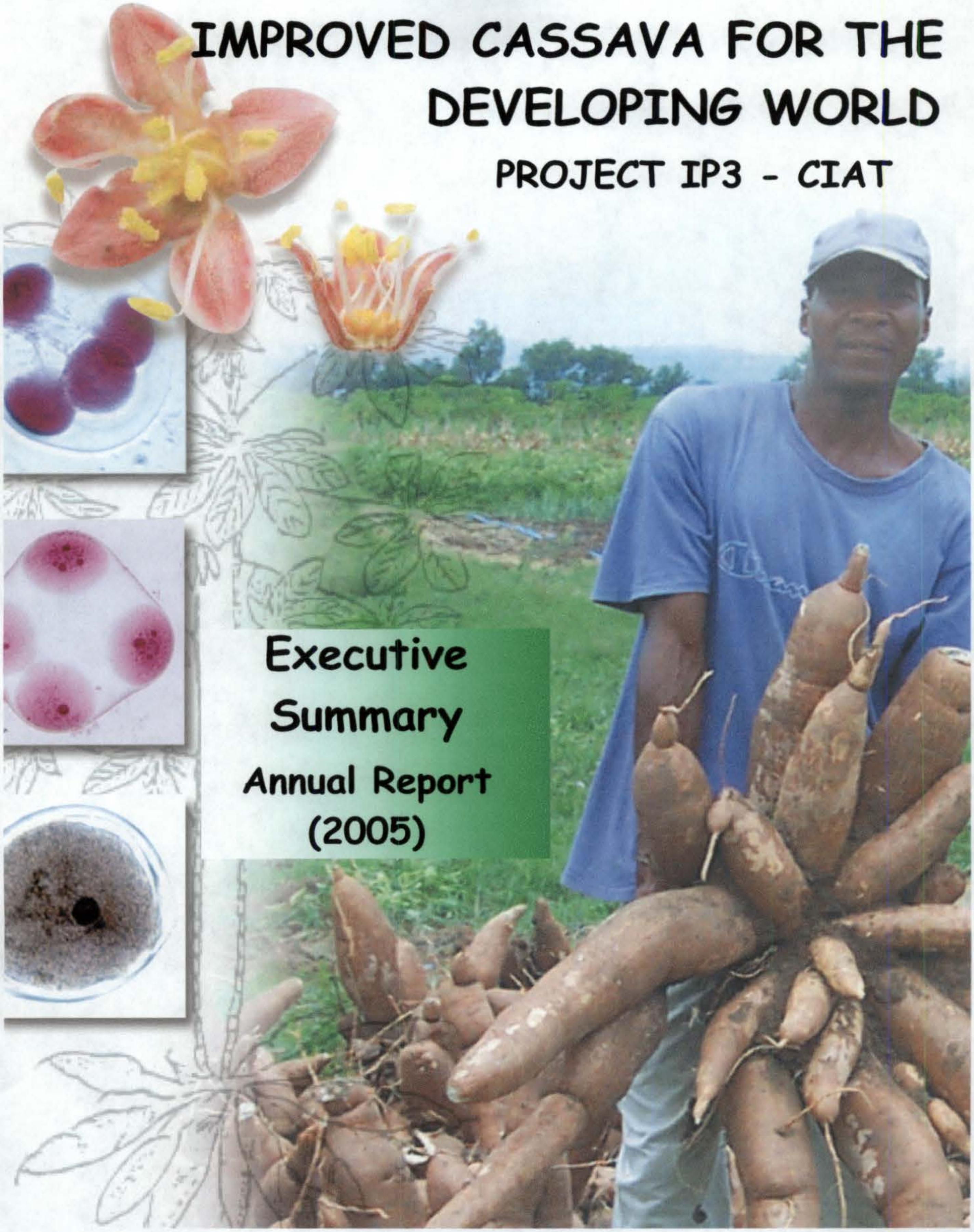
IMPROVED CASSAVA FOR THE DEVELOPING WORLD

PROJECT IP3 - CIAT



Executive Summary

Annual Report (2005)

PROJECT IP-3: IMPROVED CASSAVA FOR THE DEVELOPING WORLD

PROJECT DESCRIPTION

Objective: To develop germplasm, methods and tools for increased productivity and value of the cassava crop that will result in increased income and development of rural communities involved in growth and processing.

Outputs:

1. Genetic base of cassava and related Manihot species evaluated and available for cassava improvement.
2. Genetic stocks improved gene pools developed and transferred to national programs.
3. New methods for cassava breeding developed.
4. Research on the industrial uses of cassava and elite germplasm produced.
5. Breeding for insect and other arthropods and disease resistance and development of alternative methods for their control.
6. Development and use of biotechnology tools for cassava improvement.
7. Integrated cassava-based cropping systems in Asia. Widespread adoption of farming practices that enhance sustainability.

Gains: The rural populations in Africa, Asia and Latin America and the Caribbean benefit by increased productivity, enhanced value of the products produced, and flexibility by the availability of different processing alternatives for cassava

Milestones:

2005 Consolidations of the first “Trapiches Yuqueros” (Cassava Drying Mills) in Colombia. A novel approach for cassava to promote rural development that could be replicated in other countries.
Development of an alternative breeding method based on the production of doubled-haploids and the introduction of inbreeding in cassava genetic improvement

2006 The first set of S2 lines planted in the field and evaluated for key traits such as starch quality and cyanogenic potential.
Better understanding of methods for the control of post-harvest physiological deterioration. First generation of crosses specifically designed for increased carotene content in the roots evaluated in Clonal Evaluation Trials in target environments.
First genetically modified cassava planted in the field following strict biosafety regulations.

2007 New molecular markers developed for resistance to white flies and mites, carotene content and/or high dry matter content.
TILLING system implemented in mutagenesis project to produce and identify cassava clones with novel starch properties.
Large number of crosses with wild relatives of cassava evaluated for key agronomic traits (insect and disease resistance, nutritional quality, extended shelf life of roots and acyanogenesis).

Users: Immediate beneficiaries are farmers growing cassava as a cash crop or for subsistence farming. Close beneficiaries are processing industries related to cassava (for animal feed, for processed food, for starch or derived products and with the recent addition of production of carburant ethanol).

Collaborators: NARS in Asia (particularly Thailand, Vietnam, China, India and Indonesia), Latin America and the Caribbean (particularly Brazil, Colombia, Cuba, Dominican Republic, Haiti, Nicaragua, Honduras, Peru, Ecuador and Venezuela), and Africa (Ghana, Ivory Coast, Nigeria, South Africa, Tanzania, and Uganda). IITA and IFPRI (CG Centers), CLAYUCA, and private sector involved in cassava processing. Advanced research laboratories (Danforth Center, Cornell and Ohio State University in the USA; Wageningen University in The Netherlands, Uppsala University in Sweden, KVL University in Denmark, ETH in Switzerland, and Plant Science Center at RIKEN Yokohama Institute in Japan).

CGIAR System Linkages: IITA cassava breeding (5%); Biofortification within the HarvestPlus Initiative (25%); Training (15%); Information (15%); Networks (20%); Organization and Management (10%). Participates in the Global Cassava Strategy (10%). Linkages are gradually and constantly changing. Linkage with IITA will hopefully increase as a result of a joint research proposal to introduce germplasm with the recently discovered high-protein in the roots trait. Also, there is increasing linkages through the Generation Challenge Program and with CIP through common interests between sweet potato and cassava breeding.

