harvest processing of cassava in Cuba.

Both projects were initiated and requested by our (CIAT) collaborators in each of the two countries. As can be noted from the titles both projects include a production and post harvest component. In the production component, emphasis is given to germplasm selection, crop management and integrated pest management. In addition both projects include training and the use of farmer participatory methods, institutional strengthening, and identification and implementation of cassava value-adding interventions.

The Paraguay project has been sent to IFAD for funding consideration; the Cuba project has been sent to IFAD and IDRC. Both funding organizations have indicated their interest in the projects.

Activity 3.1.5. *Integration of private sector in cassava germplasm development projects.*

Rationale: A greater proportion of our time is being invested in building linkages with the private sector involved in processing and commercialization of cassava. Our aim is to develop cassava germplasm that can better link small poor farmers to markets in expansion. When we talk about participatory research, we usually refer to the involvement of farmers in the research process. It is also important to get other users involved in the process of selection and final evaluation (starch processors, feed industry, food industry, etc.). A good proportion of the work reported for improving production potential in Northern Colombia and Valle del Cauca has been conducted in association with starch processors. In the case of the feed industry, Colombia is importing more than 90% of the energy component that goes into animal feed. Cassava has an excellent potential to substitute a great part of it. The same situation can be found in other tropical countries. Therefore, our work has centered on improving the competitive capacity of dry cassava in animal feed, through the development and diffusion of improved germplasm and the optimization of production practices.

In relation to the food market; cassava is being used as the raw material for a variety of processed foods (frozen, croquettes, etc.). We have started a collaboration with a major company in that area, for the evaluation and selection of cassava genotypes with improved and stable productivity and quality. We intend to draw lessons from those projects that can be applied to other regions in the tropics; both for the interaction with the private sector as well as for the germplasm developed.

Methods: One of our assistants has been hired under a common fund contributed by FENAVI (National Chicken Growers Federation), ACOPOR (Colombian Pork Growers Association) and CONGELAGRO (frozen foods). Elite germplasm is being tested in sites that have been prioritized by the chicken and pork industry (Valle del Cauca, Tolima, Cundinamarca, Meta, Santander) and the food industry (Quindío). Small multiplication lots with genotypes already selected as elite materials in previous years have been established as basic seed lots. Our assistant also provides technical support to all the partners involved in this project.

Results: The project started in January 1998. A total of 95 has have been established as multiplication. The interaction has involved 8 companies related to feed production, and a company involved in food processing. Three regional trials involving 75, 48 and 30 genotypes have been established in Valle del Cauca, Tolima and Quindío. Although there are no concrete results to report; the enthusiasm of the private sector involved in this project, is an important asset to capitalize upon. Germplasm generated within this project will be freely available to interested institution within and outside Colombia.

Achievements:

- Network of regional trials established.
- Basic seed multiplication established.
- A network of companies involved in feed and food industry developed for the testing and multiplication of cassava germplasm.

Activity 3.1.6. *Latin American Research Program.*

Rationale: CIAT has been one of the leading institutions in cassava research. Throughout the last 5 years, that leadership has been weaken due to financial constraints. In Latin America there several institutions involved in cassava research and development, with different emphasis and strengths. There is also considerable interest by the governments and private sector to support research in cassava. The objective of this activity is to support cassava research and development through a consortium of institutions in Latin America. These institutions will invest and actively participate in the development and execution of the research agenda.

Methods: Based on the previous successful history of CIAT in relation to improved cassava germplasm development and the development of associated production and processing technology; we have initiated a process to increase the level of interaction with institutions interested in cassava research and development, throughout Latin America.

Results: We receive considerable support from the Ministry of Agriculture in Colombia, through its Cassava Modernization Plan (PMD). During the last 3 years, they have contributed more than U$ 300,000 supporting our activities in the sub-humid ecosystem (Northern Colombia). The Colombian private sector is supporting our research in 1998. We have also boosted our interaction in research with public and private institutions. During 1998 we have established contacts with public and private sector in Venezuela, Paraguay, Brazil, and Nicaragua.

Our goal is to root the idea of a Latin American cassava fund and research program within the most important countries and institutions; so they become the main driving force behind the definition of the research agenda, its financing and execution. There is a need to work with the most important institutions within each country in order to define a mechanism of representation to the fund, and for the definition of research priorities. In the case of germplasm development and diffusion there will be a need to identify an institution with in-vitro culture facilities and with certain research infrastructure to mount an evaluation program, from which the materials can flow to other institutions in the country. All that work is planed for the year ahead.

Achievements:

- First contact made with institutions from the private sector (mainly related to processing of cassava).
- Support to the idea of a Latin American fund, expressed by public programs.

Activity 3.1.7. *Participate in the development of a cassava multiplication scheme in Northern Colombia*

Rationale: The availability and quality of planting material will determine the rate of diffusion and the production potential of improved cassava germplasm. When we talk about quality of planting material in cassava, we refer to two aspects: phytosanitary and physiological quality. Therefore, the production of planting materials in areas that are free from the most important pests and diseases, as well as the management of the field lots in terms of the control of the biotic constraints and the improvement in soil fertility, play a very important role in

assuring an effective impact from our projects in cassava germplasm development. That is the reason why CIAT got involved in a project to build a de-centralized multiplication scheme for cassava, aiming at learning the most and developing methodologies that can be adapted and applied in other tropical countries. The main objectives of this project financed by the Ministry of Agriculture of Colombia were: a) to select appropriate cassava varieties to include in the multiplication scheme; b) to select proper multiplication sites and partner institutions; c) to organize the establishment of multiplication fields, their management, harvesting and distribution system for the planting material; and d) to train farmers and technicians in the management of seed lots.

Methods: The proposed scheme to be established is presented in **Figure 3.1.7.1**. In order to build it from existing material we established certified seed lots with 3 released varieties; 2 regional varieties and 1 pre-release genotype, with planting material originating in selected fields (free from major pests and diseases, and with good production potential). Register seed lots were established with 16 elite experimental clones, some of which have been selected under on-farm evaluation trials. These two stages were conducted in 7 sites in Northern Colombia, covering an area of 22 has. Basic seed lots were established with planting material from the 3 released and 2 regional varieties at CIAT derived from indexed in-vitro plants; to ensure the supply of clean material into future generations. Also at CIAT, we established plots of elite with planting material derived from plants in excellent phytosanitary and physiological status.

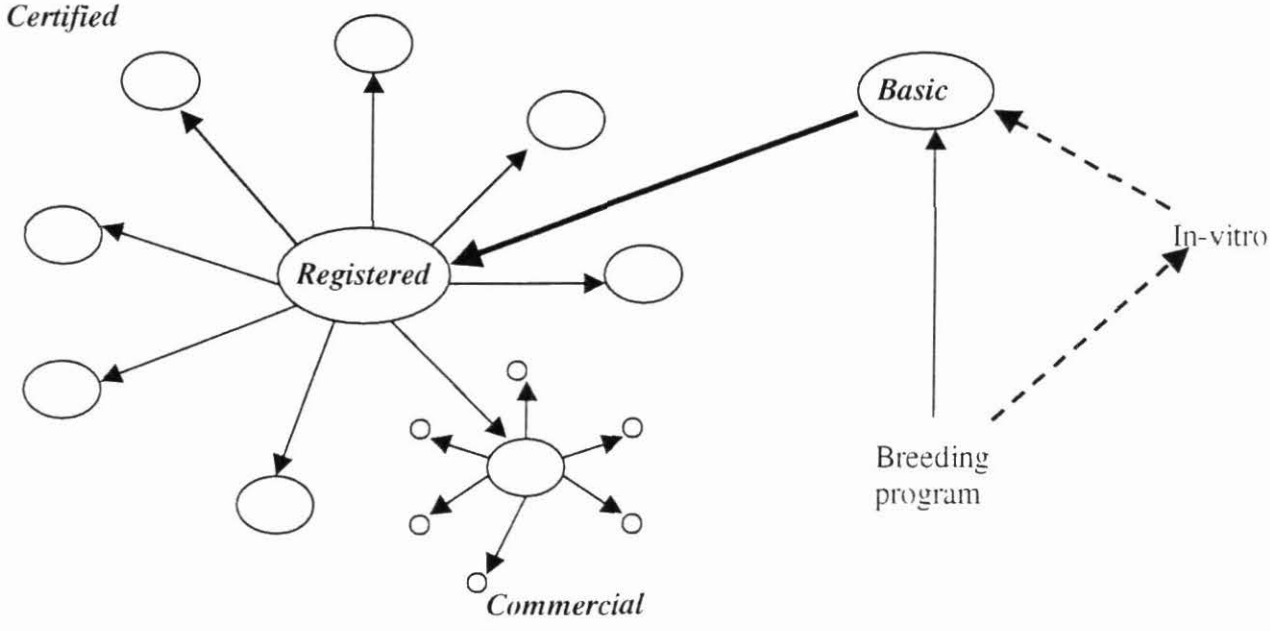


Figure 3.1.7.1. De-centralized scheme for the production and distribution of cassava planting material.

Results: A total of 22 hectares were produced as high quality planting material with released varieties and elite experimental genotypes (**Table 3.1.7.1.**). From that area we selected 1:800,000 high-quality vegetative seeds. In order to re-establish multiplication lots for the production of high-quality seed, we used 400,000 stakes. The rest was distributed for commercial multiplication in projects managed by trained technicians. One of the problems affecting cassava planting material production and distribution is the lack of synchrony between optimal root harvesting and planting times. In the target region, cassava is harvested between December and March. Planting is done in the months of May and June; therefore farmers usually have to store planting material, or set aside a proportion of the planting to be used as source of stakes. Quality of the roots deteriorates (reduced starch content) after the onset of the rains in April. Most of the multiplication lots were established on farmers fields, under the agreement that the project will cover all expenses until harvest; they will sell the roots and the project will handle the planting material that was generated. The only possibility for selling the roots was a starch factory, which closed in mid-May. Therefore, we had to harvest all lots and store the planting material. On top of this the rains were very erratic and below average, delaying planting. About 20% of the planting material was lost due to storage and delayed planting.