CIAT IP-3 Project LogFrame (2005-2007)

Project: Improved cassava for the developing world
Project Manager: Hernán Ceballos

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal To improve the livelihoods of rural populations in Latin America, Africa and Asia by increasing cassava productivity, while protecting the environment and enhancing the value of products derived from this crop.	Increased productivity of cassava clones. Widened uses for cassava. Increasing the area planted to the crop.	National statistics of different countries where projects have been implemented. Recognition of private sector (processing)	
Purpose To develop methods and tools that will make the genetic improvement of cassava more efficient and to identify valuable germplasm for the breeding project. Eventually a technology package involving germplasm, cultural practices and processing alternatives will be made available to rural communities.	By the end of year 2006, the project has consolidated the technology packages for alternative industrial uses of cassava as well as strengthened the reliability and sustainability of the crop as a source of food security for subsistence farming.	Reports and project documents of our partner institutions. Reports from the processing sector. Scientific publications	Political and institutional support for sustainable rural and agricultural development at the reference sites and targeted countries is maintained. Natural disasters and civil strife do not impede progress toward contributing to the project's goal. Absence of drastic changes in the price of maize as a commodity that greatly affects cassava competitiveness.
Output 1 Genetic base of cassava and related Manihot species evaluated and available for cassava improvement.	True retention of carotenes after processing determined (2004) and published (2005). Method for storage/shipment of roots determined (2004) and published (2005). Effect of carotene content on PPD determined (2004) and published (2005). Number of new clones and self-pollinations produced and evaluated combining high carotene content and desirable agronomic traits	Articles published. Annual reports and project proposals. Clones developed to take advantage of findings from this output.	Natural disasters or civil strife do not impede progress toward achieving the project's goal. Cassava germplasm bank is maintained in the field.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
	(2004-2007). *Confirmation of stability of carotene*, Fe and Zn contents in roots from selected clones determined (2004) and published (2005). Knowledge on the possibility of further increasing levels of carotenes through self-pollinations or specific crosses (2006). New generation of clones with higher carotenes or better agronomic performance (2007).		
Output 2 Genetic stocks improved gene pools developed and transferred to national programs.	Protein content in selected clones from Central America confirmed (2005). High and low amylose content in roots from selected clones confirmed (2005). Planting of 3000 genotypes induced for mutation (2004) production of self-pollinated seed (2005). Evaluation for starch quality (2006) and implementation of TILLING.	Project home page. Annual reports and working documents. Scientific publications. Shipment of germplasm to collaborators in different countries.	Natural disasters or civil strife do not impede progress toward achieving the project's goal. Adequate funding for research activities.
Output 3 New methods for cassava breeding developed	Number of S_1, S_2 and S_3 seed produced and planted in the field (2004-2007). Six articles on inheritance of quantitative traits submitted for publication (2004-2005). Two scientific articles on cassava breeding submitted for publication (2004-2005). Analysis of the impact of the new evaluation/ selection scheme conducted (2004) and published (2005). Search of useful recessive traits in partially inbred germplasm incorporated as routine in the breeding project (2004-2007).	Case studies published. Annual reports and working documents. Submission of joint research proposals. Support from private sector	Natural disasters or civil strife do not impede progress toward achieving the project's goal. Willingness of IITA to continue the collaboration we have had.
Output 4 Research on the industrial uses of cassava and elite germplasm produced	Number of germplasm produced and evaluated (2004-2007). Performance *of elite germplasm identified* (2004-2007). Number of officially released varieties. Area planted to cassava germplasm developed totally/partially by CIAT (2007).	Project proposals and reports. *Accessions planted and* maintained in the field. Introduction of new accessions	Natural disasters or civil strife do not impede progress toward achieving the project's goal.

Narrative Summary	**Measurable Indicators**	**Means of Verification**	**Important Assumptions**
	Number of *"Trapiches Yuqueros"* consolidated (2005). Information of alternative uses of cassava products developed by CLAYUCA from roots and foliage (2005). Progress to introduce artificial drying processes in other countries from Latin America (2007). Number of clones (vitroplants) or new genotypes shared with collaborating NARs and IITA (on a yearly base 2004-2007).		
Output 5 Breeding for insect and other arthropods and disease resistance and development of alternative methods for their control.	Number of germplasm evaluated for their reaction to insects and arthropods with emphasis in white flies and mites (2004-2007). Number of germplasm evaluated for their reaction to diseases with emphasis in bacterial blight, root rot and super elongation disease (2004-2007). Results of field studies to determine how and who transmits the frog skin disease (2007). Identification of the etiology of frog skin disease (2007). Number of crosses with wild relatives evaluated every year in search of resistance to pests and diseases (2005-2007)	Annual reports and working documents. Scientific publications. Development of commercial products for biological control of pests in cassava.	Natural disasters or civil strife do not impede progress toward achieving the project's goal. Adequate funding for research activities.
OUTPUT 6 Development and use of biotechnology tools for cassava improvement	More than 700 CMD resistant hybrids (10 plants per genotype) shipped to Africa (Tanzania, Nigeria, Uganda, and South Africa) and India. (2005). About 300 CMD resistant hybrids (10 plants per genotype) shipped to Tanzania, hardened and transferred to the field. Latin American germplasm transferred to the field in Ghana and Nigeria and evaluated for high protein content and resistance to pest and diseases. Field results on starch quality from a transgenic clone with waxy starch developed with anti-sense technology (2005-2006).		Natural disasters or civil strife do not impede progress toward achieving the project's goal. Adequate funding for research activities.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
	Molecular markers for resistance to mites developed (2005) and validated with field data (2007). Molecular markers for beta-carotene (2005) developed and validated with field data (2007). Molecular markers for resistance to dry matter content (2005) developed and validated with field data (2007).		
Output 7 Integrated cassava-based cropping systems in Asia. Widespread adoption of farming practices that enhance sustainability	Research partnerships established in Laos and Cambodia (2005). Number of trials introducing new germplasm/ technologies established (2006). Number of communities adopting new germplasm/technologies in Laos and Cambodia (2006).		

3. Research Highlights from year 2005

High-protein in the roots traits confirmed.

During 2005 a breakthrough discovery confirming cassava clones with 2-3 times more crude protein in their roots (6-8%, dry weight basis compared with the typical 2-3%) was accepted for publication. High-protein cassava will increase income to farmers that will produce a value-added cassava for improved livestock nutrition and will also improve the diet of million of people for whom cassava is a daily staple food. Because of the low protein content of "normal" cassava, the feed industry can only pay for cassava roots 60-70% of the price of alternative sources of energy (typically maize) in the diets. High-protein cassava roots offer the advantage to the feed industry that their utilization may not require changes in the formulation of diets nor additional source of proteins compared with maize. In many tropical countries, maize is currently imported from temperate regions. Therefore, it has become strategic for these countries to find local source(s) of energy for the feed industry. The high protein trait adds nutritional value to the root, increasing their value to the system, and making it more competitive. This, in turn, may increase the possibilities to compete with (imported) maize. This trait also offers an interesting possibility of collaboration between the feed industry with the animal nutrition and crop breeding research community.

Discovery of a mutant with waxy starch

For many years the cassava-breeding project at CIAT has gradually but consistently shifted its attention towards the production and/or identification of cassava clones with high-value for industrial uses. For the feed industry clones with increased nutritional value was a key target. The starch industry has requested persistently clones with altered starch properties in their roots. Acyanogenesis is an important trait for the processed food industry, and clones with molecules simpler than starch are now requested by the different initiatives that have been created to produce carburant ethanol and the bioplastics industry. The introduction of inbreeding in cassava was partially justified by the fact that it would facilitate the identification of clones with useful recessive traits. During the past few years hundreds of partially inbred plants were grown and evaluated in search of useful traits. During 2005 an S1 plant, grown at CIAT and harvested in early 2006, was found to have a modification of its starch with markedly reduced amylose content and a very distinctive amylogram (indicating differential pasting properties). The starch behaves as a typical waxy starch, one of the most common requests by the industry. This discovery, is very important not only because of its value-added characteristic (a waxy maize starch is about 30% more expensive than normal maize starch) but also because it proves the concept that inbreeding cassava will eventually allow for the identification of useful recessive traits.

Development of a quantitative-genetics-approach to quantify epistasis.

Very little research has been done to understand the inheritance of quantitative traits in cassava. As a matter of fact very little has been learned about the genetics of cassava, compared with other crops like maize, rice or soybean. Cassava, however, offers the advantage of vegetative reproduction. In this regard, cassava shares many characteristics with annual and perennial crops and could eventually serve as a bridge between the two types of crops. Because of the vegetative reproduction of cassava we can measure within-family genetic variation, something impossible in many other important annual crops. This, in turn, allows for special approaches to measure epistasis using quantitative genetic models. During 2005 an approach to quantify epistasis, that had been mentioned in books, as a theoretical model, was applied using experimental data from cassava. As a result three different research articles were published (Euphytica, Journal of Heredity and Crop Science).

Validation of molecular markers for resistance to Cassava Mosaic Disease.
Perhaps the single most limiting factor for cassava in Africa is the devastating Cassava Mosaic Disease (CMD). The disease is not present in the Americas and a related pathogen affects cassava grown in India. The absence of CMD in the Americas prevents CIAT's ability to breed for resistance to the disease. The biotypes of the vector that occur in the Americas *Bemisia tabaci* (a white fly) do not readily feed on cassava. However, recent discoveries suggest that this may change prompting the cassava breeding projects to develop a pre-emptive measure should the disease be accidentally introduced into the americas. The only feasible approach to do that is through the use of marker assisted selection using molecular markers developed at CIAT. During the past 3 years CIAT has been selecting for resistance to CMD using markers linked to a CMD resistance gene. Evaluations at 6 and 9 months after planting (in Tanzania and Nigeria) of 503 genotypes bred at CIAT for CMD resistance revealed 224 genotypes with no visible foliar symptoms for CMD and176 genotypes that did not show any visible foliar symptoms for CMD and cassava green mite. The large number of susceptible clones that had been selected with markers for resistance to CMD conferred by the *CMD2* gene was, however, unexpected. Further analysis of the results by family revealed that families with over 90% of genotypes susceptible, had as a source of resistance, the parent C127. These results suggest that the C127 parent (one of the 17 F_1 progenies of TME3, the source of *CMD2)*, is a susceptible genotype. When families having this parent were removed from the analysis, the percentage of resistant genotypes was 70%, which is the expected percentage, given that *CMD2* controls 70% of CMD resistance. These results provide an excellent example of the usefulness of marker assisted selection and provide an ideal strategy to build up resistance to the disease in cassava germplasm adapted to the Americas.

Further progress in understanding frog skin disease.
Cassava frog skin disease (CFSD) remains a frustrating problem for cassava research in Colombia. The diseases causal organism has not been definitively identified, nor its vector agent. The only protocol for the certification that a plant is disease free is through grafting into the indicator genotype *Secondina*. This is, however, a cumbersome procedure that needs about four months to provide results. Therefore the only practical procedure is to rely on the symptoms, which express (frequently) only in the roots. In spite of the measures taken at CIAT based on the elimination of any plant showing symptoms in the roots and the imposition that no vegetative cuttings will be taken if the roots of the plant have not been first analyzed to make sure they are symptoms-free, the incidence of the disease cannot be

adequately reduced. During the past year increasing evidence of the association between CFSD and a phytoplasm was provided. It has not been determinate that the phytoplasm induces CFSD but results are very promising for such an elusive disease. Significant progress was also achieved in reducing the list of candidate vectors that may be involved in the disease. It has been decided, that *Scaphytopius marginelineatus* and *Peregrinus maidis* are prime candidates as vectors of CFSD

Growing evidence of increased cassava productivity in Vietnam

Highlights in cassava research are (sometimes) difficult to be allocated to one particular year because of the large inertia frequently involved in activities related to this crop. This is the case of cassava in Vietnam. During the last few years there has been a gradual and consistent trend in Vietnam that will now be highlighted. Three major trends can be claimed for cassava in that country. The first one is a remarkable increase in the productivity of the crop that almost doubled in the last ten years (from 8.44 t/ha to more than 14 t/ha). A parallel trend to the higher productivity, which can be perceived as a consequence or a cause, is a sharp increase in the number of starch factories created in the country. Our current estimates are that there are more than 60 such facilities and this is evidence of the importance of this crop as a vehicle for rural development: these factories are typically located in rural areas. The increase in productivity and the interest shown by the processing sector, has led the government to declare cassava among the priority commodities for the country.

Demonstration of evolution of B. tabaci to adapt feeding in cassava

During the year a scientific article demonstrating the adaptation of *Bemisia tabaci, Biotype B. (Grennadius)* to cassava, was published. This is a very interesting study where CIAT scientists could gradually adapt insect populations to feed first on an intermediate plant species and then to cassava. Perhaps it is the first scientific evidence of such adaptation directed by mankind that could be liked to the evolutive potential of a pest from one host (beans) to another unrelated plant host (cassava). The importance of this research relies on the possibility of the insect (vector and perhaps the "builder" of viruses such as cassava mosaic disease) to quickly adapt to cassava as has already been reported to occasionally occur and in, more general terms, the power of nature or artificial selection to promote this change.

Large number of scientific articles published or accepted during 2005.

A total of 33 scientific articles were published in 2005 or accepted for publication during the past year and in a great diversity of journals: Journal of Crop Improvement; Crop Science (two articles); Euphytica (six articles); Fitotecnia Colombiana; Journal of Heredity; Plant Breeding; Florida Entomologist (three articles); Photosynthetica; Field Crops Research; Fitopatología Colombiana (five articles); Acta Agronómica (two articles); Nematology; Crop Protection; Biotecnología en el sector agropecuario y agroindustrial; Theoretical and Applied Genetics; Acta Horticulturae; Journal of the Science of Food and Agriculture (two articles); Journal of Food Composition and Analysis; and Phytopathology.

4. PROJECT INPUTS

4.1 Staff

Table 1 Internationally and nationally recruited staff associated with the cassava-breeding project. Underlined are the women associated with the project.

Name	Degree	Capacity Area	Name	Degree	Capacity Area
International Staff Directly Involved in Cassava Breeding Project IP3					
Alvarez, E.	Ph.D.	Pathology	Fregene, M.	Ph.D.	Genetics
Bellotti, A.C.	Ph.D.	Entomology	Howeler, R.	Ph.D.	Agronomy
Ceballos, H.	Ph.D.	Breeding	Ospina, B.	M.Sc.	Processing
National Staff Directly Involved in Cassava Breeding Project IP3					
Name	**Degree**	**Capacity Area**	**Name**	**Degree**	**Capacity Area**
Alzate, A.	I.A.	Genetics	Loke, J.B.	I.A.	Pathology
Arias, B.	M.Sc.	Entomology	Marin, J.A.	Biol.	Genetics
Barrera, E.	Biol.	Genetics	Mejía, J.F.	I.A.	Pathology
Bohorquez, A.	Biol.	Entomology	Melo, E	Biol.	Acarology
Buitrago, C.	I.A.	Genetics	Moreno, J.Z.	Biol.	Genetics
Calle, F	I.A.	Breeding	Moreno, X.	Zootec	Breeding
Carabalí, A.	I.A.	Entomology	Montaña, V.S.	I.A.	Breeding
Castelblanco, W.	Biol.	Genetics	Morante, N.	Biol.	Breeding
Guerrero. J.M.	I.A.	Entomology	Múnera, D.F.	I.A.	Entomology
Guitérrez, J.P.	Biol.	Genetics	Ortega, E.	I.A.	Breeding
Herrera, C.J.	I.A.	Entomology	Ospina, C.A.	I.A.	Genetics
Hernandez, M.P	M.Sc	Entomology	Perez, J.C.	Ph.D.	Breeding
Holguín, C.M.	M:Sc.	Entomology	Puentes, G.J.	I.A.	Genetics
Hurtado, P.X.	Biol.	Genetics	Sánchez, R.	I.A.	Breeding
Jaramillo, G.	I.A.	Breeding	Sánchez, T.	Chem.	Breeding
Lenis, J.I.	I.A.	Breeding	Santos, L.G.	I.A.	Genetics
Llano, G.	M.Sc.	Pathology	Zamora, Z.	B.S.	Pathology
López, J.	I.A.	Breeding			