At CIAT-Palmira, we established 150 plants for each of the 3 released and 2 regional varieties, originally from in-vitro cultured indexed plants. Also, 1 hectare of basic multiplication was established with elite experimental genotypes that may become new released varieties in the near future.

A total of 35 technicians working in different public and private institutions as well as in NGO s were trained in the area of seed multiplication, conditioning and distribution. The course and follow up was conducted in the target region; and has improved the technical level of regional institutions to execute projects related to cassava seed multiplication. It also provided an excellent opportunity to start developing a network of people involved in seed multiplication; through which we can test and diffuse our germplasm.

Within this project we have also service other areas outside the target region; like the Departments of Antioquia and Cesar. In all regions, the availability of good quality planting material is seen as a limitation to implement any development plan around cassava. This project has served as a starting point and a learning ground from which other institutions can take the lead. After 1998 there will be enough planting material to establish 800 hectares of commercial seed production. Therefore, after 3 years of project availability of seed will not be a strong limitation for the plans to promote cassava both for the feed and starch industries.

Table 3.1.7.1. Multiplication lots established in Northern Colombia within a de-centralized system. (1996-97).

Site/Type of seed	Genotype	Area (has)	Development	Phytosanytary status
1) Sabanas de Pedro (Sucre)	ICA-Negrita	0.90	The lot had to be re-planted because of bad quality of original seed. Thereafter, excellent development	Early symptoms of bacterial blight, then disappeared
	ICA-Costeña	1.10		
	Venezolana	1.10		
Certified	P-12	0.90		
2) Betulia (Sucre)	ICA-Negrita	0.50	The lot had to be re-planted because of bad quality of original seed. Thereafter, excellent development	Early symptoms of bacterial blight, then disappeared
	ICA-Costeña	1.00		
Certified	P-12	1.00		
	Brasilera	1.00		
	CM 4365- 3	0.50		
	CM 6119- 5	0.50		
	SM 1433- 4	0.50		
3) Repelón (Atlántico)	CM 3306-19	6.00	About 10% of the lot was lost due to salinity problems	Excellent
Certified				
4) Pitalito (Atlántico)	ICA-Negrita	0.15	Excellent development	Excellent
	ICA-Costeña	0.20		
	Venezolana	0.12		
Certified	CM 4843- 1	0.12		
	CM 4919- 1	0.13		
	CG 455- 1	0.07		
	MTAI 8	0.11		
	MVEN 25	0.11		
5) Caracolí (Atlántico)	ICA-Negrita	0.12	Excellent development	Excellent
	ICA-Costeña	0.12		
	Venezolana	0.12		
Certified	CM 4843- 1	0.12		
	CM 4919- 1	0.15		
	CG 455- 1	0.11		
	MTAI 8	0.11		
	MVEN 25	0.15		
6) Santo Tomás (Atlántico)	ICA-Negrita	0.50	Excellent development	Excellent
	ICA-Costeña	0.75		
	Venezolana	0.35		
Registered	Advanced experimental clones	1.40		
7) Media Luna (Magdalena)	ICA-Negrita	0.35	Excellent development	Excellent
	ICA-Costeña	0.45		
	Venezolana	0.20		
Certified	Advanced experimental clones	0.90		
Total:		**22.00**		

Achievements:

- A de-centralized planting material multiplication program has been established in Northern Colombia.
- A total of 1:800:000 high quality stakes were produced from regional varieties and experimental genotypes.
- Most of the technicians involved with cassava multiplication plans were trained.
- A network of institutions and technicians has been established, which will facilitate germplasm evaluation and diffusion.

Activity 3.1.8. *Participate in the release of 3 new cassava varieties*

Rationale: Our main responsibility at CIAT is to developed improved populations with an enhanced frequency of favorable alleles for each of the major ecosystems in which we work. Those populations are then transferred to institutions in National Programs either through recombinant progenies generated by intercrossing selected parents, or the direct transfer of the selected genotypes via in-vitro culture. Breeders at National Program proceed to evaluate and select locally adapted genotypes for future release to farmers. Together with certain programs (Brazil, Colombia and Cuba) we have been implementing farmer participatory evaluation for final stages of the breeding cycle in order to ensure that the released material is highly accepted by final users.

Methods: The main source of germplasm for the selected and release cassava varieties during the period 1996-98, were populations transferred as recombinant progenies. The other source of genetic diversity within joint projects with National Programs were germplasm introductions from other regions (i.e. Brazil). In the first case the programs usually proceed through the following scheme: F1 seedling nursery (single plant); clonal evaluation (non-replicated 5-10 plant plot), preliminary evaluation (1-2 reps. of 20-25 plants), advanced yield trials (3-4 reps, 1-2 sites, 1-2 years, 25-36 plants), regional and/or on-farm trials (multiple site, larger plots).

Results: During 1996-98 a total of 7 new cassava varieties were released in Latin America. The main trait for selection has been productivity and quality, although 2 varieties were released because of their resistance to specific pathogens (**Table 3.1.8.1.**)

Table 3.1.8.1. Cassava varieties released in Latin America from CIAT's improved germplasm during 1996-98.

		Parentage			
Country	**Variety**	**Female parent**	**Male parent**	**Main traits**	**Year of release**
Brazil	Tianguá	SM 975		Resistance to witches-broom disease	1996
	Caitité	CM 523- 7	CM 825- 3	Higher yield, higher dry matter content	1997
	Bibiana	MCOL 1684	MVEN 52	Root-rot resistance	1997
	Rosa*	BGM 260		Cooking quality	1998
	Amansa burro*	BGM 549		Drought resistance, foliage production	1998
Colombia	CM 3306-19*	CM 523- 7	MCOL 22	High yield potential; preference by farmers	1998
Cuba	INIVIT Y-93-4	CM 4574- 7		High yield potential and stability	1997

*Varieties selected with active participation of farmers

There is an estimated area of 200,000 has in Latin America planted to varieties derived from the germplasm maintained at CIAT. We have work very closely with the Brazilian, Colombian and Cuban programs, and that is the reason why those countries have released the majority of varieties in the whole history of our program. Paraguay is one country where cassava is extremely important and we have not had consistent interaction in the are of germplasm introduction and selection. We hope to improve that situation in the near future.

Sub-output 3.2. Support National Programs in Asia in adaptive selection, multiplication and diffusion of improved cassava germplasm.

Activity 3.2.1. *Breeding for maximum productivity and adaptation under semi-arid and sub-humid conditions in Thailand.*

Our operation at the Thai/CIAT collaborative cassava breeding program at Rayong Field Crop Research Center offers a rare example in crop breeding, where the major physiological yield components, such as biomass and harvest index are quantitatively measured at every stage of evaluation/selection. 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.

Changes in the 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. This is primarily because at this stage a good number of the most advanced materials are evaluated in a multi-location scheme and the clonal entries represent not only the level of selection accomplishment at the moment, but also the possible change that can take place in near future once these entries are released. Genotypes being evaluated at this stage are usually included as parental lines, representing the level of breeding materials (hybrid seeds) our CIAT/Thai program offers to other national programs. We can reasonable assume that the mean of this population represents the level of breeding population in each year.

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 be usually repeated, because the major portion of phenotypic value was of non-genetic nature.

There is a highly visible improvement in the actual dry root yield of the breeding population in the past 15 years (**Figure 3.2.1.1.**). This significant yield increase (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. Therefore, the comparison of the population mean with the mean of the control (Rayong 1) fives a more accurate picture. From this comparison we can clearly see that there has been a highly convincing genetic improvement in the dry root yield level of breeding populations (**Figure 3.2.1.2.**). Of the total genetic improvement, about two thirds corresponded to the improvement in fresh root yield (**Figure 3.2.1.3.**): and a smaller bur very significant proportion (close to one third) corresponded to the improvement in root dry matter content (**Figure 3.2.1.4.**).

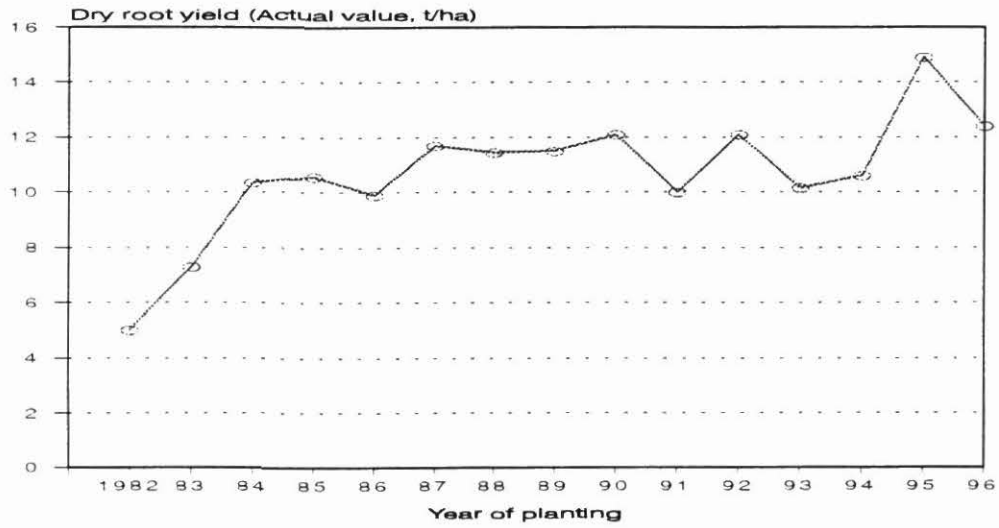


Figure 3.2.1.1. Change in mean dry root yiueld (actual value) of all clonal entries in regional trials in all locations (evaluation stage V) during 1982 – 1996 in Thailand.

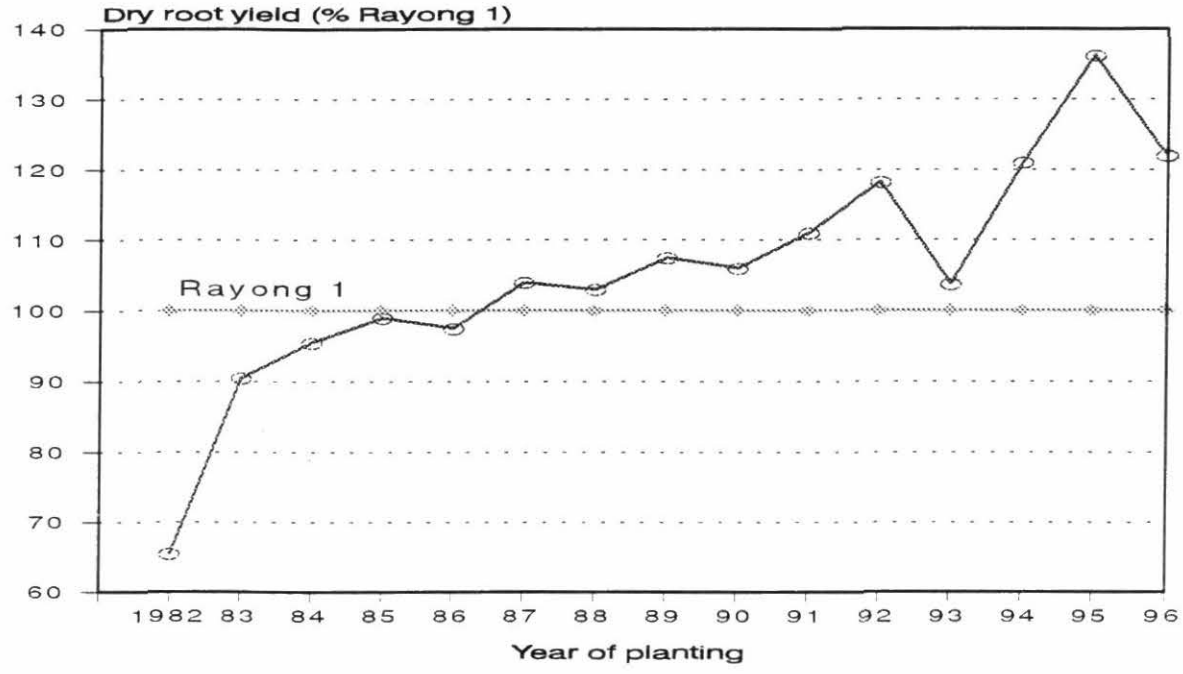


Figure 3.2.1.2. Change in relative mean dry root yield (% of common control cultivar. Rayong 1) of all clonal entries in regional trials in all locations (evaluation stage V) during 1982 – 1996 in Thailand.

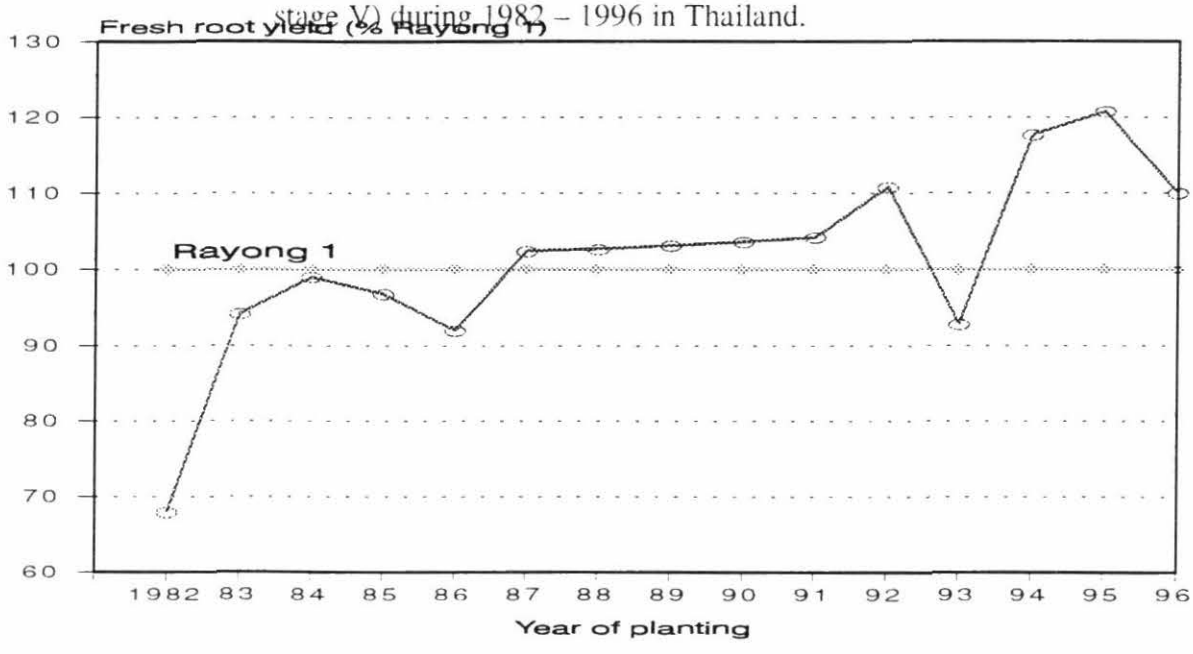


Figure 3.2.1.3. Change in relative mean fresh root yield (% of common control cultivar. Rayong 1) of all clonal entries in regional trials in all locations (evaluation stage V) during 1982 – 1996 in Thailand.

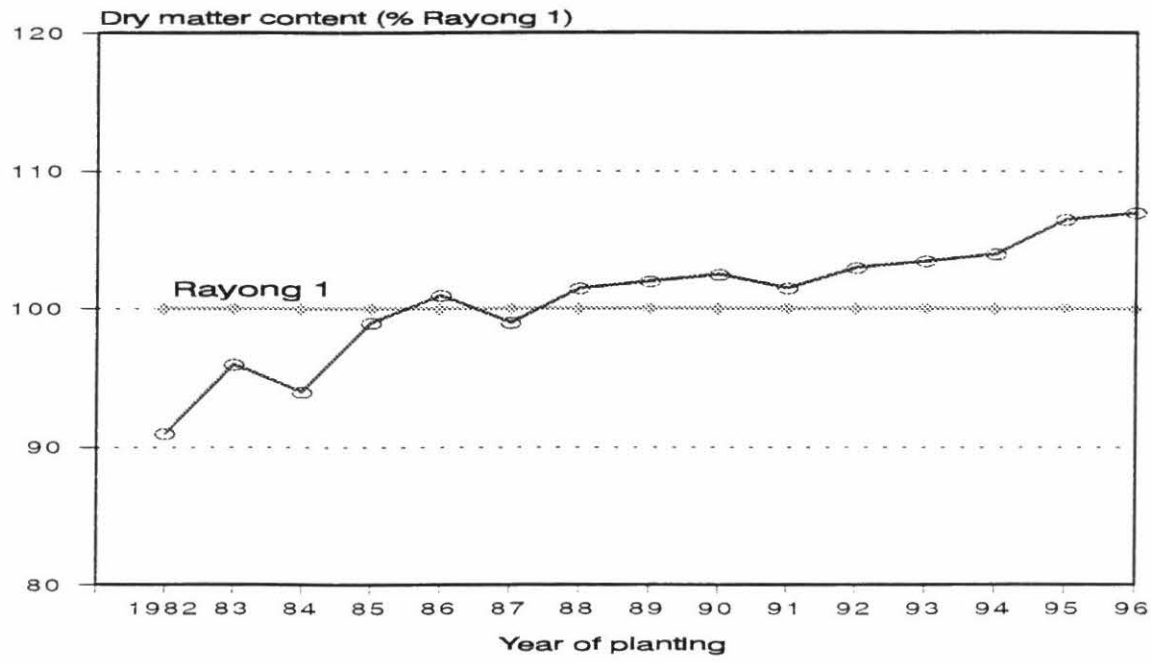


Figure 3.2.1.4. Change in relative mean root dry matter content (% of common control cultivar, Rayong 1) of all clonal entries in regional trials in all locations (evaluation stage V) during 1982 – 1996 in Thailand.

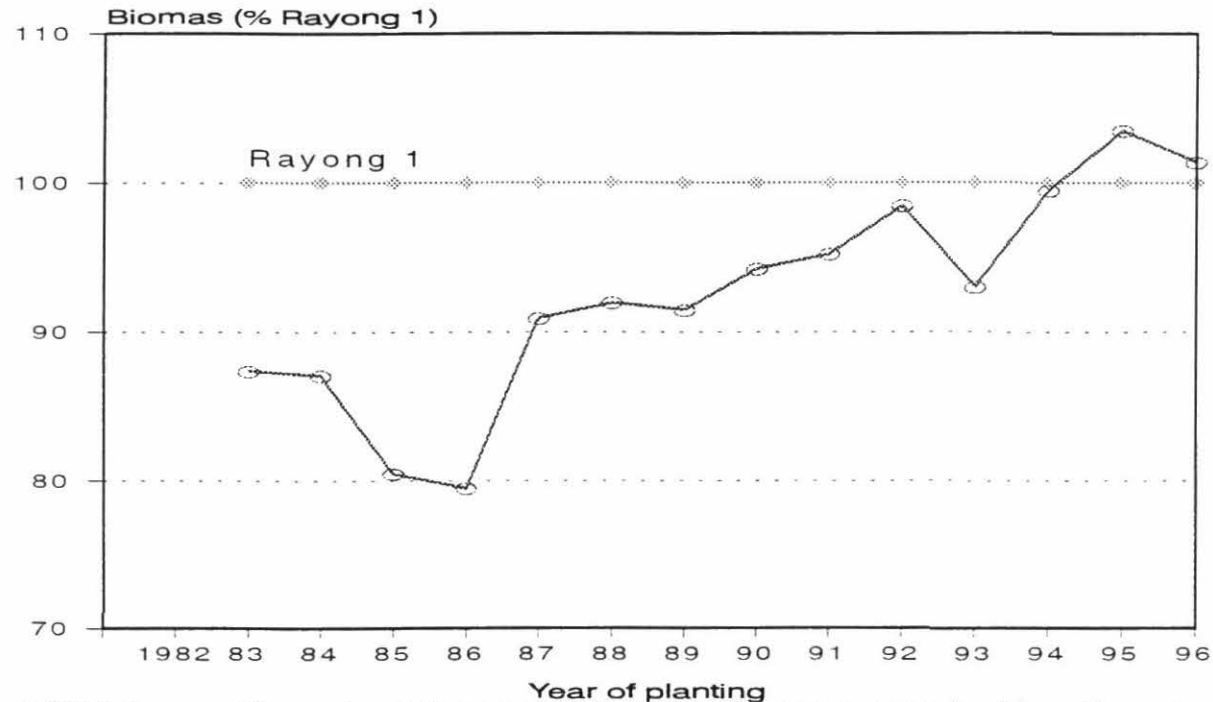


Figure 3.2.1.5. Change in relative mean biomass (% of common control cultivar, Rayong 1) of all clonal entries in regional trials in all locations (evaluation stage V) during 1982 – 1996 in Thailand.