4.2 List of partners

Table 2. Institutions with which personnel of the cassava breeding project maintains collaborative activities

Partner	Country	Partner	Country
University of Adelaide	Australia	Central Institute for Food Crops, Bogor	Indonesia
EMBRAPA - CNPMF	Brazil	Res. Inst. for Legumes & Tuber Crops, Malang	Indonesia
EMBRAPA - CENARGEN	Brazil	Soil Research Institute, Bogor	Indonesia
EMBRAPA - CTA	Brazil	KARI	Kenya
IAC - Sao Paulo	Brazil	NAFRI	Laos
Universidade de Campinas – Sao Paulo	Brazil	Bvumbwe Agricultural Research Station	Malawi
Chinese Acad. Trop. Agric. Sciences, Hainan	China	Crop and Food Research Institute,	New Zealand
Animal Husbandry Station, Mengzhe, Yunnan	China	IITA	Nigeria
Guangxi Subtrop. Crops Res. Inst., Nanning	China	National Root Crops Research Institute	Nigeria
CARDI	Cambodia	FIAFOR	Panamá
Corp. Des. Sostenible del N y O Amazónico	Colombia	CIP	Peru

Table 2 cont.
cont. Table 2

CORPOICA	Colombia	IDIAF	Rep.Dominc.
Consejo Regional Indígena del Vaupés (Mitú)	Colombia	Uppsala University	Sweden
ICA	Colombia	ETH - Zurich	Switzerland
Magro S. A.	Colombia	ARI	Tanzania
Secretaría de Agricultura del Vaupés	Colombia	Kasetsart University	Thailand
Special - La Tebaida	Colombia	Land Development Department	Thailand
UMATAs	Colombia	TTDI	Thailand
Universidad de Caldas—Manizales	Colombia	DOAE	Thailand
Universidad de los Andes—Bogotá	Colombia	Field Crops Res. Station- Banmai Samrong	Thailand
Universidad del Valle—Cali	Colombia	Field Crops Research Center- Khon Kaen	Thailand
Universidad Nacional de Colombia—Palmira	Colombia	Field Crops Research Center- Rayong	Thailand
12 Trapiches Yuqueros	Colombia	Field Crops Research Center- Bangkok	Thailand
FENAVI	Colombia	NAARI	Uganda
INYUCAL	Colombia	University of Florida, Gainsville, USA	USA
Corn Products	Colombia	Systematic laboratory in Livingston, Montana	USA
MADR	Colombia	National Starch and Chemical Co.	USA
Universidad Nacional de Colombia—Bogotá	Colombia	United States Department of Agriculture,	USA
CENICAFE - Chinchiná	Colombia	Cornell University	USA
BIOTROPICAL S.A., Medellín	Colombia	ILTAB – Danforth Center	USA
INIVIT	Cuba	Ohio State University	USA
KVL University	Denmark	INIA - Maracay	Venezuela
MAFF	East Timor	INIA - Anzoátegui	Venezuela
IRD	France	IDEA – Universidad Simón Bolivar	Venezuela
Council for Scientific and Industrial Research	Ghana	Agropecuaria Mandioca	Venezuela
Plant Genetic Resources Centre	Ghana	Thu Duc Univ. of Agric. and Forestry, HCM	Vietnam
Ministry of Agriculture	Haiti	Hung Loc Agric. Res. Center, IAS, Dong Nai	Vietnam
World Vision	Haiti	Hue Univ. of Agriculture and Forestry, Hue	Vietnam
AVEBE	Holland	Root Crops Research Center, VASI, Hanoi	Vietnam
Wageningen University	Holland	National Inst. of Soils and Fertilizers, Hanoi	Vietnam
CTCRI	India	Thai Nguyen University, Thai Nguyen	Vietnam
Brawijaya University-Malang	Indonesia		

4.3 Budget

Table 3. Core and special project budgets from the cassava breeding project activities for Africa, America and Asia.

SOURCE	**AMOUNT US$**	**PROPORTION (%)**
Unrestricted Core	11397	0%
Restricted Core: Colombia	17,794	1%
European Commission	392,200	15%
Sub-total	**421,391**	**16%**
Special Projects	1,923,457	73%
Generation Challenge Program	303,466	11%
Total Project	**2,648,314**	**100%**

5. PROBLEMS ENCOUNTERED AND THEIR SOLUTION.

4.1 One of the problems that need to be properly solved is the technical tuning of the artificial drying plants. This is a key issue for the success of the *Trapiches Yuqueros*. THe cassava-breeding project is content because the original productivity required for the Trapiches to be competitive (20-25 t/ha of fresh roots) has been widely confirmed in commercial plantings. However, the drying process in several of the initiatives developed in the past few years was inefficient. There is little that CIAT or CLAYUCA can do in this regard because this was the result of private engineering companies. One *Trapiche*, however, is successfully drying cassava roots in the Middle Magdalena River region. We are monitoring the performance of this management system and using it as an example for others to follow. CLAYUCA is ready to move in once the legal situation of the other *Trapiches* is settled, to start developing the modifications that they need to be operative.

4.2 Frog skin disease has proven to be a very elusive and frustrating problem for the project. We have failed to definitely identify the causal organism(s) and its vector(s). The disease is endemic in the region and affects particularly the breeding and evaluation activities at CIAT's Experimental Station in Palmira. During 2005 research to identify the pathogen(s) responsible for the disease continued. Important progress has been achieved regarding the potential role played by a virus and/or a phytoplasm. In a blind trial, however, the diagnosis based on the assumption of a viral origin of the disease failed to identify diseased plants. The phytoplasm alternative was much more successful. The list of insects suspected to be the vector has been reduced.

4.3 As a result of the changes that had occurred during the last decade public investment in agriculture research in general has drastically been reduced. Project IP3 frequently has trouble identifying an adequate partner in different countries with whom to collaborate. Other crops such as maize offer the alternative of interacting with the private sector (frequently multinational seed companies). But cassava has no such promoting interests either. The discovery of a waxy mutant opens a large possibility for the private sector (starch industry) to get more involved in cassava research in the process of adapting the trait to clones with better agronomic performance.

4.4 The presence of CIAT in Africa in the area of cassava research has frequently been complex. IITA expects that CIAT's technologies and products are introduced into Africa through IITA. There are some justifications for CIAT and IITA to proceed this way but also some problems. NARs have expressed their interest in a direct contact with CIAT. Another problem has been the issue of recognition, because once the technologies moved to IITA they became IITA's assets. CIAT has had difficulty, therefore, documenting its significant contributions to Africa. This also implied difficulty for CIAT to get proper feedback on the performance of technologies, breeding materials, etc. introduced into Africa. Also there have been objections that CIAT searches for resources for cassava research in Africa. The approach that CIAT has taken is to search for a productive and open dialog with IITA. The new emphasis in high-value cassava given by cassava research at CIAT offers a new alternative. The traits are much easier to trace and, therefore, the contribution that CIAT makes for cassava in Africa are easier to be demonstrated. Therefore, there is a possibility of a better defined research agenda between the two Centers: CIAT would screen the large genetic variability available to the Center in search of useful traits and IITA would receive these traits and adapt them to the African conditions. This is, for example, the case of the high-protein trait and the research proposal currently under join development by the two Centers.