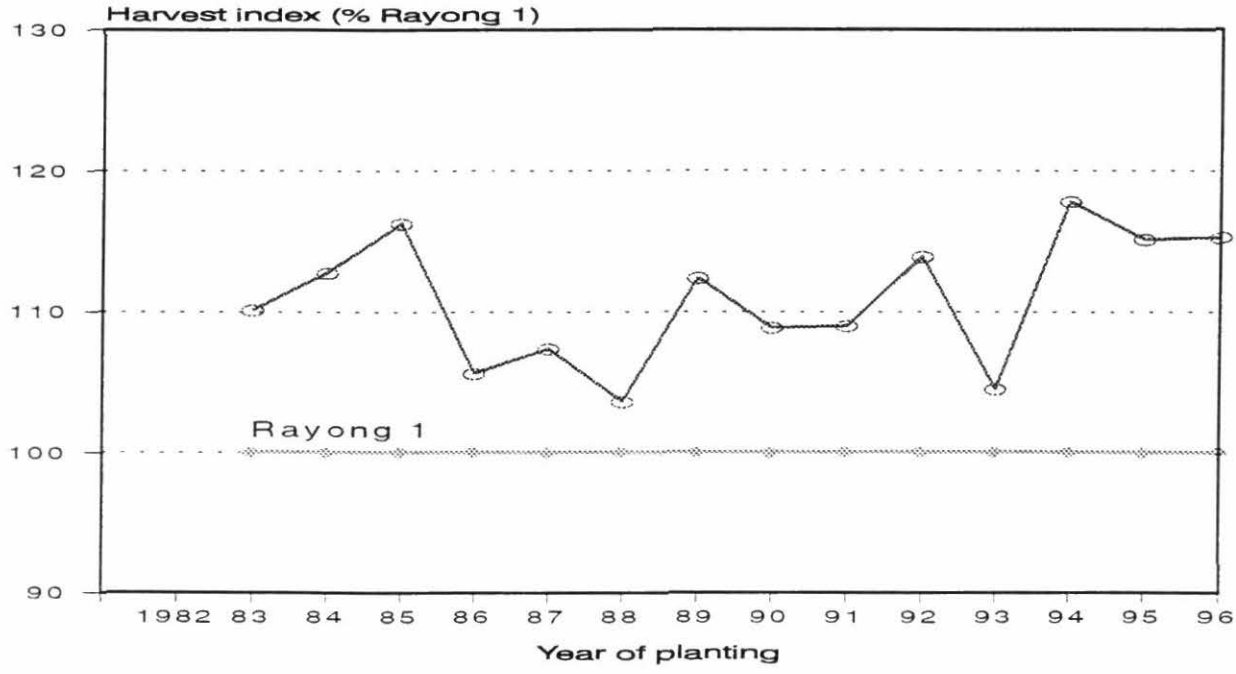


Figure 3.2.1.6. Change in relative mean harvest index (% of common control cultivar, Rayong 1) of all clonal entries in regional trials in all locations (evaluation stage V) during 1982 – 1996 in Thailand.

Fresh root yield is a resultant from the product between total biomass and harvest index, where the former represents the integrated assimilation activity of the plant, while the latter represents the division of the assimilated mass into economically utilizable products. Of the improvement in fresh root yield, a major part (25 to 30%) corresponded to he improvement in biomass (**Figure 3.2.1.5.**) and only a minor part (5 to 10%) corresponded to the improvement in harvest index (**Figure 3.2.1.6.**). We can safely conclude that the significant genetic improvement in cassava yielding ability that has taken place 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 he 1970's 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) will be released in 1998). 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 in Thailand (**Figure 3.2.1.7.**).

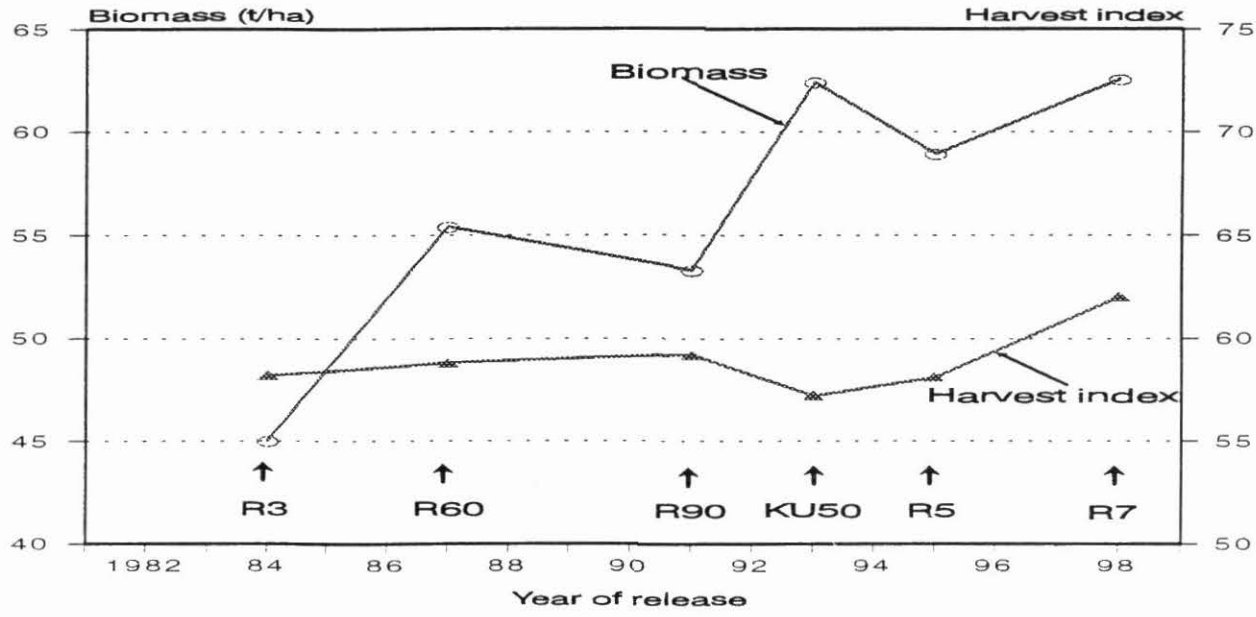


Figure 3.2.1.7. Biomass and harvest index of officially recommended cassava cultivars in Thailand in relation to the year of their release.

A comparison among an old table cultivar (Hanatee), the leading local cultivar (Rayong 1), 5 released cultivars and a most advanced elite clone (CMR33-57-81) firmly testify the progress we have made, and suggest a possibility of further improvement (**Table 3.2.1.1.**). The overall yield superiority of CMR33-57-81 is clear, but its root dry matter content, is somehow far from what we wished. The result of standard yield trial, which consisted of clones derived from a breeding population (CMR 36) derived 3 years later than CMR33, appeared to be promising in combining high fresh yield with high dry matter content beyond the level of Kasetsart 50 (**Table 3.2.1.2.**).

Table 3.2.1.1. Yield performance of 6 new cultivars and 2 traditional cultivars in regional trials in Thailand, harvested in 3 cropping seasons from 1994 to 1997 (Mean values from7 regional trials.

Variety	Parents	Year of release	Dry root yield t/ha	Fresh root yield t/ha	Root dry matter %	Biomass t/ha	Harvest index
CMR 33-57-81	Rayong 1 x Rayong 5	1998	13.0	38.7	33.7	62.0	0.63
Rayong 5	27-77-10 x Rayong 3	1995	11.5	33.4	34.3	58.4	0.58
Kasetsart 50	Rayong 1 x Rayong 90	1993	11.7	33.7	34.8	60.1	0.57
Rayong 90	CMC 76 x V43	1991	11.2	31.8	35.4	53.0	0.60
Rayong 60	Mcol 1684 x Rayong 1	1987	10.5	31.1	33.2	55.5	0.56
Rayong 3	Mmex 5 x Mven 307	1984	9.3	26.1	35.5	45.0	0.58
Rayong 1	Leading local variety		9.4	29.6	31.7	58.0	0.51
Hanatee	Traditional variety		5.8	18.3	31.7	43.6	0.42

Table 3.2.1.2. Results from standard yield trials (mean of 3 locations) in Thailand in 1996/97.

Genotypes	Parents	Dry root yield t/ha	Fresh root yield t/ha	% dry root matter	Biomass t/ha	Harvest index
Selected clones						
CMR 36-31-381	Rayong 5 x OMR 29-20-118	13.4	36.8	36.3	54.8	0.68
CMR 36-54-40	CMR 30-71-25 x CM 3299-15	13.4	38.2	34.5	54.4	0.71
CMR 36-30-329	Rayong 5 x Kasetsart 50	13.3	35.4	37.2	58.4	0.61
CMR 36-90-2	Kasetsart 50 x Rayong 5	13.0	35.5	36.0	54.7	0.65
CMR 36-71-33	CMR 31-19-23 x Kasetsart 50	12.9	36.6	34.8	51.5	0.72
CMR 36-55-166	CMR 30-71-25 x Rayong 5	12.6	36.6	34.3	48.4	0.76
Released cultivars						
Kasetsart 50	Rayons 1 x Rayong 90	12.5	34.4	36.2	51.9	0.67
Rayong 5	27-77-10 x Rayong 3	12.4	34.7	34.9	48.3	0.72
Control variety						
Rayong 1		10.0	30.1	32.3	51.5	0.59

It was clearly noticeable 10 years ago that CIAT/Colombia hybrids did not offer the same selection opportunity as Rayong hybrids for the conditions in Thailand (**Table 3.2.1.3**). While considerable improvement with the CIAT/Colombia materials has been made, the Rayong materials were also improved and the superiority of the Rayong materials has persisted up to now, although at a lower rate. 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.

Table 3.2.1.3. Comparison between Rayong (Thai/CIAT) and CIAT/Colombia genotypes in single-row trial at Rayong, Thailand, over 12 years.

	1986/87[1]		1991/92[1]		1995/96[2]		1996/97[2]	
Character	Rayong genotypes	CIAT genotypes (% of Rayong)	Rayong genotypes	CIAT genotypes (% of Rayong)	Rayong genotypes	CIAT genotypes (% of Rayong)	Rayong genotypes	CIAT genotypes (% of Rayong)
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)
% dry matter content	34.3	32.9(96)	33.1	30.9(93)	32.7	31.6(97)	30.3	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 trials (1228 Rayong and 735 CIAT genotypes pr 1986/87, and 1696 Rayong and 621 CIAT clones for 1991/92).
[2]mean of primary selections in single-row trials (378 Rayong and 104 CIAT genotypes pr 1995/96, and 309 Rayong and 66 CIAT clones for 1996/97).
[3]1=very poor, 5=very favorable
[4]Data from preliminary yield trial of the following year.

Our 14 years of observations on our multistage breeding program in Thailand has yielded 3 MS thesis. 1 Ph.D. thesis and 1 academic article in Crop Science, as well as the following conclusions:

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 for 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 by evaluation stage interaction for root yield is greatest between single-row trial and plot trial, while that of harvest index is much smaller. Selection at single-row trial, usually the second stage of evaluation, 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.

Activity 3.2.2. *Upgrading yield potential and adaptation of breeding populations together with NARs in Asia.*

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 seeds (**Table 2.1.3.1.**). A total of 112,500 hybrid seeds have been contributed from the Rayong program to other national programs in Asia and CIAT/Colombia from 1985 until 1997.

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 20 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 3 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 eliminates local genetic diversity. When we discuss about the biodiversity of crops, we tend to regard only the existing landraces and the accessions in germplasm collections, and overlook the genetic materials actually being utilized by many functional breeding programs. Genetic variability not in a utilizable from has a very low potential for benefiting cassava 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.

Activity 3.2.2. *Multiplication, release and diffusion of improved varieties.*

Three new clones (OMR33-17-5 and KM 95, SM 1157- 3 as KM 95-3 and SM 937-26) in Vietnam and 3 new clones (CMP62-15 as VC6, CMP21-15 as VC7 and CM 3422- 1 as Lakan 4) were officially released, making the total number of CIAT-related cultivars in Asia raise to 31 (Thailand 7, Indonesia 3, Philippines 10, Malaysia 2, China 4 and Vietnam 5).

According to the latest statistics and estimations of the Department of Agricultural Extension of Thailand, 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 (**Figure 3.2.2.1**, **Table 3.2.2.1**. Following the data by Thai Tapioca Association, in which the data estimation includes an extrapolation from the percent area planted with new cultivars and the total national acreage, gives 0.695 million ha for the area planted with new cultivars. Similarly, the area for new cultivars is estimated to be 0.136 million ha in Lampung, Sumatra, Indonesia (an extrapolation from the percent adoption and the total cassava area in Lampung alone provided by Umas Jayas Farms, the figure may be a gross underestimate for the total of Indonesia) and 21.3 thousand ha in South Vietnam (given by the addition of each province, provided by the IAS) (**Table 3.2.2.2.**). This and additional smaller areas in other countries result in a total area planted with CIAT-related new cultivars between 0.787 and 0.860 million ha in 5 countries (Thailand, Indonesia, Vietnam, Phillipines and China) in Asia.

All these varietal dissemination follow the scheme of small farmers producing cassava to be processed for starch or animal seeds by medium to large scale factories. One notable exception is the varietal dissemination to a mass of small farmers in North Vietnam, where the planted area is expressed in m2 rather than hectares, and the yield advantage of new cultivars is used for increasing the number of pigs and poultry in each family.

As a consequence of these, we can now clearly see a significant increase of mean cassava yield at the country (Thailand, **Fig. 3.2.2.2**) and the provincial (Dong Nai, South Vietnam, **Fig. 3.2.2.3.**) levels. The mean yield increase in Thailand coincided timely with the recent government policy of maintaining the total production by reducing cassava area and elevating the mean yield. In South Vietnam, the sharp mean yield increase was accompanied by the simultaneous increase in planted area, which resulted in a sudden glut of cassava roots beyond the processing capacity of factories, causing a price decrease this year, a process the newly emerged market system would have to handle for future good. In North Vietnam, we have recorded the effects of new cassava cultivars throughout all the levels from family to hamlet to village to district. We now have hard data to show the effect of new cassava cultivars on yield increase at all levels.

Activity 3.2.4. *Adoption of cassava varieties and impact studies in selected countries.*

As the basis for measuring the economic effects generated by new cassava cultivars, we used the sales value of the additional products directly attributable to the adoption of new cultivars. Value of sales includes production costs and net profits. The gross production costs are made up of expenditures for labor, equipment, supplies, maintenance and depreciation. For regular

Table 3.2.2.1. Yield advantage of new cassava varieties and monetary gain caused by their adoption in Thailand during 1996/97.

			Yield difference from the traditional cultivar Rayong 1 in:		Monetary gain per unit area over Rayong 1 in[3]:			Total additional sale valued due to adoption of new varieties in:	
Varieties	Fresh root yield t/ha[1]	Root starch content (%)[2]	Fresh root yield t/ha	% starch content	Fresh root yield t/ha	% starch content	Area planted in 1996/97[4] (1000 has)	Fresh root yield ($ 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 fresh root yield 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 3.2.2.2. Yield advantage of new cassava varieties and monetary gain caused by their adoption in 4 Asian countries outside Thailand during 1996/97.

Region/country				Yield difference from the traditional cultivar Rayong 1 in:		Monetary gain per unit area over Rayong 1 in[3]:			Total additional sale valued due to adoption of new varieties in:	
		Fresh root yield t/ha[1]	Root starch content (%)[2]	Fresh root yield t/ha	% starch content	Fresh root yield t/ha	% starch content	Area planted in 1996/97[4] (1000 has)	Fresh root yield ($ 1000)	Starch ($ 1000)
Sumatra /	Traditional	20.2	18.1							
Indonesia	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 Vietnman	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 /	Traditional	10.0	19.0							
Philippines	VC 5	16.0	19.0	6.0	0	180	0	5.5	990	0
Negros, Bohor	Traditional	10.0	19.0							
/ Philippines	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 Indonesias. 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 Hong Loc Ag. Res. Center in South Vietnam, by BTAFRC and RCRC in North Vietnam, by PRCRTC in the Philippines, and by GSCRI in China.

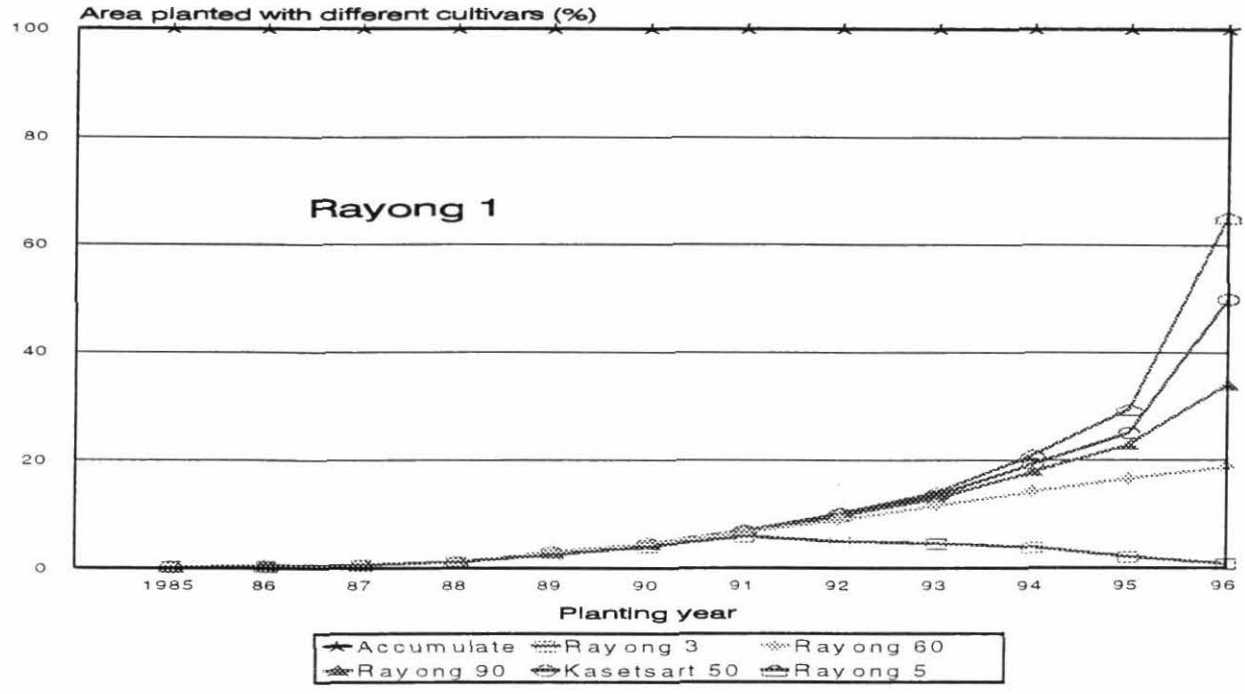


Figure 3.2.2.1. Change in area planted with different cassava cultivars in the recent 12 years in Thailand (Data source: Department of Agricultural Extension, Thailand).