4.5 Limitations in the availability of core resources imply that the project cannot plan long-term activities research which are considered fundamental for the genetic improvement of crops, particularly such as cassava, because of its long breeding cycle. The project is trying to find resources through special projects, but these are typically short in time and limited in scope of action.

5. INDICATORS: LIST TECHNOLOGIES, METHODS & TOOLS

5.1 Germplasm distributed

A considerable fraction of the seed produced by the project has been transferred to National Programs in different regions of the world. As shown in Table 4, more than 115,000 recombinant seeds were produced between June 2004 and October 2005 and about 50% of that seed (57,468) has been shipped to our collaborators. In addition a large number of plants in vitro were shipped to different collaborating institutions.

Table 4. Shipments of germplasm (recombinant seed and in vitro clones) produced within the project from September 2003 through September 2004.

Continents	Genotypes in-vitro	Crosses (families)	Plants (in-vitro)	Seeds in the shipment
Latin America				
In-vitro	34		2587	
Hybrid seed		277		18881
Asia				
In-vitro	248		610	
Hybrid seed		263		24775
Africa				
In-vitro	1189		2510	
Hybrid seed		102		13812
Europe and USA				
In-vitro	123		277	
Total In-vitro	**1594**		**3397**	
Total hybrid seed		**642**		**57468**

5.2 Other methods & tools

The introduction of inbreeding in cassava genetic improvement has been already adopted in different collaborating NARs (Brazil, Vietnam, Cuba, Thailand, Uganda, and Ghana). The discovery of a waxy mutant is certainly going to encourage these countries to increase the efforts in that direction and may encourage other countries to follow suit.

Methodologies for the identification of amylose-free cassava mutants are now used by NARs, the utilization of selection indexes and molecular markers are increasingly adopted with strong collaboration from CIAT scientists.

6. INDICATORS: PUBLICATION LIST.

6.1 Publications: journal articles.

1. Kawano, K. and J.A. Cock (2005). Breeding cassava for underprivileged: institutional, socio-economic and biological factors for success. Journal of Crop Improvement 14:197-219.
2. Jaramillo, G., N. Morante, J.C. Pérez, F. Calle, H. Ceballos, B. Arias, and A.C. Bellotti (2005). Diallel analysis in cassava adapted to the midaltitude valleys environment. Crop Sci. 45:1058–1063.
3. Perez J.C., H. Ceballos, G. Jaramillo, N. Morante, F. Calle, B. Arias, A.C. and Bellotti (2005). Epistasis in cassava adapted to mid-altitude valley environments. Crop Sci. 45:1491-1496.
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28. Ceballos, H., M. Fregene, Z. Lentini, T. Sánchez, Y.I. Puentes, J.C. Pérez, A. Rosero and A.P. Tofiño. Development and Identification of High-Value Cassava Clones. Acta Horticulturae (in press).
29. Ceballos, H., T.Sánchez, A.L. Chávez, C. Iglesias, D.Debouck, G. Mafla, and J. Tohme. Variation in crude protein content in cassava *(Manihot esculenta* Crantz) roots. Journal of Food Composition and Analysis (in press).
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33. Balyejusa Kizito E., L. Chiwona-Karltun, T. Egwang, M. Fregene and A. Westerbergh. Genetic diversity and variety composition of cassava on small-scale farms in Uganda: An interdisciplinary study using genetic markers and farmer interviews. Euphytica (in press).
34. Chávez, A.L., T. Sánchez, H. Ceballos, D.B. Rodriguez-Amaya, M.E. Buitrago, P. Nestel, J. Tohme and M. Ishitani. 2006. Retention of carotenes in cassava roots upon alternative processing methods. Journal of the Science of Food and Agriculture (In press).
35. Howeler, R.H., Watana Watananonta, Wilawan Vongkasem, Kaival Klakhaeng and Tran Ngoc Ngoan. 2005. Working with farmers: The key to achieving adoption of more sustainable cassava production practices on sloping land in Asia. Paper presented at 2nd Intern. Symp. on Sweetpotato and Cassava, held in Kuala Lumpur, Malaysia, June 14-17, 2005. Accepted for publication in Acta Horticulturae in 2006.

6.2 Proceedings and Presentations in Scientific Meetings

1. Cach, N., F. Calle, H. Ceballos, Perez, J.C., G. Jaramillo, J.I. Lenis, and N.Morante Effect of epistasis in the expression of relevant traits of cassava. Biotechnology, breeding, and seed systems for African crops. January 24-27, 2005. Nairobi, Kenya.
2. Ceballos, H., M.Fregene, J.C. Perez, F. Calle, G.Jaramillo, N.Morante, T.Sanchez, A.L. Chávez, and X.Moreno. Production and identification of high-value cassava clones. Biotechnology, breeding, and seed systems for African crops. January 24-27, 2005. Nairobi, Kenya.
3. Fregene, M. A. Kullaya, K. Mtunda, H. Kulembeka, E. Masumba, M. Freguson, C. Ospina, E.J. Marin, L.G. Santos, E. Barrera, N. Morante, J. Tohme and H. Ceballos. Molecular marker-assisted selection for starchy staples. Biotechnology, breeding, and seed systems for African crops. January 24-27, 2005. Nairobi, Kenya.
4. Lenis, J.I., F.Calle, G. Jaramillo, N.Morante, E. Ortega, Perez, J.C., and H. Ceballos. Relationship between traits measured at different stages of the selection process in cassava. Biotechnology, breeding, and seed systems for African crops. January 24-27, 2005. Nairobi, Kenya.
5. Perez, J.C., E. Ortega, J.I. Lenis, N.Morante, M.Espitia, and H. Ceballos. Genetic, phenotypic and environmental relationships between different traits in cassava (*Manihot esculenta* Crantz). Biotechnology, breeding, and seed systems for African crops. January 24-27, 2005. Nairobi, Kenya.
6. Calle, F., H. Ceballos, J. C. Pérez, G. Jaramillo, J. I. Lenis, N. Morante and N. Cach. Efecto de la epistasis en la expresión de caracteres relevantes en yuca. IX Congreso de la

Asociación Colombiana de Fitomejoramiento y Producción de Cultivos. May 11-13, 2005. Palmira, Colombia.