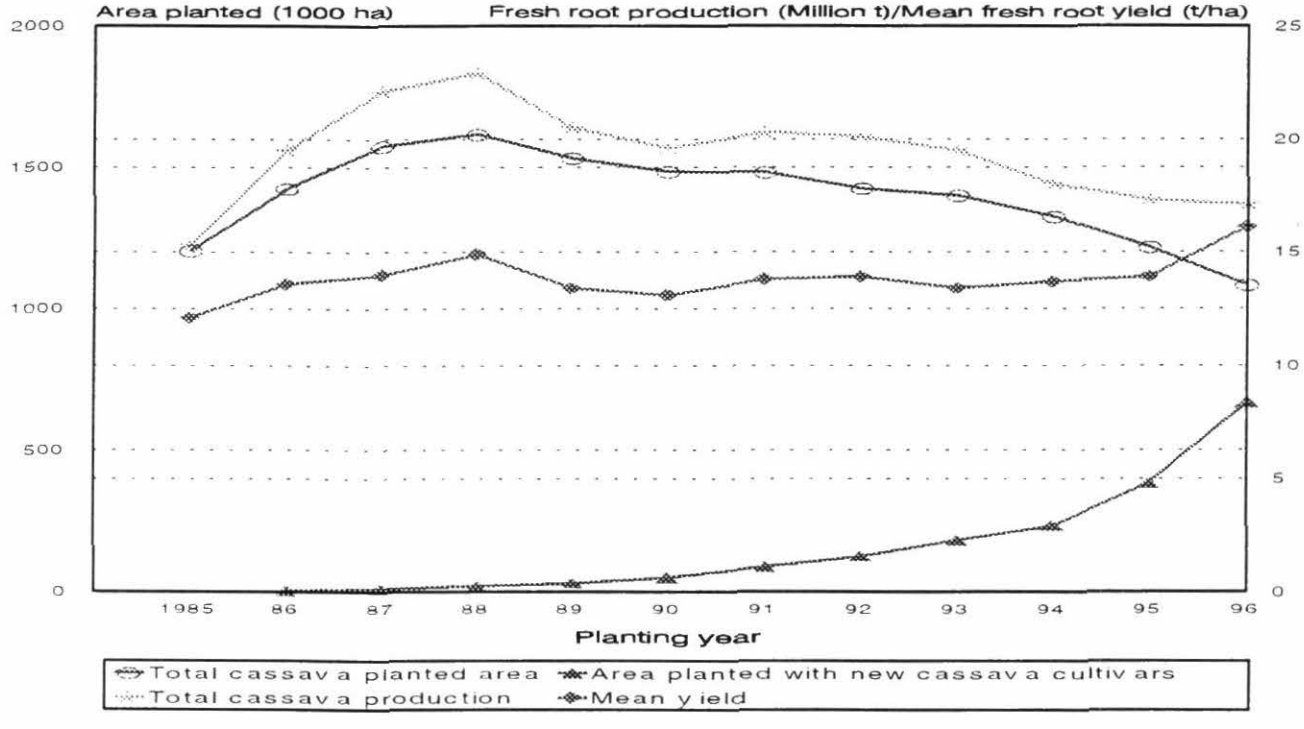


Figure 3.2.2.2. Change in total cassava planted area, area planted with new cultivars, mean yield and total production in the past 12 years in Thailand.

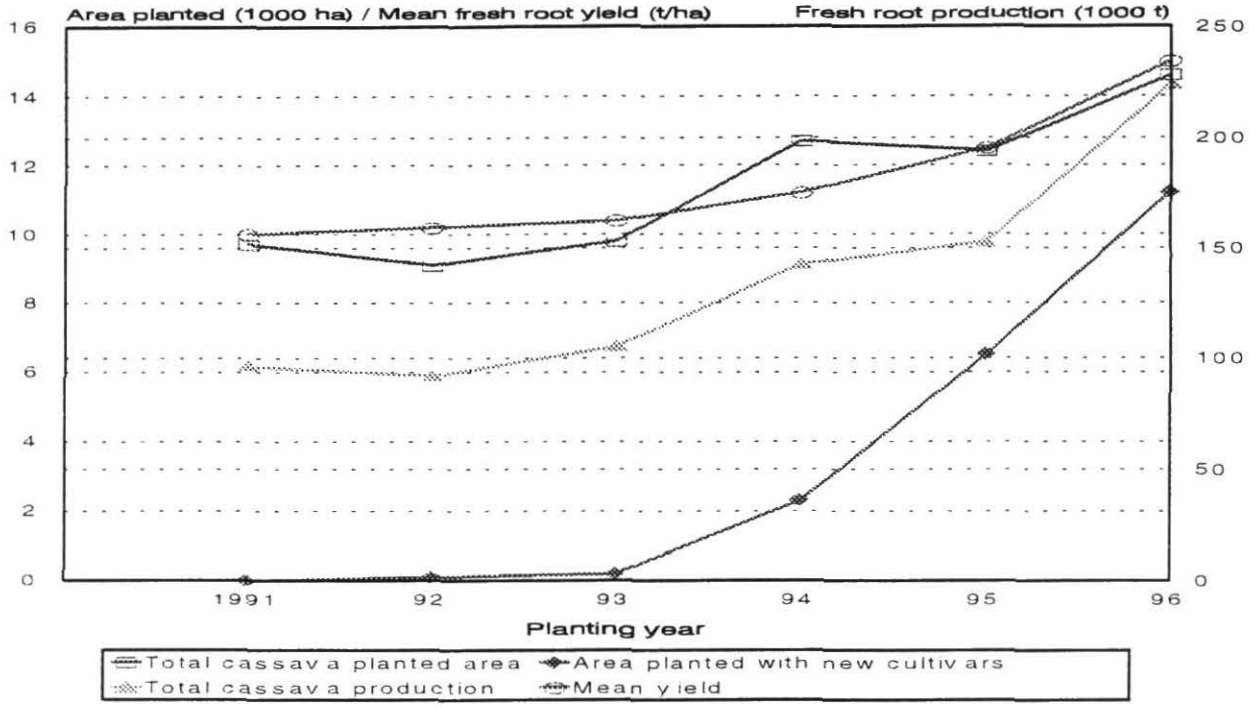


Figure 3.2.2.3. Change in cassava planted area, area planted with new cultivars, mean yield and production in Dong Nai province, Vietnam.

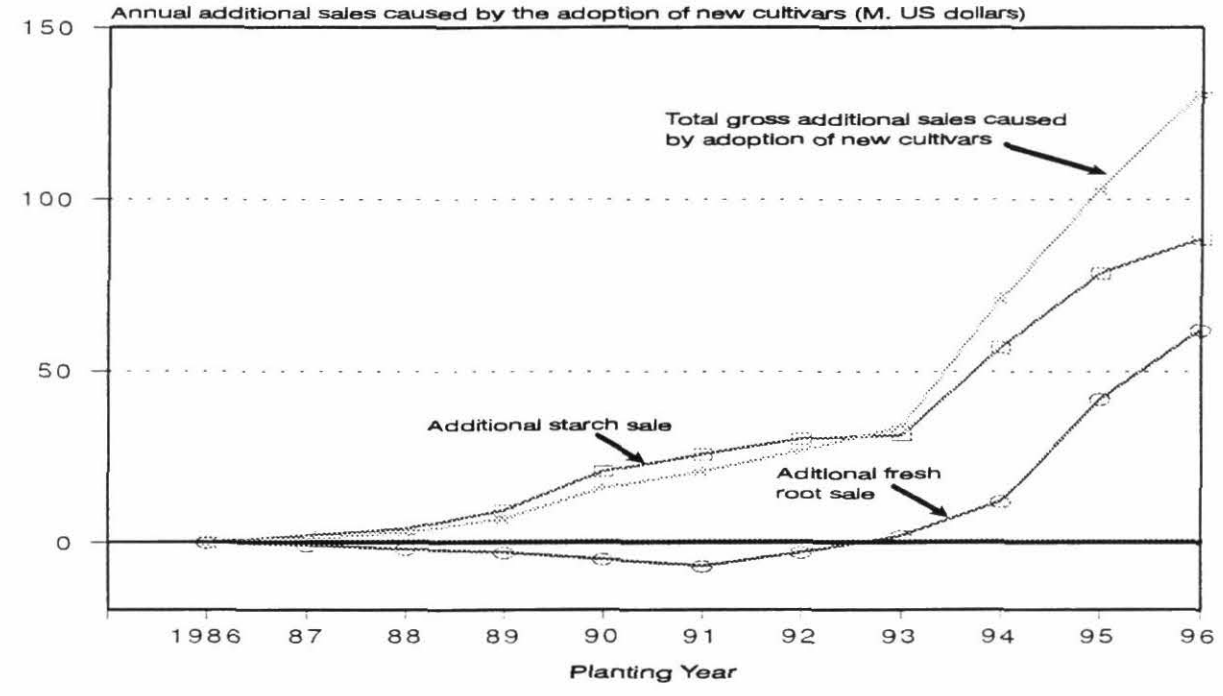


Figure 3.2.2.4. Additional economic effects generated by the adoption of new cassava cultivars in Thailand in the past 10 years.

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.

To concentrate in most direct monetary effects and avoid possible duplicates, we used only two measures for the 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. The additional factory profit generated by the gross additional availability of raw materials is not accounted for, let alone the additional production of numerous secondary products. This, the real gross additional economic effects are much more than the ones described in these simple analyses.

For the yield and starch content advantage (or disadvantage) conferred by the adoption of new cultivars, we used the means of many on-farm trials. The absolute yield figures represent what average farmers would be able to obtain in their fields and the yield difference from the traditional cultivar, which actually matters more, would represent what they could benefit from planting new cultivars in a wide range of farming conditions. For on-farm price of fresh cassava roots and factory starch price, we used the low price in Thailand for 1996/97.

Cassava market for starch processing is rapidly expanding in Asia. It must be reasonably safe to assume that the additional productions herein reported led to the additional cash incomes in their near entirety and the adoption of new high yielding cultivars is an indirect proof for this. The subsequent analyses prove that cassava is clearly an attractive means for small farmers to improve their cash income.

In Thailand, where the varietal adoption started with Rayong 3 (higher starch content, but lower fresh yield), the farmers have been actually losing money by the sales of fresh roots until recently when new cultivars with both high fresh yield and starch content started to replace Rayong 3 (**Figure 3.2.2.4.**). 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 dollars in fresh root production and 87.6 million in starch production for the 1996/97 season in Thailand (**Table 3.2.2.1., Figure 3.2.2.4**).

In Indonesia, the advantage of new cultivars is clearly in both fresh yield and starch content; thus, the additional fresh root yields in the fields and the additional starch production in the factories, both induced substantial economic gains, 32.6 and 44.7 million US dollars, respectively (**Table 3.2.2.2., Figure 3.2.2.5.**).

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. However, the benefits caused by the additional fresh root production and the additional starch production will soon outstrip the stake sale from the 1996/97 season (**Figure 3.2.2.6.**).

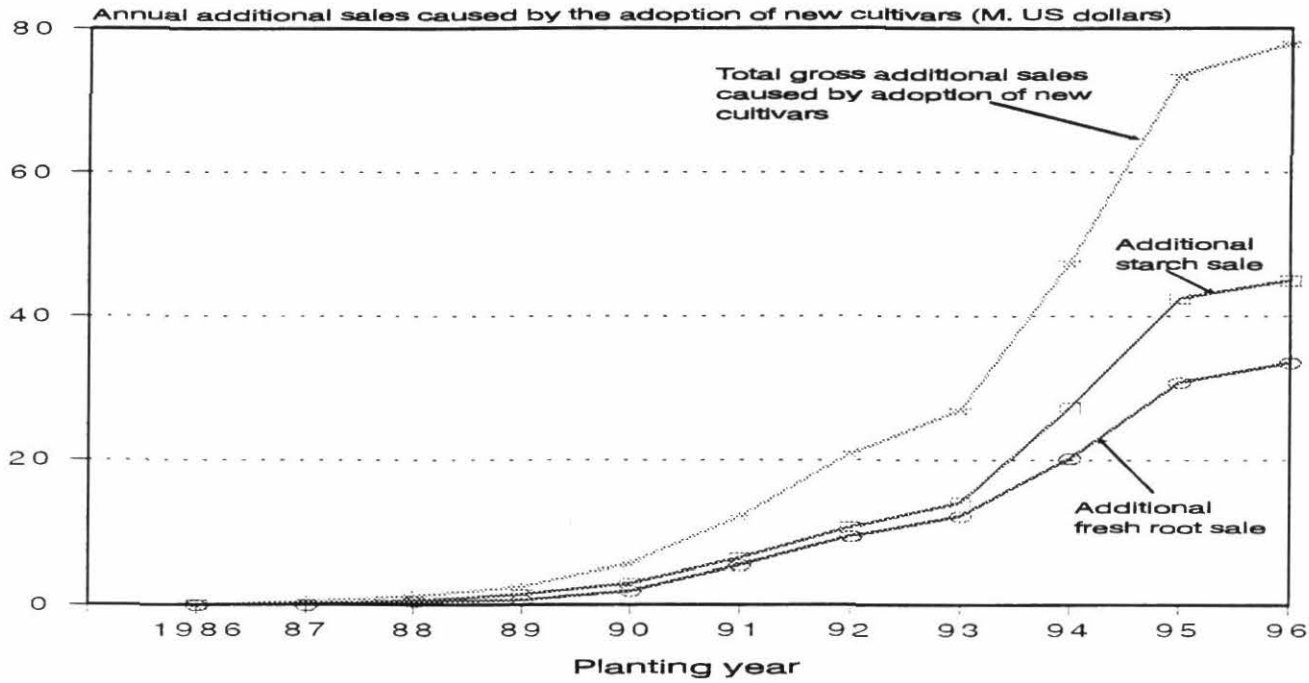


Figure 3.2.2.5. Additional economic effects generated by the adoption of new cassava cultivars in Sumatra, Indonesia in the past 10 years.

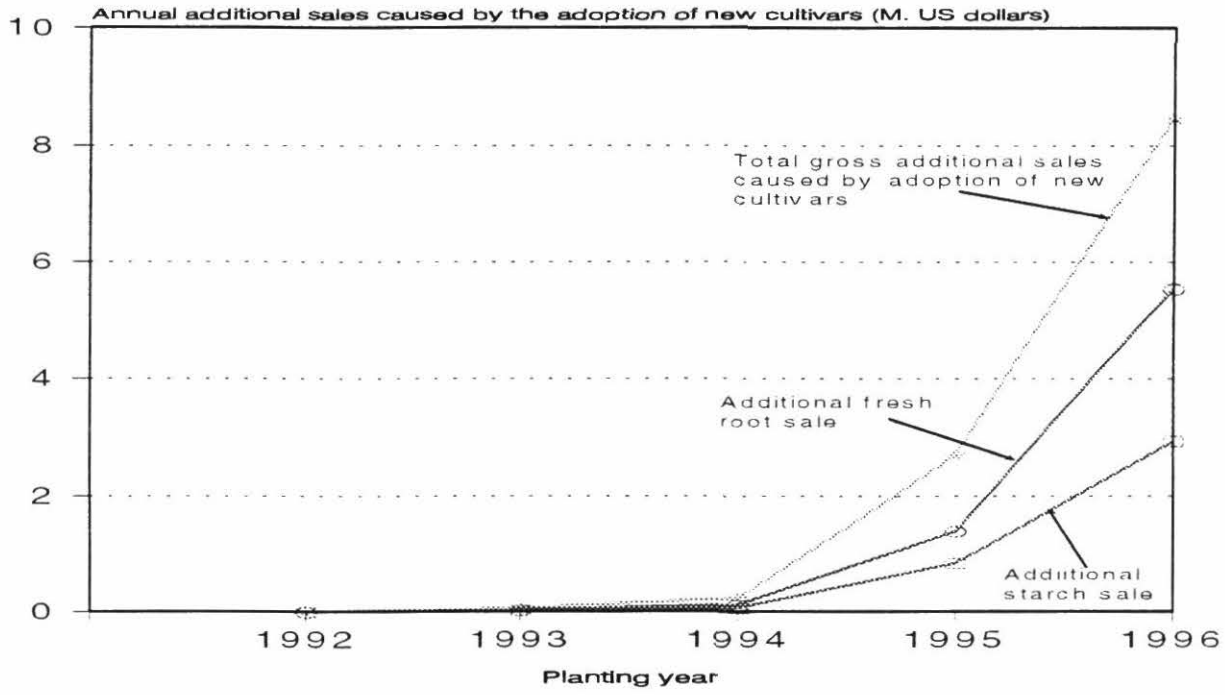


Figure 3.2.2.6. Additional economic effects generated by the adoption of new cassava cultivars in South Vietnam in the past 5 years.

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 (**Figure 3.2.2.7.**).

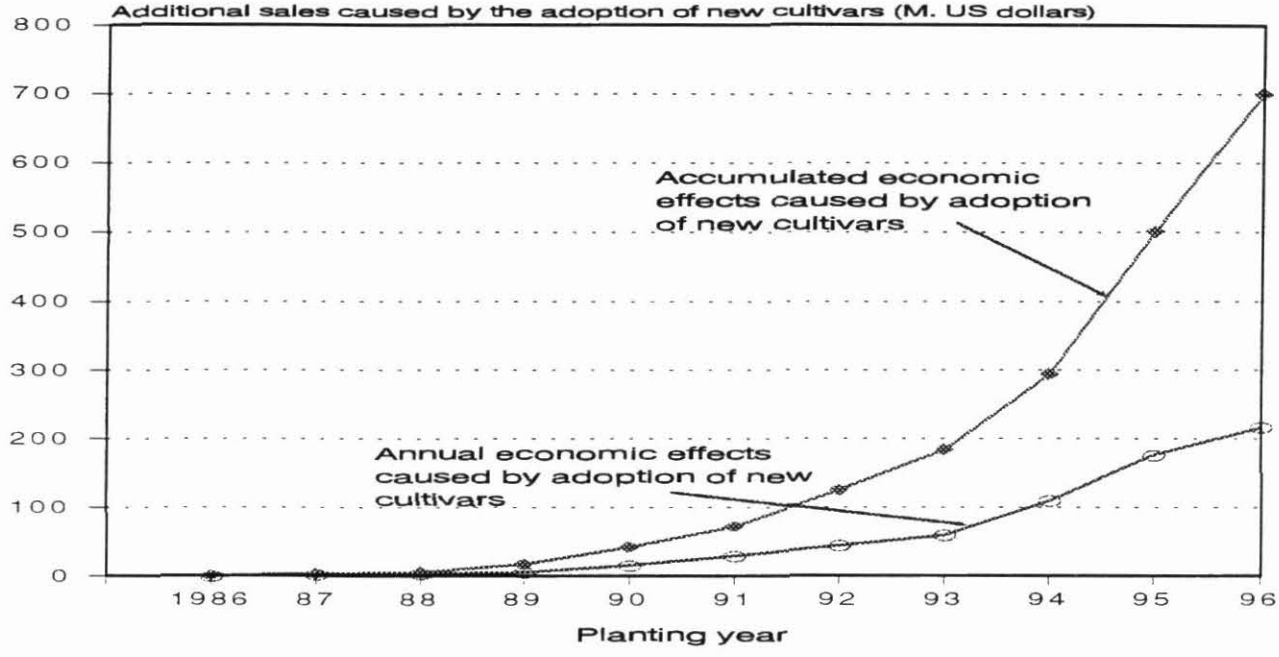


Figure 3.2.2.7. Total additional economic effects, accumulated and annual, generated by the adoption of new cassava cultivars in 5 countries in Asia in the past 10 years.