7. Ceballos, H., M.Fregene, J.C. Perez, F. Calle, G.Jaramillo, N.Morante, T.Sanchez, A.L. Chávez, and X.Moreno. Desarrollo e identificación de yucas de alto valor para la industria. IX Congreso de la Asociación Colombiana de Fitomejoramiento y Producción de Cultivos. May 11-13, 2005. Palmira, Colombia.
8. Jaramillo, G., F. Calle, J. I. Lenis, N. Morante, E. Ortega, J. C. Pérez and H. Ceballos. Relación entre caracteres medidos en diferentes etapas del proceso de selección clonal en yuca (Manihot esculenta Crantz). IX Congreso de la Asociación Colombiana de Fitomejoramiento y Producción de Cultivos. May 11-13, 2005. Palmira, Colombia.
9. Lentini, Z., E.Tabares, H.Ceballos, M.Fregene y J.C. Perez Introducción de la endogamia en el mejoramiento de especies semi-perennes. IX Congreso de la Asociación Colombiana de Fitomejoramiento y Producción de Cultivos. May 11-13, 2005. Palmira, Colombia.
10. Pérez Velásquez, J.C., H. Ceballos, E. Ortega and J.I. Lenis. Análisis de la interacción genotipo por ambiente en yuca (*Manihot esculenta* Crantz) usando el model AMMI. IX Congreso de la Asociación Colombiana de Fitomejoramiento y Producción de Cultivos. May 11-13, 2005. Palmira, Colombia.
11. Pérez V., J.C., E. Ortega, J. I. Lenis, N. Morante, M.Espitia y H. Ceballos. Correlaciones fenotípicas, genéticas y ambientales entre diferentes caracteres en yuca (*Manihot esculenta*, Crantz). IX Congreso de la Asociación Colombiana de Fitomejoramiento y Producción de Cultivos. May 11-13, 2005. Palmira, Colombia.
12. Rosero, A.; Ceballos, H.; Fregene, M.; Tofiño, A.; Morante, N. and Castelblanco W. 2005. Inducción de mutaciones en yuca (Manihot esculenta Crantz) para alta calidad de almidón. IX Congreso de la Asociación Colombiana de Fitomejoramiento y Producción de Cultivos. May 11-13, 2005. Palmira, Colombia.
13. Morante, N., H. Ceballos, M. Fregene, J.C. Pérez, T. Sánchez, A.L. Chávez, F. Calle, G. Jaramillo and X. Moreno. Development of cassava clones with traits of commercial value for the industry. Second International Symposium on Sweetpotato and Cassava. June 14-17, 2005. Kuala Lampur, Malaysia.
14. Alves, A., M. Fregene, H. Ceballos, M. Ferguson and T. Setter. Identificando as características fisiológicas e genéticas da mandioca relacionadas com a tolerância à seca. Congresso Brasileiro de Mandioca. OCt. 25-28, 2005. Campo Grande, MS, Brazil.
15. Ceballos, H., M. Fregene, Z. Lentini, T. Sánchez, Y.I. Puentes, J.C. Pérez, A. Rosero and A.P. Tofiño. High-value cassava clones for the starch industry. 3rd Conference on Starch Technology. Bangkok, Thailand. 4-5 November 2005.
16. Pérez Velásquez, J.C. y H. Ceballos. 2005. Mejoramiento genético de la yuca: yucas de alto valor. II Congreso Venezolano de Mejoramiento y Biotecnología Agrícola. Octubre 19-21. Instituo de Estudios Avanzados – IDEA, Caracas, Venezuela.
17. Álvarez, E. and Loke, J.B. 2005. Managing cassava diseases transmitted through asexual Seed. Memories 5th ISTA - SHC Seed Health Symposium, Angers, Francia. P 52-53.
18. Llano, G.A., Alvarez, E., Loke, J.B. Fregene. M., and Muñoz, J.E. 2005. Identificación de genes análogos de resistencia y QTLs asociados con resistencia a enfermedades de yuca. Memorias IX Congreso Asociación Colombiana de Fitomejoramiento y pudrición de Cultivos CORPOICA, Palmira. P 137.
19. Alvarez, E. and Gómez, E.A. 2005. Identificación y caracterización de cepas de *Ralstonia solanacearum* raza 2, agente causante del Moko de plátano en Colombia. Memorias II seminario Internacional sobre producción, comercialización e industrialización de plátano, Manizales. P 29-36

20. Arenas, A., López, D., Álvarez, E., Llano, G. and Loke, J.B. 2005. Efecto de prácticas ecológicas sobre la población de *Ralstonia Solanacearum* Smith, causante de Moko de plátano. Memorias II seminario Internacional sobre producción, comercialización e industrialización de plátano, Manizales. P 201-208
21. Loke, J.B., Corredor, J.A., Alvarez, E., Sánchez, T. and Folgueras, M. 2005. La escopoletina como indicadora para la resistencia a la pudrición de la raíz por *Phytophthora tropicalis* en yuca (*Manihot esculenta* Crantz). Memorias IX Congreso Asociación Colombiana de Fitomejoramiento y pudrición de Cultivos. CORPOICA, Palmira. P 47.
22. Gómez, E.A., Álvarez, E. y Llano, G. 2005. Variabilidad Genética y patogénica de *Ralstonia solanacearum* Raza 2, Agente causante del Moko en plátano en Colombia. Memorias XXVI congreso de ASCOLFI, Bogotá. P 3.
23. Bellotti, A.C., M. Fregene, A. Carabali, J. Montoya-Lerma, M. Burbano, A. Alves, A. Farias, J. Tohme. 2005. Wild *Manihot* species as a source for resistance for Arthropod pests of cassava. Congress of Entomology Society of America. Nov. 9-12, 2005. Ft. Lauderdale, FL, USA.
24. Bellotti, A.C., M. Fregene, A Carabali, J. Montoya-Lerma, M. Burbano, A. Alves, A. Farias, J. Tohme. 2005. Especias silvestres de *Manihot* como fonte para resistencia as pragas de mandioca. X1 Congresso Brasileiro de Mandioca. Campo Grande, MS, Brasil. Oct. 25-28.
25. Bellotti, A.C. 2005. Resent advances in whitefly (*Aleurotrachelus socialis*) in cassava. Tropical Whitefly IPM. DFID, London, England, Feb. 27 – March 2005.
26. Bellotti, A.C. 2005. Integrated management of cassava pests. In, Course in Tropical Entomology. Univ. of Florida, Gainesville, FL. USA. June 6,2005
27. Bellotti A.C. 2005. Host Plant Resistance in cassava. Training NARS scientists from Brasil, Nigeria, Ugnda, and Ghana in Molecular Breeding. Training Course at CIAT. April, 2005.
28. Holguin, C.M., A. Carabali, A.C. Bellotti. 2005. Tasa intrisinseca de crecimiento de la poblacion de *Aleurotrachelus socialis* Bonder, en el cultivo de yucca, *Manihot esculenta* Crantz. XXXII Congreso de Entomologia, SOCOLEN, Julio 27-29, Ibague, Colombia.
29. Bellotti, A.C., E. L. Mello, et al. 2005. Biological control in the neotropics: a selective review with emphasis on cassava.. II International Congress on Biological Control of arthropods. Davos, Switzerland. Sept. 12-16, 2005.
30. Bellotti, A.C.. 2005. Effects of genetically modified crops on non-target organisms. Biosafety in the Centers of Biodiversity/World Bank meeting. CIAT, Oct.24, 2005.
31. Best, R., A. Westby and B. Ospina. 2005. Linking Small-Scale Cassava and Sweetpotato Farmers to Growth Markets: Experiences, Lessons and Challenges. Second International Symposium on Sweetpotato and Cassava. June 14-17, 2005. Kuala Lampur, Malaysia.
32. Hoang, K., B.V. Pham, R.H. Howeler, J. J. Wang, N.N. Tran, K. Kawano and H. Ceballos. 2005. The history and recent developments of the cassava sector in Vietnam. Poster presented at the 2nd Intern. Symp. on Sweetpotato and Cassava, held in Kuala Lumpur, Malaysia, June 14-17, 2005.
33. Howeler, R.H. 2005. Cassava in Asia: Present Situation and Future Prospects in Agro-Industry. Poster presented at 2nd Intern.. Symp. on Sweetpotato and Cassava, held in Kuala Lumpur, Malaysia, June 14-17, 2005.
34. Peaingpen Sarawat, Ch. Martwanna, A. Limsila, S. Tangsakul, Ch. Wongwiwatchai, S. Kebwai, W. Watananonta and R.H. Howeler 2005. Cassava leaf production research in Thailand. Poster presented at 2nd Intern. Symp. on Sweetpotato and Cassava, held in Kuala Lumpur, Malaysia, June 14-17, 2005.
35. Watana Watananonta, Wilawan Vongkasem, Kaival Klakhaeng and R.H. Howeler. 2005. Working with farmers: Enhancing the adoption of cassava varieties and more sustainable

production practices. Poster presented at 2nd Intern. Symp. on Sweetpotato and Cassava, held in Kuala Lumpur, Malaysia. June 14-17, 2005.

36. Hoang Kim, Pham Van Bien, R.H. Howeler, J.J. Wang, Tran Ngoc Ngoan, K. Kawano and H. Ceballos. 2005. The history and developments of the cassava sector in Vietnam. Paper presented at Workshop on "Enhancing Agriculture Economics and Teaching in Laos" held in Vientiane, Laos. March 16-17, 2005. 11 p.
37. Howeler, R.H. 2005. Working with farmers in Asia: Spreading new varieties, improved practices and ...... new hope. Paper presented at Regional Workshop on "The Use of Cassava Roots and Leaves for On-farm Animal Feeding" held in Hue, Vietnam, Jan 17-19, 2005.
38. Howeler, R.H. 2005. Cassava in Asia: Present situation and its future potential in agro-industry. *In:* A. Setiawan and K.O. Fuglie (Eds.) Sweetpotato Research and Development: Its Contribution to the Asian Food Economy. Proc.. Intern. Seminar on Sweetpotato, held in Bogor, Indonesia, Sept 19, 2003. pp. 17-61.
39. Howeler, R.H. 2005. Cassava in Asia. Present situation and its future potential in agro-industry. *In*: The Thai Tapioca Trade Association (TTTA), Year Book 2004. pp. 67-81.
40. Howeler, R.H., Watana Watananonta and Tran Ngoc Ngoan. 2005. Working with farmers: The key to achieving adoption of more sustainable cassava production practices on sloping land in Asia. Paper presented at UPWARD Network Meeting, held in Hanoi, Vietnam. Jan 19-21, 2005. Paper available on CD.
41. Howeler, R.H., Watana Watananonta and Tran Ngoc Ngoan. 2005. A case study on working with farmers: The key to achieving adoption of more sustainable cassava production practices. Paper presented at Workshop on "Enhancing Agricultural Economics Research and Teaching in Laos", held in Vientiane, Laos. March 16-17, 2005. 22 p.
42. Howeler, R.H. Watana Watananonta, Wilawan Vongkasem and Kaival Klakhaeng. 2005. Working with farmers: The challenge of achieving adoption of more sustainable cassava production practices on sloping land in Asia. Proc. of the SSWM 2004 International Conference on Innovative Practices for Sustainable Sloping Land and Watershed Management, held in Chiangmai, Thailand. Sept 5-9, 2004. pp. 217-238.
43. Martwana, Ch., A. Limsila, S. Tangsakul, P. Sarawat, Ch. Wongwiwatchai, S. Kebwai, W. Watananonta, and R.H. Howeler. 2005. Cassava leaf production research at Rayong and Khon Kaen provinces in Thailand. Paper presented at Regional Workshop on "The Use of Cassava Roots and Leaves for On-farm Animal Feeding" held in Hue, Vietnam, Jan 17-19, 2005.
44. Nguyen Thi Hoa Ly, Dao Thi Phuong, Le Van Phuoc, Le Van An and R.H. Howeler. 2005. The use of ensiled cassava roots and leaves for on-farm pig feeding in Central Vietnam. Paper presented at Regional Workshop on "The Use of Cassava Roots and Leaves for On-farm Animal Feeding" held in Hue, Vietnam, Jan 17-19, 2005.
45. Watana Watananonta, Surapong Charoenrath, Saowari Tangsakul, Samnong Nual-on, Wilawan Vongkasem, Kaival Klakhaeng, Banyat Waenkaew and R.H. Howeler. 2005. The use of a farmer participatory approach in the development of technologies to control erosion for sustainable cassava production. Proc. Mejo Univ. 5th Annual Scientific Meeting, Chiangmai, May 20-21, 2004. pp. 255-265. (in Thai with English abstract)
46. Watana Watananonta, S. Tangsakul, S. Katong, P. Phetprapai, J. Jantawat, N. Samuthong and R.H. Howeler. Effect of land preparation on the yield of four cassava varieties in Thailand. Paper presented at 2nd International Symposium on Sweetpotato 47.
48. Watana Watananonta, Tran Ngoc Ngoan and R.H. Howeler. 2005. Farmer participatory approaches in the development of technologies to achieve sustainable cassava production in Thailand and Vietnam. Paper presented at UNESCAP CAPSA Regional Workshop on "Rural Prosperity and Secondary Crops", held in Bogor, Indonesia. Dec 6-9, 2005.

6.3 Chapters in Books

1. Bellotti, A., J. Tohme, M. Dunbier and G. Timmerman. 2005. Sustainable integrated management of whiteflies through host plant resistance. In, Whitefly and Whitefly Borne Viruses in the Tropics. Eds. P.K. Anderson and F, J. Morales. CIAT, Cali Colombia. Pp 303-312.
2. Bellotti, A., J. Pena, B. Arias, J.M. Guerrero, H. Trujillo, C. Holguin and A. Ortega 2005. Biological control by indigenous natural enemies for major food crops in the tropics, In. Whitefly and whitefly-borne Viruses in the Tropics. Eds. P.K. Anderson and F.J. Morales. CIAT, Cali, Colombia. Pp 313-323
3. Bellotti, A.C., E.L. Melo, B. Arias, C.J. Herrera, M de P. Hernandez, C.M Holguin, J.M. Guerrero, H. Trujillo. 2005. Biological control in the Neotropics: A selective review with emphasis on cassava.. In. International Symposium on Biological Control of Arthropods. Eds. M.S. Hoddle. USDA Publication FHTET 2005-08. Vol. 1 pp206-227.
4. Fregene M. and C. Mba. Molecular Marker-Assisted selection (MAS) in cassava genetic improvement. In: Genetic Improvement of Cassava Hershey C. (ed) FAO, Via Caravalle, Rome, Italy. (In press)
5. Ceballos, H. Introduction to quantitative genetics. In: Genetic Improvement of Cassava Hershey C. (ed) FAO, Via Caravalle, Rome, Italy. (In press).
6. Blair, M. W., Fregene, M.A., Beebe, S. E. and Ceballos, H. Marker Assisted Selection in Common Beans and Cassava. In: Marker-Assisted Selection (MAS) in Crops, Livestock, Forestry and Fish: Current Status and the Way Forward FAO, Via Caravalle, Rome, Italy. (In press).
7. Howeler, R.H., Watana Watananonta and Tran Ngoc Ngoan. 2005. Farmer Participation in Research and Extension: The Key to Achieving Adoption of More Sustainable Cassava Production Practices on Sloping Land in Asia and their Impact on Farmers' Income. Chapter in Book entitled "Monitoring and Evaluation of Soil Conservation and Watershed Development Projects" to be published by World Assoc. of Soil and Water Conservation (WASWC). 31 p. (In press)

6.4 Other publications

1. Watana Watananonta, Chamlong Kogram, Suwapan Ratanarat, Saowari Tangsukul, Sompong Chompunukulrat, Preecha Pretprapai, Methee Kamthung, Sukit Patanasriwong and R.H. Howeler. 2005. The response of micronutrients on cassava root yield of Rayong 72 and Kasetsart 50. Thai J. Agric. Science. 22(1): 24-38. (in Thai with English abstract).
2. Dalton, T., N. Lilja, N. Johnson and R. Howeler. 2005. Impact of participatory natural resource management research in cassava-based cropping systems in Vietnam and Thailand. Paper submitted for publication to the Systemwide Participatory Impact Assessment (SPIA). PRGA Working Document No. 23. 27 p.

8. INDICATORS: TRAINING

7.1 Courses and workshops organized or supported with scientific capacity from the project.

Table 5. Events where personnel from cassava breeding project participated for the development or execution of research proposals. Additional events were attended by personnel working in the areas of enthomology, plant pathology, and biotechnology and are not listed here to avoid duplications.

Type of event	Number of events	Number of people
Seminaries	5	342
Technical training	10	216
Technical visits	13	174
Meetings with farmers	71	993
Conferences	8	261
Field days	2	489
Harvest days	5	26
Practical events in the field	8	171
Workshops	18	612
Courses	4	98
TOTAL	145	3432

7.2 Training through research thesis of undergraduate and graduate students.

Table 6. List of undergraduate and graduate students, trainees and visiting scientists enrolled during 2005 with the cassava project.