In this report, we primarily analyze the economic effects caused by the additional yield level and additional starch content of the CIAT-related new culivars. Yet, when we consider all the history of cassava processing industry in Asia, the establishment and development of large cassava product market by the Thai entrepreneurs and the selection of cultivar Rayong 1, which has been the back bone of Thai cassava production, are the most significant factors. The monetary contributions of these must be in the billions of US dollars. The greatness of Rayong 1 is not limited to the immensely successful field production in the past 2 or 3 decades, but also extended to the role of effective cross parents as it produced Rayong 60 and Kasetsart 50 among others through hybridizing with the introduced parents from CIAT, Colombia. The contribution of Thai farmers who selected Rayong 1 should be remembered.

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 Indonesia and Philippines, some field productions are handled by large plantations; yet, the majority of production takes place in small farmer's

fields. Thus, we can assume that virtually all the additional economic effects generated by the higher fresh root yield of new cultivars are entering directly to the pockets of small farmers.

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 the 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.

A recent price scheme at a starch factory in Rayong, Thailand, indicates that more than a half of the cost of starch is the cost of fresh cassava even with cassava roots of high starch content, suggesting that in general a fair price is paid to the producers. More interesting is what proportion of additional starch amount produced by the higher starch content is compensated back to the farmers. Since the factory can benefit from the increased amount of final product, its business can still be viable even if the factory fully (100%) compensates farmers for the higher starch content. 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. All in all, the scheme is not out rightly unfair to the farmers. We can safely assume that a substantial portion, more than half, of the 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 m2). Virtually all of them use the additional cassava yield for pig feeding which results in 50-600 kg additional sale (U$ 45-454) per family per year to the market. The whole scheme is not as spectacular as the rapid varietal dissemination in South Vietnam or other countries. Yet, here is a scheme where a new technology is spreading thin and wide very democratically, creating economic opportunities for bettering their farm lives. This is in sharp contrast to the accustomed schemes where powerful ones (starch factory owners or smart organizers of stake multiplication of production) take the best share of the profit. Here appears to be a most equitable contribution of crop breeding.

Activity 3.2.5. *Local training of Asian cassava breeders.*

Until 1990 the main strategy for training Asian scientists working on cassava was through a one-month course held at CIAT-Colombia. As available funds got reduced, the strategy switch to on-site training. CIAT's breeder got together with National Program breeders at harvesting time to evaluate and make selections together. From this process a set of selection criteria and strategies for the diffusion of improved varieties have been established for each on the main regions. The interaction has also provided opportunities for training in specific aspects for which the National Programs appeared weak.

In 1995, we had a unique opportunity to gather all Asian cassava breeders and accompany the harvest of all breeding stages in Thailand. The workshop was organized upon request from Asian cassava breeders that wanted to witness well organized and executed breeding and dissemination programs. A total of 44 participants from 7 countries joined the event. The

workshop provided good methodological learning, set goals and strategies to achieve those goals in a given time. This kind of activity was only possible thanks to the hospitality of the Food Crops Research Institute of Thailand. They openly shared their results, allowed participants to take active part of the selection process, and gave representatives from each of the institutions a set of recombinant progenies from the most elite genotypes in the program, to take home and initiate an adaptive selection process.

Activity 3.2.6. *Facilitate communication within the Asian cassava breeders network.*

Within the informal network of Asian cassava scientists, breeders represent the majority of active participants. In November 1996, the V Asian Cassava Research Workshop was held in the Chinese Academy of Tropical Agricultural Sciences (Hainan). The workshop was attended 58 cassava scientists from Asia and CIAT-Colombia. There has been a consistent improvement from previous workshops. Presentations were better prepared and the level of participation in the discussion from the floor was much more active than previously. Many more national program participants could find their own source for financing the trips to attend the Workshop. There was a unanimous feeling that this network meeting every 3 years is a highly worthwhile undertaking. The continuation and invitation to new members are very desirable.

In varietal improvement, most national institutions reported on their favorable progress in selection and dissemination of elite genotypes. Both at Rayong and Kasetsart cassava breeding programs in Thailand, further selection for yet higher physiological yield level is promising. Other national programs are yet to select their own superior materials while the further dissemination of presently available materials, mostly selected from CIAT introductions, can bring about significant contributions to the farmers. All these developments offer ample opportunities for further socio-economic analyses. In general, the feeling of having come to the best period of development and "let go on with the present momentum" was strong. Everyone was convinced that the network was functioning well and producing actual results.

Together with members of the network we have analyzed the present situation in germplasm development and dissemination (**Table 3.2.6.1.**). The situation is a reflection more of the current institutional and socio-economic difficulties rather than the level of personal competence and commitment. There are several countries with strong programs in germplasm selection and dissemination. For some of the countries there is variability in terms of the capacity of different institutions to progress in each of the stages that lead to the dissemination of successful cassava varieties (i.e. China and Indonesia)

Among the positive aspect of a network of institutions in Asia, has been the capitalization on the strength of institutions like FCRI (Thailand) and others for the support of those weaker programs, and the development of synergistic interactions.

Table 3.2.6.1. Strength in cassava varietal development and dissemination at National research institutions in Asia

		Breeding program			Extension scheme			
Country	Institution[1]	Institutional support	Human resources	Technical progress	Institutional support	Organizational effectiveness	Social interest	Socio-economic effects
Thailand	FCRI	++++	+++	++++	+++	+++	+++	++++
	KU	++	++	+++	++	++	+++	++++
Indonesia	UJF	+++	++	+++	++	+++	+++	++++
	BW	++	++	+++	0	+	++	+
Vietnam	IAS	++	+++	+++	+++	+++	+++	++++
	AU3	+	++	+++	+	++	+++	++
	PVRC	+	++	++	++	++	+++	+++
China	CATAS	++	++	+++	++	++	++	+
	GSCRI	+	++	+++	++	++	+++	++
	UCRI	+	+	++	+	+	+++	+
Philippines	PRCRTC	++	++	++	+	+	++	++
India	*CTCRI*	++	+++	+++	++	+	+	++
	TNU	+	+	++	0	0	++	++

[1]FCRI, Field Crop Research Institute, Department of Agriculture; KU, Kasetsart University; UJF, Umas Jaya Farms; BW, Brawija University; IAS, Institute of Agricultural Sciences of South Vietnam; AU3, Agricultural University # 3; PVRC, Potato and Vegetable Center; CATAS, Chinese Academy of Tropical Agricultural Sciences; GSCRI, Gungxi Subtropical Crops Research Institute; UCRI, Upland Crop Research Institute; PRCRTC, Philippines Root Crop Research and Training Center; CTCRI, Central Tuber Crops Research Institute; TNU, Tamil Nadu University.

PUBLICATIONS

1. Refereed Journals

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.

2. Alvarez, E. and M. L Molina. 1997. Caracterización Morfológica y Molecular de Aislamientos de *Sphaceloma manihoticola* (Bitancourt & Jenkins) en Colombia. Fitopatología Colombiana. In preparation.

3. Fukuda WMG; Cavalcanti J; Oliveria SL; Dallalibera I; Iglesias C & Mesa E 1998 Response of cassava varieties to drought and green mite (*Mononychellus tanajoa*) attack. Submitted to Field Crops Research.

4. Iglesias, C.; Mayer, J. Chavez, L. & Calle F. 1997. Genetic potential and stability of carotene content in cassava roots. Euphytica 94:367-373.

5. Iglesias C. J Bedoya, N Morante & F. Calle (1996) Genetic diversity for physiological deterioration in cassava roots. In Kurup GT et al. Tropical Tuber Crops: Problems, prospects and future strategies. Science Publishers Inc., Lebanon, NH, USA. pp 115-126.

6. Kawano K; Narintaraporn K; Narintaraporn P; Sarakarn S; Limsila A; Suparhan D; Sarawat V & Watananonta W. 1998 Yield improvement in a multi-stage breeding program for cassava. Crop Science 38 (in press).

7. Restrepo S., Verdier V., Mosquera G., Gersti A., Laberry R., Valle T. and E. Alvarez. 1997. Cassava bacterial blight in South America: pathogenic and genetic characterization of the causal agent and its application to screening methods. African Journal of Root and Tuber Crops. Vol. 2. p. 7-9.

8. 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.).

9. Yeoh HH; Sanchez T; & Iglesias C. 1997 Cassava linamarases for cyanide determination. Trop. Sci. 38:91-96.

10. Yeoh HH; Sanchez T; & Iglesias C. 1997 Large scale screening of cyanogenic potential in cassava roots using the enzyme-based dip-stick. J Food Comp Anal 11:2-10.

2. *In conference proceedings, posters, manuals*

1 Alvarez, E., Chacón, M.I., Loke, J.B., N. J. Sánchez. 1997. Genetic variation in strains of *Phytophthora* spp. affecting cassava. Phytopathology Vol. 87, No. 6, p. S3 - S4. Abstract presented at APS-Annual Meeting, 9-13 August, Rochester, N.Y., USA.

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.

4 Alvarez, E., M. Valencia, J.B. Loke and E. Rosero. 1995. A new approach to characterize cassava root rot pathogens. CIAT Internal Review (Plant Breeding for Sustainable Agriculture).

5 Fukuda, WMG; Magalhaes, JA; Cavalcanti J; Pina PR; Tavares JA; Iglesias C; Hernandez Romero LA & Montenegro EE. 1997. Pesquisa Participativa em melhoramento de Mandioca: Uma Experiencia no semi-árido do Nordeste do Brasil. CNPMF, Cruz das Almas, Bahia, Brazil. pp 46.

6 Restrepo,S., Verdier,V. and E. Alvarez. 1996. Cassava Bacterial Blight in South America: Pathogenic and Genetic Characterization of the causal agent and its aplication to screening methods. Poster presentation in: CBN III, Kampala, Uganda.

7 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).

FINANCIAL SUPPORTERS

Donor agency	Project
IFAD: International Fund for Agriculture Development	Cassava germplasm development for semi-arid ecosystems
Ministry of Agriculture of Colombia (Plan de Modernización de la Yuca)	Development of de-centralized planting material multiplication systems
DANIDA: Danish International Development Agency	Improvement of cassava for micro-nutrient content
FENAVI: Colombian National Chicken Growers Federation	Selection and diffusion of improved cassava varieties in Central Colombia
ACOPOR: Colombian Pork Growers Association	Selection and diffusion of improved cassava varieties in Eastern Colombia

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