	Female	**Male**
Undergraduate	8	11
M.Sc. Program	3	3
Ph.D. Program	4	1
CLAYUCA Course in production and processing	6	32
Breeding course	5	8
Visiting scientists*	4	5

* Visiting scientist: a person who stays involved in activities within the proyect for more than one week

7.3 Special events: breeding course in cassava for scientists from NARs.

With funding from the Rockefeller Foundation and the Generation Challenge Program (GCP), an advanced breeding course was held at CIAT from April 10- May 8, 2005. The course brought together cassava breeders from Mozambique, Kenya, Tanzania, Ethiopia, Nigeria, Uganda, Ghana, and Brazil. The immediate objective of the course was to provide participants up to date information on field-based and molecular marker-assisted selection (MAS) methods in cassava breeding. Subjects covered include basic quantitative genetics, selection methods, crossing designs, field evaluations, molecular markers, QTL/gene mapping, *association* mapping, and linkage analysis. Others topics were genetic transformation, haploid technology, molecular breeding, tissue culture (in vitro propagation and post flask management), germplasm development, host plant resistance, integrated pest management, cassava production, and genetic diversity. Most of the subjects were covered in formal class room lecture but practical sessions were also included in the program from field tours, lab demonstrations of DNA isolation, gel electrophoresis, polymerase chain reactions, embryo rescue, in vitro propagation, two-node cutting multiplication, screen house screening of pests and disease, to computer sessions in gene mapping and diversity assessment analysis using Q-gene, Mapmaker/QTL, NTSYS, and GENESURVEY software packages. The course ended with one-week field work to harvest different types of trials in our Acid-soil environment at CORPOICA – Villavicencio.

8. INDICATORS: RESOURCE MOBILIZATION LIST

8.1 List of proposals funded in 2005; dollar value of contract & donor

1. Modification *of Flowering in* cassava and Mango using cloned flower gene from Arabidopsis. Rockefeller foundation US$280,000 for 4 years.
2. Development of a High Capacity Starch Laboratory Analysis. Colciencias/Corn Products. US$ 118,000 for three years.
3. Introduction of inbreeding in cassava. Rockefeller Foundation. US$ 1,000,000 for three years.
4. HarvestPlus Challenge Program. US$238,221/year (renewable every year depending on the delivery of results).
5. Mutagenesis in cassava (in collaboration with National Univ. Colombia). IAEA. US$.50,000 for five years.
6. Cassava Development Poles in Colombia. MADR/FENAVI. US$120,00/year (renewable every year depending on the delivery of results).
7. Sustainable cassava production in key countries in Asia. NIPPON Foundation. Duration of the project is three years. 154,000US$/year.
8. Enhancing the Adoption of Improved Cassava Production and Utilization Systems in Indonesia and East Timor. Financed by ACIAR with 17,225 US$/year.
9. Elaboración de una guía técnica para procesos y análisis de almidones de yuca. FAO. US$13,800 for one year.
10. Development of Low-Cost Technologies for Pyramiding Useful Genes from Wild Relatives of Cassava *into* Elite Progenitors. Generation Challenge Program – 1. US$894,906 for three years.
11. Identifying the physiological and genetic traits that make cassava one of the most drought tolerant crops. Generation Challenge Program – 2. US$237,569 for three years.
12. Commissioned Research GCP Consortium Members. Generation Challenge Program – 3. US$319,648 for one year.

8.2 List of proposals submitted.

The project has been successful in procuring resources that can no longer be provided by core. However, the research capacity of its personnel has reached (and perhaps exceeded) a maximum. The project continues searching for special projects, but the list is not provided here since the ongoing activities and special projects already funded provides evidence of our efforts and guidance regarding the kind of activities that we conduct.

9. NEW DIRECTIONS FOR 2006.

The emphasis in the search of high-value cassava germplasm will continue encouraged by the developments confirming the high-protein roots trait and the waxy starch mutant recently discovered. We will now focus in identifying "sugary" types for the ethanol industry and high-amylose starches because they are "resistant" starches that offer a healthy alternative for people with problems such as diabetes. As is frequently the case these high-value traits imply a close interaction with the processing sector. For instance, research will now be conducted to identify new diet compositions for feed made with high-protein cassava roots. This in turn will allow the estimation of the added economic value of such a trait for the entire system. In addition to quantity, we will also do research related to the quality of proteins. In general all these activities will require better protocols for the identification of high-value traits that will allow massive screening of the segregating progenies. The use of NIR is very appealing because it allows the simultaneous quantification of different traits, because it is not expensive (once the calibration curves have been developed) and very fast.

10. RESEARCH ACTIVITIES FOR THE PERIOD 2006-2008.

In October 2006 the cassava-breeding project will organize a meeting at the Bellagio facilities of the Rockefeller Foundation. The meeting has their financial support as well and will gather a small group of (retired) maize breeders and few cassava breeders as well. The purpose of this meeting is to discuss alternatives for exploiting heterosis in cassava. To do that we will benefit from the experience of key scientists that so successfully developed the maize hybrid industry (i.e. D.Duvick, A.Hallauer, V.Gracen, F.Troyer. etc.) from the private sector and/or the Universities. We hope that this meeting will help us to define the way ahead. The introduction of inbreeding in cassava genetic improvement implies a fundamental change in the way we operate. We are going to "design" parents to produce better-performing progenies and this should lead to more consistent and larger genetic gains. We hope that in the few years to come the strategies to do this will be defined and initiated. Two technologies remain to be fully developed: the development of a protocol for the production of homozygous lines (doubled-haploids) through the use of anther culture and/or the induction of flowering through exogenous application of phyto-hormones. As it should be expected these changes are but an adaptation to the new directions mentioned for 2006. The discovery of high-value traits, such as the high-protein or waxy starch of the roots are indeed breakthrough discoveries but their usefulness is somewhat diminished by the limitations imposed by the current breeding system. Today we have to "build" again a new variety in the process of introducing a high-value trait. In the future we hope to introduce the trait into a good parental line by means of a conventional back-cross scheme.

The discovery of high-value traits unavoidably implies a much closer interaction with the private sector. Intellectual property rights are likely to become an important issue that needs to be addressed, but in a way that the advantages that these traits offer are not prevented to reach the resource-limited farmers that our project has to help. The interaction with the private sector is not only technological, but also a promising source of financial support for our project.

The globalization of the economies and the signing of free trade agreements are likely to create a new economic environment for agriculture in tropical countries. Regardless of the wisdom or justifications for these changes they are a reality that we have to address. Based on the trends and experiences that we have seen during the 1990s we expect to see even more opportunities and needs of tropical countries to rely on cassava as a source of raw material for the feed and starch industries. In addition, the crop is increasingly seen as an economic alternative for the production of ethanol for vehicles. The changes that we are gradually introducing in methods for the genetic improvement of cassava and the shift towards the identification of traits that will better satisfy the needs of different industries are represent an appropriate response of our project to the expected changes of the near future. As an integral approach we are also increasing our capacity to screen wild relatives of cassava in search of new traits (i.e. reduced post-harvest physiological deterioration of the roots) and sources of resistance to abiotic stresses, pests and diseases. We have two ongoing projects with the Generation Challenge program in this regard which has been yet another way for CIAT's cassava breeding project to partner with EMBRAPA – Brazil.

Finally we also see new opportunities in relation to the development of new technologies. Molecular markers, marker-assisted selection and genetic transformation are becoming standard technologies in the genetic improvement of different crops important in the developed world (i.e. maize, soybean, wheat, rice, etc). Cassava benefits from these technologies but the massive amount of investments by the private and official sectors of that region of the world imply a drastic contrast and a real threat to the competitiveness of cassava in the long term. We need to be aggressive in incorporating these new tools in an efficient way and with a very strategic prioritization of objectives in such a way that the small investments of resources can be, to some extent, overcome.